Original Article

How the COVID-19 pandemic changed treatment of severe aortic stenosis: a single cardiac center experience

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Background: Currently, two effective therapeutic options for severe aortic stenosis (AS) are available, one catheter-based [transcatheter aortic valve implantation (TAVI)], the other open surgical approach [surgical aortic valve replacement (SAVR)]. The COVID-19 pandemic has limited the availability of medical procedures. The purpose of this cross-sectional study was to assess if this pandemic had any impact on the treatment strategy of severe AS in a single cardiac center.

Methods: This study involved AS patients treated in 3-month periods (February through April) over 3 consecutive years 2018, 2019 [defined as COV(–) group] and 2020 [COV(+)]. We assessed if there were any differences regarding patients' clinical profile, applied therapeutic method, procedure complexity and early clinical outcomes.

Results: In the years 2018 through 2019, approximately 50% of AS patients were treated classically (SAVR) while in 2020 this rate dropped to 34%. The preoperative clinical characteristic of TAVI subjects was comparable irrespective of the year. Regarding SAVR, more patients in COV(+) underwent urgent and more complex procedures. More of them were found in NYHA class III or IV, and had lower left ventricular ejection fraction (LVEF) (51.9%±14.4% *vs.* 58.3%±8.1%; P=0.021) than in COV(–) individuals. During the pandemic, a change in applied therapeutic methods and differences in patients' clinical profile did not have an unfavorable impact on in-hospital mortality (2.0% before *vs.* 3.6% during pandemic) and morbidity. Of note, intubation time and in-hospital stay were significantly shorter (P<0.05) in 2020 (4.2 hours and 7.5 days) than in the previous years (7.5 hours and 9.0 days, respectively).

Conclusions: The coronavirus pandemic has changed substantially the management of severe AS. The shift into less invasive treatment method of AS patients resulted in shortening of in-hospital stay without compromise of short-term outcomes.

Keywords: Aortic stenosis (AS); transcatheter aortic valve implantation (TAVI); aortic valve replacement; COVID-19 pandemic

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Introduction

Severe aortic valve stenosis (AS) is one of the most prevalent forms of acquired valvular heart disease (1,2). Currently two therapeutic options for AS are available; transcatheter aortic valve implantation (TAVI), a percutaneous minimally invasive method, and surgical aortic valve replacement (SAVR) which is performed with cardio-pulmonary bypass (CPB) (3). Although SAVR can be done from a partial sternotomy which is considered as less invasive access, the patients still require both meticulous care and treatment soon after surgery in the intensive care units (ICUs) (4). In contrast, TAVI patients are usually transferred to cardiac ICUs which are a part of the cardiologic wards (5). The coronavirus (SARS-CoV-19) pandemic has created an enormous challenge for all health care systems around the world. This is especially true for ICUs as many infected patients develop hypoxia and require intense respiratory support (6,7). Certain multispecialty hospitals were converted into COVID-19 treatment centers with the intention being to exclusively treat coronavirus patients. Consequently, the majority of ICU beds in these hospitals were occupied by the victims of the pandemic. In addition, extraordinary financial resources were allocated to the diagnosis and management of COVID-19 patients (8). As many countries also had drastic lockdowns, a global economic regression followed (9). Due to the state of emergency, the rate of elective procedures decreased substantially including cardiac surgical operations (10). Furthermore, patients with mild symptoms of cardiovascular diseases preferred to stay at home instead. For stable individuals with valvular heart disease postponing surgery and optimal pharmacotherapy were recommended by some national cardiac societies (11). A number of cardiac surgery departments limited their operations to cases such as aortic dissection in young patients or urgent coronary artery bypass grafting (CABG) that could not be fixed through percutaneous coronary interventions (PCIs) (10,12). Furthermore, less invasive therapeutic options, even if not the method of choice, were used to reduce the length of both intensive treatment and total in-hospital stay (10,12).

Therefore, the purpose of our cross-sectional study was to determine if the COVID-19 pandemic had any impact on management, the clinical profile and early outcomes of patients treated for severe AS. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/jtd-20-3025).

Methods

Patients

The periods of interest confined to 90 days, from February 1st to April 30th, during 3 consecutive years, 2018–2020. All patients were treated invasively for severe AS in the Department of Cardiac Surgery and Transplantology in Poznan (Poland). Individuals who required simultaneous CABG were also included. The following exclusion criteria such as concomitant severe other valves defects, aortic diseases, significant aortic valve insufficiency and infective endocarditis were applied.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). As this study is a retrospective analysis of routine patients treated in the Department of Cardiac Surgery and Transplantology, approval of the Bioethical committee was not necessary and the Institutional Review Board waived the requirement of individual patient consent.

Preoperative period

Patients diagnosed with severe AS were given either TAVI or SAVR after the recommendations of the local heart team that consisted of specialists in echocardiography, interventional cardiology and cardiac surgery. The patients' medical history such as clinical presentation, findings in the imaging studies such as transthoracic echocardiography (TTE), contrast enhanced computed tomography with off-line reconstructions and coronary angiography were analyzed. Patients not suitable or disqualified from SAVR were conserved as candidates for TAVI. Thus, the latter method was reserved mostly for elderly subjects with serious comorbidities being at moderate or high risk for early mortality and morbidity. In cases with critical stenosis in the coronary arteries, PCI was carried out a few weeks before TAVI while in SAVR, CABG was done simultaneously.

TAVI

TAVI procedures were described earlier and were usually done in deep sedation, preferred, or general anesthesia with a percutaneous femoral approach (13). Routinely, a temporary pacemaker to the right ventricle was deployed through the femoral vein. Once the prosthesis was correctly positioned and expanded, the contrast medium was injected to check for the presence of a paravalvular leak. In addition, echocardiography was done to check the function of the implanted bioprosthesis.

SAVR

SAVR individuals were treated either electively or urgently. Operations were defined as urgent if the patients had to wait for aortic valve surgery in the hospital whereas elective cases stayed at home for usually a few weeks or even months after the final diagnosis had been established.

All surgeries were performed through partial or full median sternotomy with the use of CPB in moderate hypothermia (28 to 30 ℃) and cardioplegic arrest. If the patients had to undergo simultaneous CABG, distal anastomoses of free grafts, usually segments of saphenous vein, were done first after aortic cross-clamping and cardioplegic arrest. The valve replacement and left internal thoracic artery anastomosis followed. After resuming the coronary flow, proximal anastomoses of the free grafts were performed on the partially clamped ascending aorta. In general, younger patients received mechanical prostheses while the elderly received bioprostheses. Of note, the final choice was always left to the patients' decision.

Postoperative period

The selected individuals after TAVI (with intraprocedural complications or these considered preoperatively as very high risk) and all patients who got SAVR were transferred to the postoperative ICU, intubated and mechanically ventilated. According to the hospital rules, patients in stable clinical status after ICU stay were further treated at either the cardiac surgery (SAVR) or cardiology (TAVI) ward. The subjects after open surgical operations were usually discharged to rehabilitation centers whereas those following percutaneous interventions usually were sent home directly.

Parameters included

The following variables were analyzed:

- ❖ Demographic: age, rate of elderly (>75 years), gender;
- ❖ Clinical: priority of surgery (elective/urgent), functional status according to New York Heart Association (NYHA) classification, concomitant disorders such as arterial hypertension (AH), hyperlipidemia, diabetes mellitus, peripheral vascular disease, chronic obstructive pulmonary disease, chronic kidney disease;
- ❖ Results of the imaging studies (echocardiography or coronary angiography);
- ❖ A risk of intervention on the aortic valve stratified by means of EuroSCORE II calculator.

Postoperative in-hospital course, including mortality and morbidity was also analyzed. Moreover, a length of endotracheal intubation (if applicable), ICU and in-hospital stays were evaluated. Additionally, the following serious adverse events were taken into account:

- ❖ Myocardial infarction (defined if all conditions such as significant increase in troponin I concentration, ischemic changes in electrocardiogram and new local disturbances in myocardial contractility were fulfilled simultaneously);
- ❖ Atrioventricular block (AVB) requiring permanent pacemaker implantation;
- ❖ Renal failure treated by means of renal replacement therapy [continuous veno-venous hemodialysis (CVVHD)];
- ❖ Respiratory failure if patients had to be intubated longer than 12 hours or be reintubated;
- ❖ Stroke [confirmed in neurological (specialist consultation) and imaging examinations (computed tomography or magnetic resonance imaging)];
- ❖ Bleeding from surgical access (TAVI) or bleeding/tamponade requiring chest re-exploration;
- ❖ Deep surgical site infection (DSSI) treated with repeat sternal reosteosynthesis (after SAVR);
- ❖ Peripheral TAVI access serious complications (e.g., artery dissection, false aneurysm) if vascular open or intravascular interventions were necessary.

Data analysis

First, all continuous variables were checked for normality by means of the Shapiro-Wilk test. If the variables satisfied the normal distribution criteria, they are presented as means with standard deviation (SD) and then compared with the use of ANOVA followed by the Scheffe Post Hoc test. Otherwise, they are expressed as the medians with interquartile ranges (25^{th}–75^{th} percentile). Categorical data are presented as the numbers (n) with percentages (%). The aforementioned variables were analyzed with the use of the Kruskal-Wallis test followed by multiple comparisons of the ranks. In addition, we compared the most basic variables

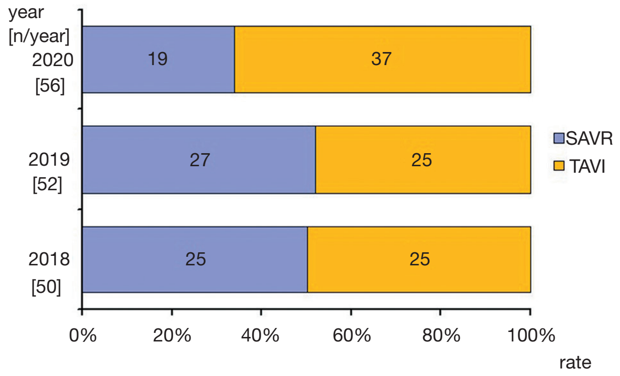

Figure 1 Applied method of treatment of severe AS. AS, aortic stenosis; SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

describing patients who underwent surgery for significant AS before [years 2018 to 2019; COV(–) group] and during COVID-19 pandemic [year 2020; COV(+) group]. To compare COV(–) with COV(+) subjects, unpaired t-test, Mann-Witney U and χ^2 tests with or without Yates correction were employed. A P value below 0.05 was considered as statistically significant. All calculations were done in the Statistica 10.0 software package (StatSoft, Tulsa, OK, USA).

Results

Applied therapeutic method

A total number of AS patients treated in our center were similar over the 3 consecutive years and ranged from 50 in 2018 to 56 in the corresponding months of 2020. However, a shift from SAVR to minimally invasive TAVI procedures was seen. In the years 2018 through 2019, approximately 50% of patients were treated classically (AVR; 50% in 2018 and 52% in 2019) while after the COVID-19 pandemic outbreak this rate dropped to 34%. The detailed numbers of AS patients treated in the years 2018 through 2020 are presented graphically (*Figure 1*).

Preoperative patients' characteristics

The preoperative clinical characteristics were similar in TAVI group irrespective of the year. The only exception was a higher prevalence of patients after neurological events [either transient ischemic attack (TIA) or cerebrovascular accidents (CVAs)] in 2018 (7/25, 28.0%) compared to 2020 (2/37, 5.4%; P=0.035).

Post hoc analysis (of normally distributed continuous data) or multiple comparisons between ranks (for the other variables) did not reveal any differences in SAVR patients treated before pandemic outbreak, specifically between 2018 and 2019. Therefore, they were entered into the further analysis as an one group [COV(–)].

In contrast, substantial differences in the clinical profile of COV(–) and COV(+) individuals were noted. Firstly, more than 50% of patients who underwent SAVR during the pandemic were found in NYHA classes III and IV as well as more frequently presenting with symptoms of coronary artery disease (CAD). Although post hoc analysis of the mean age of SAVR individuals did not reveal any differences, the rate of elderly patients (75 years and more) decreased significantly in 2020 [COV(+) group]. The other findings of the preoperative clinical evaluations are outlined in *Table 1*.

In the preoperative TTE, left ventricular (LV) performance was worse in COV(+) compared to those operated earlier, the COV(–) group. In the COV(–) group mean left ventricular ejection fraction (LVEF) was markedly lower (P=0.021) and LV end-diastolic dimension (LVEDd) larger (P=0.016) than in COV(–). Additionally, significantly more subjects in COV(+) (P=0.023) presented markedly impaired LV systolic function (LVEF below 30%). More echocardiographic data are listed in *Table 2*.

No comparison between TAVI and SAVR patients regarding preoperative demographics and clinical status was performed because it was beyond the scope of this study.

Priority of surgery and SAVR details

Regarding SAVR patients, more of them required urgent treatment as well as simultaneous CABG in 2020 than previously. However, the number of implanted aortocoronary grafts were similar in the consecutive years. Selected data regarding open surgery are outlined in *Table 3*. In general, COV(–) subjects were of lower risk than COV(+) individuals.

Postoperative course

Overall, short-term mortality defined as all deaths that occurred within the first 30 days following procedure irrespective of patient stay (hospital, rehabilitation center, home) was 2.5% (n=4), two fatal cases in both subgroups. Mortality rate among COV(–) individuals was 2.0%

Table 1 Demographic and preoperative clinical data

Groups*	All patients		TAVI		SAVR	
	COV(–) (n=102)	COV(+) (n=56)	COV(–) (n=50)	COV(+) (n=37)	COV(–) (n=52)	COV(+) (n=19)
Age (years)	71.8±9.7	71.4±10.2	78.2±7.5	75.6±6.1	66.3±9.2	63.5±13.2
>75 years	52 (51.0)	28 (50.0)	38 (76.0)	27 (73.0)	**14 (26.9)**	**1 (5.3)#**
Gender (F/M)	59 (57.8)/43 (42.2)	32 (57.1)/24 (42.9)	29 (58.0)/21 (42.0)	20 (54.1)/17 (45.9)	30 (57.7)/22 (42.3)	12 (63.2)/7 (36.8)
NYHA III/IV	**21 (20.6)**	**23 (41.1)#**	13 (26.0)	13 (35.1)	**8 (15.4)**	**10 (52.6)#**
Obesity[1]	21 (20.6)	13 (23.2)	14 (28.0)	10 (27.0)	7 (13.5)	3 (15.8)
AH	73 (71.6)	44 (78.6)	43 (86.0)	31 (83.8)	30 (57.7)	13 (68.4)
HL	**26 (25.5)**	**23 (41.1)#**	13 (26.0)	13 (25.0)	**13 (25.0)**	**10 (52.6)#**
COPD	6 (5.9)	7 (12.5)	**3 (6.0)**	**6 (16.2)#**	3 (5.8)	1 (5.3)
DM	38 (37.3)	24 (42.9)	21 (42.0)	17 (45.9)	17 (32.7)	7 (37)
PVD[2]	25 (24.5)	18 (32.1)	15 (30.0)	15 (40.5)	10 (19.2)	3 (15.8)
TIA/CVA	11 (10.8)	2 (3.6)	9 (18.0)	2 (5.4)	2 (3.8)	0 (0.0)
CAD	44 (43.1)	29 (51.8)	25 (50.0)	16 (43.2)	**19 (36.5)**	**13 (68.4)#**
Prev. MI	19 (18.6)	13 (23.2)	14 (28.0)	9 (24.3)	5 (9.6)	4 (21.1)
PCI in hist.	25 (24.5)	19 (33.9)	19 (38.0)	14 (37.8)	6 (11.5)	5 (26.3)
RF[3]	**31 (30.4)**	**27 (48.2)#**	28 (56.0)	24 (64.9)	3 (5.8)	3 (15.8)
ES II[4] (%)	**1.70 (1.21–2.99)**	**2.68# (1.72–3.56)**	2.80 (1.78–4.66)	3.09 (2.04–5.30)	**1.21 (0.93–1.59)**	**1.84# (1.11–3.35)**

*, continuous data are expressed as the means ± SD or the medians with interquartile ranges (25^{th}–75^{th} percentile) while categorical as the numbers (n) with percentages (%); #, P<0.05 COV(–) *vs.* COV(+) groups; bolded data are of statistical significance. [1], defined if BMI exceeded 30 kg/m^2; [2], if glomerular filtration rate (eGFR) was below 60 mL/kg/1.73 m^2; [3], it refers only to the arteries of the lower extremities; [4], logistic EuroSCORE II stratifies risk of early mortality (up to 30 days following intervention). TAVI, transcatheter aortic valve implantation; SAVR, surgical aortic valve replacement; COV, patients treated before (–) or during COVID-19 (+) pandemic; F, female; M, male; NYHA, New York Heart Association class; AH, arterial hypertension; HL, hiperlipidemia; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; PVD, peripheral vascular disease; TIA, transient ischemic attack; CVA, cerebrovascular accident (brain stroke); CAD, coronary artery disease; MI, myocardial infarction; PCI, percutaneous coronary intervention; RF, renal failure; ES, EuroSCORE; SD, standard deviation; BMI, body mass index.

while 3.6% in COV(+) group (ns). Taking into account a method of aortic valve implantation, single SAVR patients died either in the years 2018–2019 or in 2020 (both had combined procedures, SAVR completed by CABG) whereas all TAVI subjects (n=2) before SARS-CoV-2 pandemic. The reasons of death myocardial ischemia-induced low cardiac output syndrome (LCOS) (n=2; on 3rd and 5th postoperative days) in SAVR group whereas fatal bleeding due to perforation of left ventricle (intraoperative death) and LCOS preceding multi-organ failure (MOF) in TAVI subjects.

The other postprocedural serious adverse events are summarized in *Table 4*. Of note, the rate of them was comparable in the consecutive years in TAVI group (28% in 2018, 36% in 2019 and 24% in 2020; ns) while in SAVR subset it was significant higher (P=0.048) in 2020 (42%) than in the years 2018–2019 (19%).

Additionally, comparison of intubation time and in-hospital stay revealed their median times for of all patients irrespective of valve implantation technique was significantly shorter in the year of SARS-CoV-2 pandemic than previously (see *Figure 2*). It probably resulted from higher contribution of TAVI procedures after pandemic outbreak. Detailed analysis of the aforementioned variables of the postoperative course were comparable within both subgroups in the consecutive years (SAVR 2018 = SAVR 2019 = SAVR 2020; TAVI 2018 = TAVI 2019 = TAVI 2020) but notable they were always markedly shorter in TAVI

Table 2 Preoperative echocardiographic findings

Groups*	All patients		TAVI		SAVR	
	COV(–) (n=102)	COV(+) (n=57)	COV(–) (n=50)	COV(+) (n=37)	COV(–) (n=52)	COV(+) (n=19)
LA (mm)	**40.7±6.8**	**44.1±7.2**#	44.5±6.8	45.7±6.5	**37.1±4.7**	**41.6±7.7**#
LVEDd (mm)	**45.9±8.2**	**49.0±8.2**#	44.3±9.4	45.1±8.9	**47.5±6.4**	**51.3±7.0**#
IVSd (mm)	**15.0±3.1**	**13.9±2.6**#	13.5±2.3	13.3±1.4	**16.3±2.2**	**15.2±1.7**#
LVPWd (mm)	14.3±2.8	13.4±2.2	12.7±1.8	12.8±1.4	15.7±2.7	14.8±2.7
RV (mm)	**30.0±4.3**	**32.1±5.1**#	29.8±4.7	29.4±5.3	**30.2±3.8**	**33.7±4.4**#
LVEF (%)	**56.8±8.0**	**51.9±12.8**#	55.1±8.5	52.3±11.9	**58.3±8.1**	**51.9±14.4**#
LVEF below 30%	3 (2.9)	6 (5.9)	2 (4.0)	2 (5.4)	**1 (1.9)**	**4 (21.1)**#
PPG (mmHg)	90.6±24.9	84.3±19.6	89.4±22.6	85.7±22.2	**91.8±27.0**	**81.5±15.2**#
MPG (mmHg)	56.0±15.1	53.1±14.2	56.6±14.8	53.2±14.8	55.0±15.9	52.6±10.9

*, continuous data (as normally distributed) are presented as the means ± SD whereas categorical data as the numbers (n) with percentages (%); #, P<0.05 COV(–) *vs.* COV(+); bolded data are of statistical significance. TAVI, transcatheter aortic valve implantation; SAVR, surgical aortic valve replacement; COV(–)/(+), patients treated before (–) or during (+) SARS-CoV-2 pandemic; LA, left atrial; LVEDd, left ventricular end-diastolic dimension; IVSd, interventricular septum thickness in diastole; LVPWd, left ventricular posterior wall thickness in diastole; RV, right ventricular; LVEF, left ventricular ejection fraction; PPG, peak pressure gradient; MPG, mean pressure gradient; SD, standard deviation.

Table 3 Details of SAVR

Groups*	2018 (n=25)	2019 (n=27)	2018–2019, COV(–) (n=52)	2020, COV(+) (n=19)	P value[1]
Priority					**0.015**
Elective	22 (88.0)	24 (88.9)	46 (88.5)	14 (73.7)	
Urgent	3 (12.0)	3 (11.1)	6 (11.5)	5 (26.3)	
Complexity					**0.030**
SAVR isolated	21 (84.0)	24 (88.9)	45 (86.5)	12 (63.2)	
SAVR + CABG	4 (16.0)	3 (11.1)	7 (13.5)	7 (36.8)	
Number of ACBG					1.000
1	2 (50.0)[2]	1 (33.3)	3 (42.9)	4 (57.1)	
2	2 (50.0)	2 (66.7)	4 (57.1)	3 (42.9)	
CPB time (min)	88.5±27.4	86.4±20.7	87.3±23.7	84.9±14.5	0.674
ACC time (min)	65.7±20.1	64.9±16.6	65.3±18.1	62.3±11.1	0.503

*, continuous data are expressed as the means ± SD while categorical ones as the numbers (n) with percentages (%). [1], P<0.05 COV(–) *vs.* COV(+) groups; bolded P values indicate statistically significant difference. [2], It indicates the rate of patients who underwent simultaneously SAVR and CABG. SAVR, surgical aortic valve replacement; COV, patients treated before (–) or during (+) coronavirus pandemic; CABG, coronary artery bypass grafting; ACBG, aorto-coronary bypass grafts; CPB, cardio-pulmonary bypass; ACC, aortic-cross clamping; SD, standard deviation.

Table 4 Serious adverse events in the early postoperative period

Groups#	TAVI			SAVR		
	2018 (n=25)	2019 (n=25)	2020 (n=37)	2018 (n=25)	2019 (n=27)	2020 (n=19)
Myocardial infarct	–	–	1 (2.7)	2 (8.0)	1 (3.7)	–
Complete AVB	5 (20.0)	6 (24.0)	5 (13.5)	1 (4.0)	2 (7.4)	2 (10.5)
Renal failure	1 (4.0)	2 (8.0)	2 (5.4)	1 (4.0)	–	3 (15.8)
Respiratory failure	1 (4.0)	1 (4.0)	1 (2.7)	1 (4.0)	–	2 (10.5)
Stroke	–	–	1 (2.7)	–	–	–
Bleeding/tamponade	1 (4.0)	1 (4.0)	–	1 (4.0)	2 (7.4)	1 (5.3)
DSSI	N/A	N/A	N/A	–	1 (3.7)	–
Peripheral access adverse event	1 (4.0)	1 (4.0)	1 (2.7)	N/A	N/A	N/A

#, All data are presented as the numbers (n) with percentage (%), definition of all serious adverse events are listed in the text ('method'). TAVI, transcatheter aortic valve implantation; SAVR, surgical aortic valve replacement; AVB, atrioventricular block; DSSI, deep surgical site infection; N/A, non-applicable.

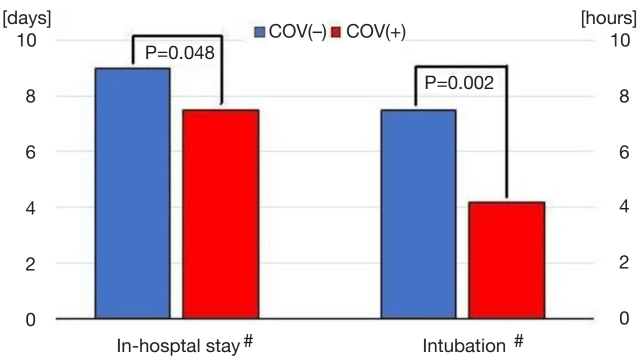

Figure 2 Comparison of intubation time and in-hospital stay length. #, Both continuous variables are expressed as the medians since they have not fulfilled criteria of normal distribution; &, it refers to all cases, including those who were not intubated during procedures. COV(+)/(–), patients who were operated on during (+) or before (–) SARS-CoV-2 pandemic outbreak.

individuals (i.e., TAVI 2018 < SAVR 2018, TAVI 2019 < SAVR 2019, TAVI 2020 < SAVR 2020) (see *Table 5*).

Discussion

The main finding in our analysis was a decreased rate of AS patients treated classically in CBP by cardiac surgeons accompanied by an increase in the numbers of TAVI procedures whereas the total number of patients remained unchanged. It is likely that some patients who had TAVI procedures in 2020 would have undergone SAVR in the pre-coronavirus era. However, the tendency to perform more percutaneous cardiac interventions on the aortic valves, at least in the richest countries, is starting to be seen regardless of the COVID-19 pandemic. It seems that in our center, the pandemic had more significant impact of a choice of therapeutic option than a global tendency of TAVI promotion. Herein, the only difference regarding therapeutic method rate was found between 2019 and 2020 but not earlier. In the recent years, more scientific evidence has been accumulated in the clinical trials that TAVI is a safe and efficacious procedure with low complication rates, shorter length of hospital stay, reduced mortality and minimal strokes rate at 30 days as well as years later (14,15). Consequently, according to the current ESC/EACTS guidelines, TAVI can be recommended not only in high but also moderate risk patients (16). Moreover, the recent trials that involved low risk AS subjects, such as PARTNER 3 or EVOLUT, showed better outcomes, including both mortality and morbidity, following TAVI than after SAVR (17,18). The significance of these findings is of crucial importance as most patients (even up to 80%) with severe AS are usually at low surgical risk (19). We must be aware that they referred not to all AS subjects but only to those who were appropriate candidates for implantation of biological prostheses. Due to a lack of long-term data on the rate of bioprosthetic structural valve deterioration in younger individuals, low risk but middle-aged patients should still undergo SAVR (16,20).

In our opinion, there are a few possible explanations for

Table 5 Intubation time and in-hospital length in the consecutive years

	2018	2019	2020
Intubation time (hours)[#]			
SAVR	11.5 (8.5–13.7)	12.3 (10.0–18.6)	12.4 (9.1–23.8)
TAVI[&]	7.7 (3.0–11.9); 0 (0–5.3)	7.0 (4.0–10.0); 0 (0–4.7)	5.5 (2.5–6.8); 0 (0–3.4)
P value*	**0.001**	**<0.001**	**<0.001**
In-hospital stay (days)			
SAVR	13.0 (10.5–16.0)	13.0 (10.5–14.5)	15.0 (11.0–17.0)
TAVI	6.0 (6.0–8.5)	7.0 (5.0–8.0)	7.0 (4.0–8.0)
P value*	**<0.001**	**<0.001**	**<0.001**

[#], the continuous variables are expressed as the medians with interquartile ranges (25^{th}–75^{th} percentiles) since they have not satisfied criteria of normal distribution. [&], the upper raw refers to TAVI patients who had to be intubated whereas lower one to all TAVI patients. *, It refers to the comparisons of SAVR *vs.* TAVI [for all patients (lower raw of TAVI subgroup)]. Bolded P values indicate statistically significant difference. SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

why TAVI procedures were more common in the coronavirus era. Percutaneous techniques are minimally invasive enabling faster recovery and many TAVI cases after careful post-procedure monitoring in the recovery room, may be transferred safely to the cardiology ward (21). As during the pandemic, it is absolutely vital to conserve as many ICU beds or even increase ICU capacity for coronavirus induced hypoxemic respiratory failure patients (22). In addition, innovations in transcatheter heart valve technology, gained experience, smaller sheaths, common application of steadily improving vascular closing devices have resulted in much lower rates of vascular and cardiac complications, reducing a need for ICU admissions (23). Between TAVI and SAVR, the former has a substantially shorter recovery time. Thanks to the experience that we have gained in percutaneous techniques in the last few years, we are able to handle extremely demanding cases (such as after mechanical valve implantations in the mitral position, with a short distance between aortic annulus and coronary ostia, bicuspid aortic valves, moderate dilation of ascending aorta root) as well as shift away from general anesthesia to local with conscious sedation. In the last 3 years, we have had only 20% of our patients intubated due to either hemodynamic instability or the vascular/cardiac complications of the procedure, comparable with recent reports (24). In our center, conscious sedation is currently the approach of choice as it seems safer and is particularly useful in the coronavirus pandemic. Perioperative viral transmission to the anesthetic team was shown to be reduced if applying just sedation instead of endotracheal intubation and general anesthesia by minimizing the aerosol-generating procedures and reducing the exposure to patient respiratory secretions (25). In many published papers, it can be seen that in experienced centers, in-hospital stay was significantly shorter after TAVI when compared to SAVR (26-30). In addition, SAVR required the application of CPB which is associated with an acute and pronounced inflammatory response consequently activating the complement system and the coagulation pathways. The levels of many pro-inflammatory cytokines such as tumor necrosis factor α as well as interleukin-6 and -8 (IL-6, IL-8) are high which are proved to be the causative factors of perioperative myocardial and lung injury (31). These increased levels of inflammatory cytokines, particularly IL-6, were also found be correlated with disease severity and mortality in coronavirus induced adult respiratory distress syndrome (ARDS) (32). Therefore, connection of CPB should be avoided in high-risk patients for COVID-19 infection. Of note, only TAVI enables deployment of bioprosthesis on the beating human in CPB. Elderly patients, with many concomitant disorders are considered high risk and the subjects of choice for TAVI.

We also found that patients of higher risk stratified in EuroSCORE II calculator underwent SAVR in the COVID-19 pandemic. It must be stressed that many factors can imply on the final score of perioperative risk (33). Differences in age, NYHA classification, LV performance, and priority of surgery between COV(–) and COV(+) SAVR subjects were noted. Although the mean age of subjects in both subgroups were similar, in the COV(+) subset only one patient was older than 75 years. In 2020, more than one fourth were operated urgently due to severe clinical symptoms while in the earlier years only approximately 10%. In the coronavirus era, more symptomatic patients in NYHA III and IV classes with markedly impaired LV systolic performance were operated on. This increase in urgent cases most likely resulted from a fact their clinical status did not allow them to postpone surgery. The vast majority of asymptomatic cases (probably with well-preserved LVEF) could stay at home and wait for surgery. According to some studies even up to 50% of all elective cases were cancelled or delayed (34). While beyond the scope of this study, it can be presumed that the operations of many elective patients in good clinical shape and with well-preserved LV systolic function were postponed. It is possible that some of the patients on the waiting list with borderline (e.g., moderate or even low risk, with not so many concomitant diseases) indications for TAVI, eventually underwent percutaneous procedures due to aforementioned limitations regarding access to ICU facilities. On the other hand, it must be consistently kept in mind that severe AS even with trivial symptoms but with hypertrophic myocardium still poses a risk of sudden cardiac death (35). Notable, it was shown previously that nearly 70% of sudden death episodes that had been reported were not preceded by the classical AS symptoms (36).

Herein, we also observed the changed management with AS patients in the pandemic era did not negatively impact the early clinical outcomes expressed as in-hospital mortality and prevalence of serious adverse events. In our group, overall mortality rate was comparable or slightly higher than in the previously published studies (37,38). Contrary to them, in our group of SAVR cases, even one-thirds had to undergo simultaneous CABG (17,18). The latter one was proved to have unfavorable influence on both early and late outcomes, particularly in women (39-41). Moreover, CAD accompanying hypertrophic LV myocardium induced by severe AS poses a high risk of intraoperative myocardial ischemia. Of note, in both patients who died soon after surgery, preoperative coronary angiography revealed significant lesions that had to be addressed during surgery.

Very important issue during the SARS-CoV-2 pandemic is a limited number of beds with monitoring of vital signs. Therefore, currently all actions resulting in the shortening of in-hospital stay are welcome. We did observe the shortest hospitalization time in 2020, mainly due to an increased rate of TAVI procedures. The latter ones, especially these performed on moderate risk patients and with uneventful postprocedural course, were found to be associated with earlier discharge than after SAVR. Our findings regarding this issue supported the previous reports (17,18,42,43). Some of them stressed economic aspects of AS treatment (44). It was showed that more common application of TAVI procedures, in spite of high price of implanted bioprostheses, had important implications in the era of constrained resources with a growing emphasis on reducing health care costs (44).

Furthermore, we are aware of the limitations of this study. First, the number of patients who underwent invasive treatment for severe AS was relatively low and this fact could have impacted the results of the statistical analysis. However, even in this group significant changes were noted. One can not exclude that involving more patients might have been disclosed additional differences between examined periods, for example early mortality. Of note, this is simply a study of a single cardiac surgical center that has had extensive experience in TAVI and most likely not a good representative of the average cardiology ward (45,46). In addition, it must be kept in mind that owing to our experience, some borderline patients were selected for TAVI. Moreover, our hospital is in an example of excellent cooperation between interventional cardiologists and cardiac surgeons that unfortunately is not the rule everywhere. Consequently, a final decision regarding optimal management of AS patients is always the common consensus. As our department was not in the epicenter of the COVID-19 pandemic, a relatively large number of elective patients could be treated. The availability of aortic valve procedures in cardiac centers of hospitals that have been dedicated to the treatment of COVID-19-related severe organ complications is severely reduced.

Conclusions

The Coronavirus pandemic has changed substantially the management of severe AS. More percutaneous interventions had been performed whereas the open surgical approach was chosen predominantly for urgent patients requiring more complex procedures. This shift into less invasive method of treatment of AS patients resulted in shortening of in-hospital stay without compromise of short-term outcomes. This strategy fulfilled expectations of health care system during SARS-CoV-2 pandemic.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). As this study is a retrospective analysis of routine patients treated in the Department of Cardiac Surgery and Transplantology, approval of the Bioethical committee was not necessary and the Institutional Review Board waived the requirement of individual patient consent.

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