Facilitated Data Relay and Effects on Treatment of Severe Aortic Stenosis in Europe

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Background—Many patients with severe aortic stenosis are referred late with advanced symptoms or inappropriately denied intervention. The objective was to investigate whether a structured communication to referring physicians (facilitated data relay) might improve the rate and timeliness of intervention.

Methods and Results—A prospective registry of consecutive patients with severe aortic stenosis at 23 centers in 9 European countries with transcatheter as well as surgical aortic valve replacement being available was performed. The study included a 3-month documentation of the status quo (phase A), a 6-month intervention phase (implementing facilitated data relay), and a 3-month documentation of a legacy effect (phase-B). Two thousand one hundred seventy-one patients with severe aortic stenoses were enrolled (phase A: 759; intervention: 905; phase-B: 507). Mean age was 77.9±10.0 years, and 80% were symptomatic, including 52% with severe symptoms. During phase A, intervention was planned in 464/696 (67%), 138 (20%) were assigned to watchful waiting, 8 (1%) to balloon aortic valvuloplasty, 60 (9%) were listed as not for active treatment, and in 26 (4%), no decision was made. Three hundred sixty-three of 464 (78%) patients received the planned intervention within 3 months. Timeliness of the intervention improved as shown by the higher number of aortic valve replacements performed within 3 months (59% versus 51%, P=0.002) and a significant decrease in the time to intervention (36±38 versus 30±33 days, P=0.002).

Conclusions—A simple, low-cost, facilitated data relay improves timeliness of treatment for patients diagnosed with severe aortic stenosis, resulting in a shorter time to transcatheter aortic valve replacement. This effect was mainly driven by a significant improvement in timeliness of intervention in transcatheter aortic valve replacement but not surgical aortic valve replacement.

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Key Words: Quality of care • aortic stenosis • transcatheter aortic valve implantation • surgical aortic valve replacement • facilitated data relay

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Aortic stenosis (AS) is a progressive, life-threatening valve disorder that is characterized by a rapid increase in risk of sudden death once symptoms appear.[1] Despite clear American and European guidelines on management,[2–5] there

is evidence that gaps between current recommendations and actual clinical practice exist.[6–9] Patients with severe symptomatic AS may be referred late with advanced symptoms or inappropriately denied intervention.[7,8,10] Patients managed in an inappropriate or untimely way incur excess morbidity and mortality, not only because of the risk of "death on the waiting list" but also from increased perioperative complications and incomplete recovery.[11,12] It is therefore important to identify ways of improving the timeliness of healthcare delivery for patients with AS.

Lack of awareness of the condition and of its consequences may represent a potentially important reason for the undertreatment observed in patients with valvular heart disease. In a recent community-based study,[13] although echocardiography correctly identified the disease and its severity, a significant proportion of the patients were left

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Clinical Perspective

What Is New?

- Many patients with severe aortic stenosis are referred late with advanced symptoms or inappropriately denied intervention.
- A simple, low-cost, facilitated data relay improves timeliness of treatment for patients diagnosed with severe aortic stenosis, resulting in a shorter time to transcatheter aortic valve replacement.

What Are the Clinical Implications?

- Facilitated data relay has the potential to reduce perioperative and postoperative morbidity, while decreasing the number of patients dying on the waiting list for aortic valve replacement.
- Future studies are now needed to formally demonstrate the impact of facilitated data relay on outcome.

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untreated. We then collected pilot data that replicated these findings in hospitals (secondary and tertiary care), indicating that a significant proportion of patients with symptomatic severe AS were not being referred for consideration of aortic valve intervention in a timely fashion. Simple, low-cost facilitated data relay (FDR) interventions may help. We hypothesized that using a dedicated nurse to inform referring physicians of a finding of severe AS in a prompt and structured manner might increase the rate of referral of patients for intervention and timeliness thereof.[14]

Methods

Study Design and Site Selection

IMPULSE was a prospective, multinational registry of patients with severe AS in Europe, the rationale and design of which has been described recently.[14] In brief, IMPULSE evaluated the effect of a nurse-led FDR on the timing and rate of valve procedures. A total of 23 centers from 9 countries (Austria, Czech Republic, France, Germany, Italy, The Netherlands, Spain, Switzerland, and the United Kingdom) were involved, with patients enrolled between March 2015 and April 2017. The sites were selected on the basis that each offered the full range of treatment options for AS, including surgical and transcatheter procedures, the rationale being that these might provide the best picture of service delivery. Although the 2012 guidelines applied during the conduct of the study, the results were considered against the background of the 2017 European Society of Cardiology[15] and 2017 American College of Cardiology guidelines.[3] The study was carried out in accordance with the Declaration of Helsinki, was approved by the independent ethics review board at each participating institution, and patient informed consent was obtained. The data that support the findings of this study are available from the corresponding author upon reasonable request.

The study had 3 phases: baseline observation phase A, to document the management of patients with severe AS enrolled during a 3-month period; FDR intervention phase, to evaluate the efficacy of the FDR intervention among patients enrolled during the subsequent 6-month period; and follow-up observation phase B, to evaluate any legacy effect of the FDR intervention among patients enrolled during a final 3-month period (Figure 1). During the intervention phase, the study nurse contacted the referring physician within 7 days to implement the FDR. During the 2 observation phases, there was no contact with the referring physicians. Follow-up for all patients was capped at 3 months, when details of any treatment during the period were collected.

Patients

Patients over 18 years of age were included in the registry based on a new finding at echocardiography of native severe AS, whether symptomatic or asymptomatic. A diagnosis of severe AS was defined as 1 or more of the following findings on echocardiography: an aortic valve area of <1 cm^2 (computed using a continuity equation), an indexed aortic valve area of <0.6 cm^2/m^2, a maximum jet velocity of >4 m/s, or a mean transvalvular gradient of >40 mm Hg.[15] Patients were excluded if they had prior aortic valve intervention.

Intervention: FDR

A study nurse was used at each center to monitor echocardiography results. During the first observational phase, the communication between the hospitals and referring physicians relied on usual practice in each center (eg, via a standard report or electronic discharge letter provided to the office-based physician). This letter commonly summarizes any clinical findings, may give recommendations for further investigations but is not highlighted, may potentially not be reviewed in a timely fashion, and there may be no mechanism in place to record appropriate action.

During the intervention phase, the nurse contacted the relevant referring physician in addition to the aforementioned measures for each center and about 1 week after a patient was enrolled, to inform them that their patient had been diagnosed with severe AS on echocardiography (FDR) and had consented to participation in a study assessing follow-up of patients with severe AS. The FDR outlined the class 1 indications for intervention in severe AS and gave all possible management options, without recommending a specific technique (transcatheter aortic valve replacement [TAVR] or surgical aortic
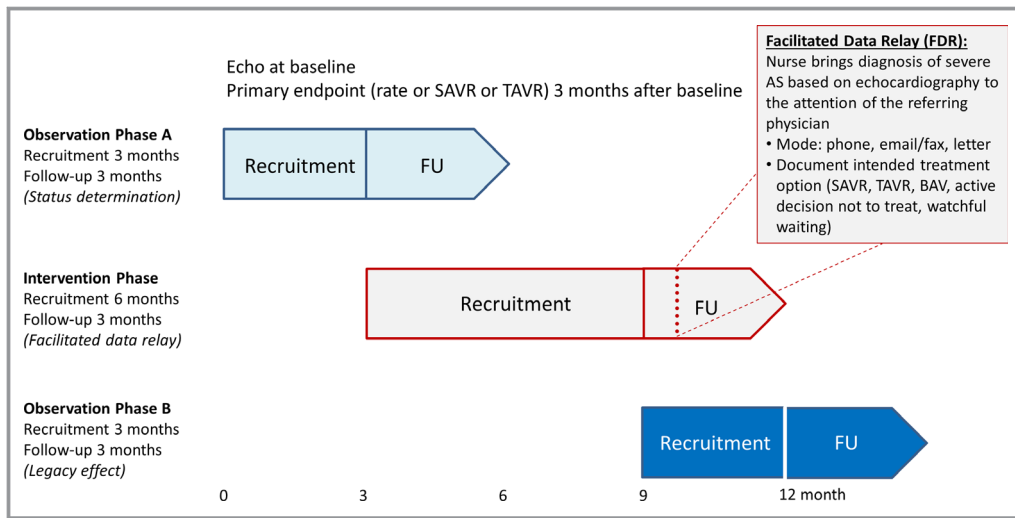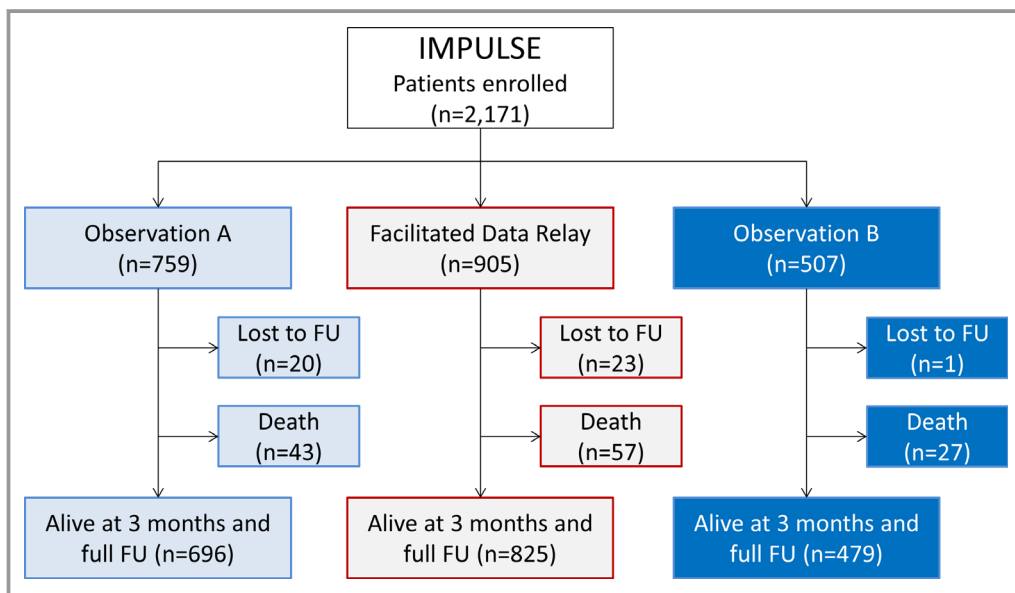
Figure 1. Facilitated data relay. FU (follow-up) indicates 3 months follow-up period where effects of a potential intervention are collected and performance/nonperformance of an intervention are documented; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

valve replacement [SAVR]) over one another. Physicians and/or patients were contacted again 3 months later to collect details of the actual treatment given. Contact was made via a structured email, fax, or when necessary, by telephone call. A standard format was used for all communications.

Data Collection

Data collected at baseline for all patients included demographics, medical history, and symptoms (chest pain, shortness of breath, and dizziness on exertion/syncope). Severe symptoms

were defined as the presence of Canadian Cardiovascular Society class III or IV angina, New York Heart Association functional class III or IV, and/or dizziness on exertion/syncope. The logistic EuroScore I and the EuroScore II were calculated as an indication of surgical risk. Frailty was assessed according to the ability of the patient to walk 5 meters in <6 s and to perform activities of daily living.[16] Activities of daily living and life expectancy were assessed by the dedicated nurses or physicians, but no specific list of activities of daily living or risk calculator was recommended. The results of the echocardiographic assessment were recorded, including the presence of

Figure 2. Patient flow across phases. FU (follow-up) indicates 3 months follow-up period where effects of a potential intervention are collected and performance/nonperformance of an intervention are documented. Full FU refers to data available.

coexisting aortic regurgitation, mitral or tricuspid valve disease; transvalvular gradient; left ventricle dimensions; and left ventricular ejection fraction.

At 3 months after enrollment, information on vital status (alive/dead), treatment decisions (SAVR, TAVR, balloon aortic valvuloplasty [BAV], active decision not to treat, or watchful waiting/further diagnostics) and the number of interventions performed were documented for all patients enrolled into the study. Watchful waiting was defined as the scheduling of further patient follow-up. Data were entered into a standardized electronic case report form by a dedicated study nurse. The primary outcome measure was

the rate of planned and performed SAVR or TAVR within 3 months and the time to intervention.

Statistical Analysis

Data are presented descriptively, using means with SD, medians with interquartile ranges, or absolute values with percentages. Comparisons between patients enrolled during the FDR phase or observation phase B and observation phase A were made using a Pearson χ^2 or Fisher exact test for categorical variables, and a t test, Mann–Whitney–Wilcoxon rank sum test, or ANOVA for continuous variables. A P value of <0.05 was considered statistically significant. Statistical

Table 1. Patient Characteristics

	Total (n=2171) Mean±SD or n/N (%)	Observation A (n=759) Mean±SD or n/N (%)	Facilitated Data Relay (n=905) Mean±SD or n/N (%)	Observation B (n=507) Mean±SD or n/N (%)	P Value for Comparison Across Phases
Age, y	77.9±10.0	77.6±10.2	78.0±9.5	78.1±10.5	0.520
Female sex	1041/2171 (48)	360/759 (47)	436/905 (48)	245/507 (48)	0.938
BMI, kg/m^2	27.4±5.3	27.4±5.8	27.2±4.8	27.7±5.5	0.258
Symptoms					
Chest pain	487/2076 (24)	166/726 (23)	201/873 (23)	120/477 (25)	0.606
Shortness of breath	1576/2123 (74)	548/744 (74)	645/888 (73)	383/491 (78)	0.084
Dizziness on exertion/syncope	471/1941 (24)	157/679 (23)	210/835 (25)	104/427 (24)	0.657
NYHA class III or IV	859/2142 (40)	315/755 (42)	338/900 (38)	206/487 (42)	0.120
Angina CCS class III or IV	91/1901 (5)	45/676 (7)	29/788 (4)	17/437 (4)	0.018
Symptomatic*	1743/2171 (80)	605/759 (80)	717/905 (79)	421/507 (83)	0.199
Severe symptoms	1122/2171 (52)	402/759 (53)	455/905 (50)	265/507 (52)	0.526
Echocardiographic valve-related parameters					
Aortic valve area, cm^2	0.73±0.2	0.74±0.2	0.73±0.2	0.72±0.2	0.323
Indexed aortic valve area, cm/m^2	0.40±0.1	0.40±0.1	0.40±0.1	0.39±0.1	0.312
Maximum jet velocity, m/s	4.3±0.7	4.3±0.7	4.3±0.6	4.3±0.7	0.724
Mean transvalvular gradient, mm Hg	47.1±14.7	47.2±15.0	47.6±14	46.2±14.7	0.237
LVH (>12 mm thick)	1324/2132 (62)	490/758 (65)	560/902 (62)	274/472 (58)	0.068
EF, %	55.8±12	56.0±12	56.5±12	54.4±11	0.008
>50%	1492/2054 (73)	520/720 (72)	634/854 (74)	338/480 (70)	0.245
30–50%	496/2054 (24)	174/720 (24)	191/854 (22)	131/480 (27)	
<30%	66/2054 (3)	26/720 (4)	29/854 (3)	11/480 (2)	
PAP, mm Hg	39.4±13	39.4±13	40.1±13	38.2±13	0.098
Frailty (severe)†	110/2141 (5)	55/755 (7)	33/899 (4)	22/487 (5)	0.003
Surgical risk					
Logistic EuroScore I, %	15.6±13.9	15.9±13.8	16.3±14.5	14.1±12.9	0.157
Logistic EuroScore II, %	4.0±5.0	3.9±5.0	4.1±4.7	4.1±5.4	0.710

Comparisons were analyzed using Pearson χ^2 or Fisher exact test for categorical variables, and ANOVA for continuous variables. BMI indicates body mass index; CCS, Canadian Cardiovascular Society; EF, ejection fraction; LVH, left ventricular hypertrophy; NYHA, New York Heart Association; PAP, pulmonary artery pressure.
*Defined as 1 or more cardiac symptoms presumably related to severe aortic stenosis (chest pain, shortness of breath, dizziness on exertion/syncope).
†Defined as inability to perform 2 or more activities of daily life.

analysis was performed using SPSS Version 23.0 (IBM Corp., Armonk, NY).

Results

Patient Characteristics

A total of 2171 patients with severe AS were enrolled (759 in observation phase A, 905 in the FDR intervention phase, and 507 in observation phase B; Figure 2). Of those, 1562 patients were referred by cardiologists, 273 by general physicians, 111 by cardiac surgeons, 32 by geriatricians, and 192 by other physicians (1 unknown). During the study, 44 patients were lost to follow-up (data completeness at 3 months 98.0%) and

127 patients died (death rate 5.9%) including postoperative death. The mean age of the overall (n=2171) study population was 77.9±10.0 years, and 80% had symptomatic AS including 52% with severely limiting symptoms. Echocardiography revealed a mean aortic valve area of 0.73±0.2 cm^2, mean indexed aortic valve area of 0.40±0.1 cm/m^2, mean maximum jet velocity of 4.3±0.7 m/s, and mean transvalvular gradient of 47.1±14.7 mm Hg. The mean EuroScore II was 4.0±5.0%.

Patients enrolled in the different study phases had similar demographic and disease characteristics, apart from a slightly higher proportion of patients with angina pectoris Canadian Cardiovascular Society class III/IV and severe frailty in observation phase A, and a slightly lower mean ejection
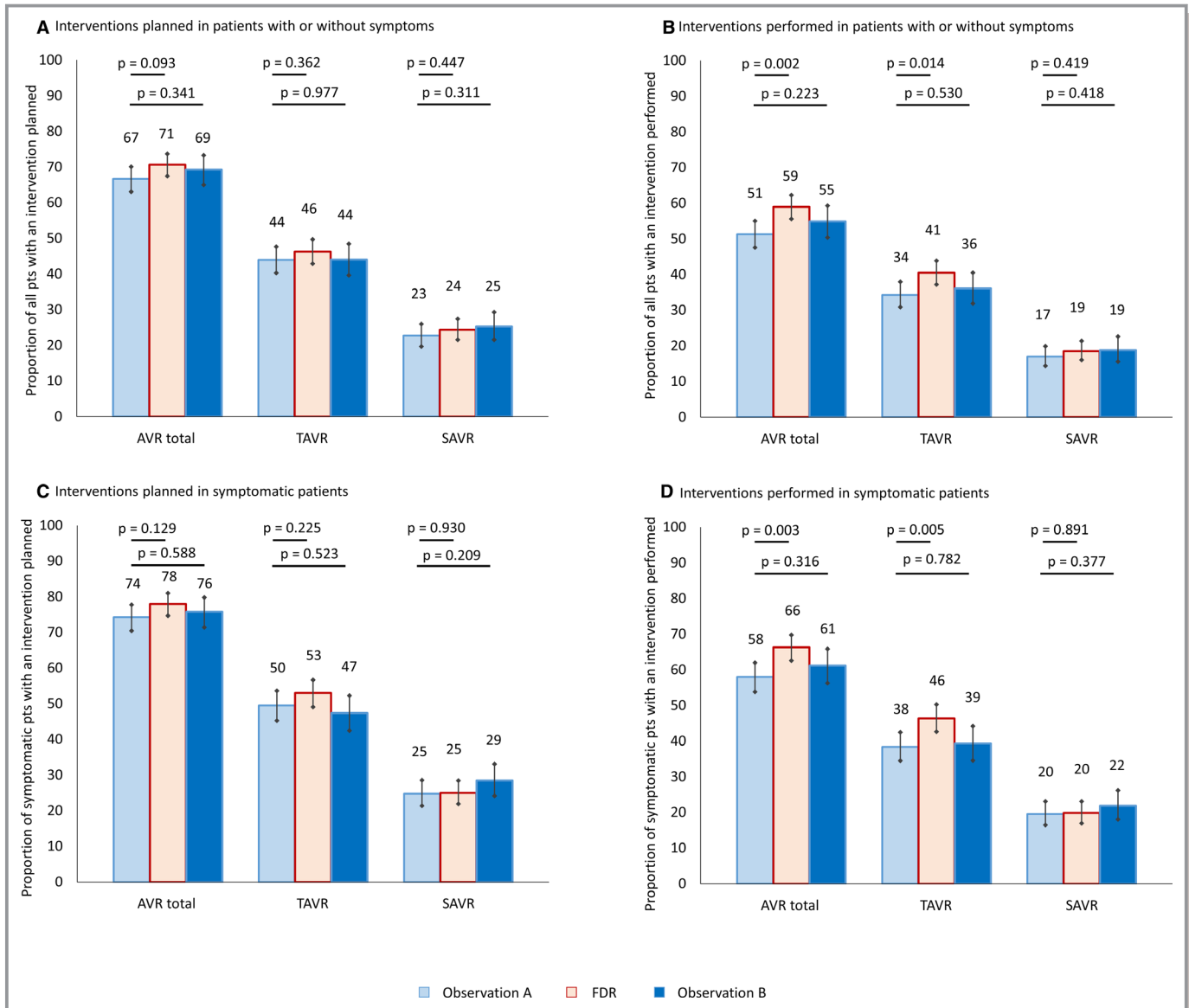
Figure 3. Proportion of AVR (total), TAVR or SAVR planned (**A**) and performed (**B**) in all patients AND planned (**C**) and performed (**D**) in symptomatic patients within 3 months during the 3 study phases. AVR indicates aortic valve replacement; FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

fraction among patients enrolled in observation phase B (Table 1). Specifically, the rate of symptomatic patients and patients presenting with severe symptoms was not different across the different phases.

Rate and Timeliness of Intervention for AS

During observation phase A, which was designed to demonstrate the status quo at each participating hospital before the introduction of FDR (baseline), an AVR was planned in 464/696 (67%) patients (Figure 3A planned; Figure 3B performed). Of these 464, the plan was for the majority to undergo TAVR (n=306) and fewer to undergo SAVR (n=158). Of the remaining patients identified with severe AS, 138 (20%) were considered suitable for watchful waiting, 8 (1%) were planned for balloon aortic valvuloplasty, 60 (9%) were listed as not for active treatment, and in 26 (4%), no decision was made at all. Data for the subgroup of symptomatic patients are displayed in Figure 3C and 3D. In total, 363/464 of patients (78% of the overall population) received the planned intervention within 3 months at a mean of 36±38 days in total (Figure 4A) and 36±37 days in symptomatic patients (Figure 4C).

Effect of FDR

During the intervention (FDR) phase B, there was a trend toward an increase in the number of AVRs planned compared with the observation phase, although this did not reach statistical significance (583/825, 71% versus 464/696, 67%, P=0.093; Figure 3A). There was no correlation between the timeliness of the FDR and the actual date of the intervention (Pearson r=0.090). There were also no differences between contact methods (phone, email/fax, or letter) for the time to intervention except for those who were referred from a physician within the hospital (P<0.001). FDR did not alter the ratio of patients listed for TAVR as opposed to SAVR. However, timeliness of the intervention improved as shown by the higher number of AVR performed within 3 months (59% versus 51%, P=0.002; Figure 3B) and a significant decrease in the time to intervention by 6 days (36±38 versus 30±33 days, P=0.002) (Figure 4A). Interestingly, this effect was mainly driven by a significant improvement in timeliness of intervention in TAVR but not in SAVR (Figures 3 and 4). Of interest, the effect of FDR was seen whether patients were symptomatic or not (Figure 3B and 3D).

We performed a time-to-event analysis for the overall AVR group as well as for those undergoing TAVI and SAVR, respectively. The time-to-intervention (if we consider it an event) was significantly reduced for the overall AVR analysis when the intervention phase was compared with the observational phase A with a P=0.002 using a log-rank and <0.001 using the Breslow test. This was seen when comparing observational phase B to observational phase A (P=0.188 and
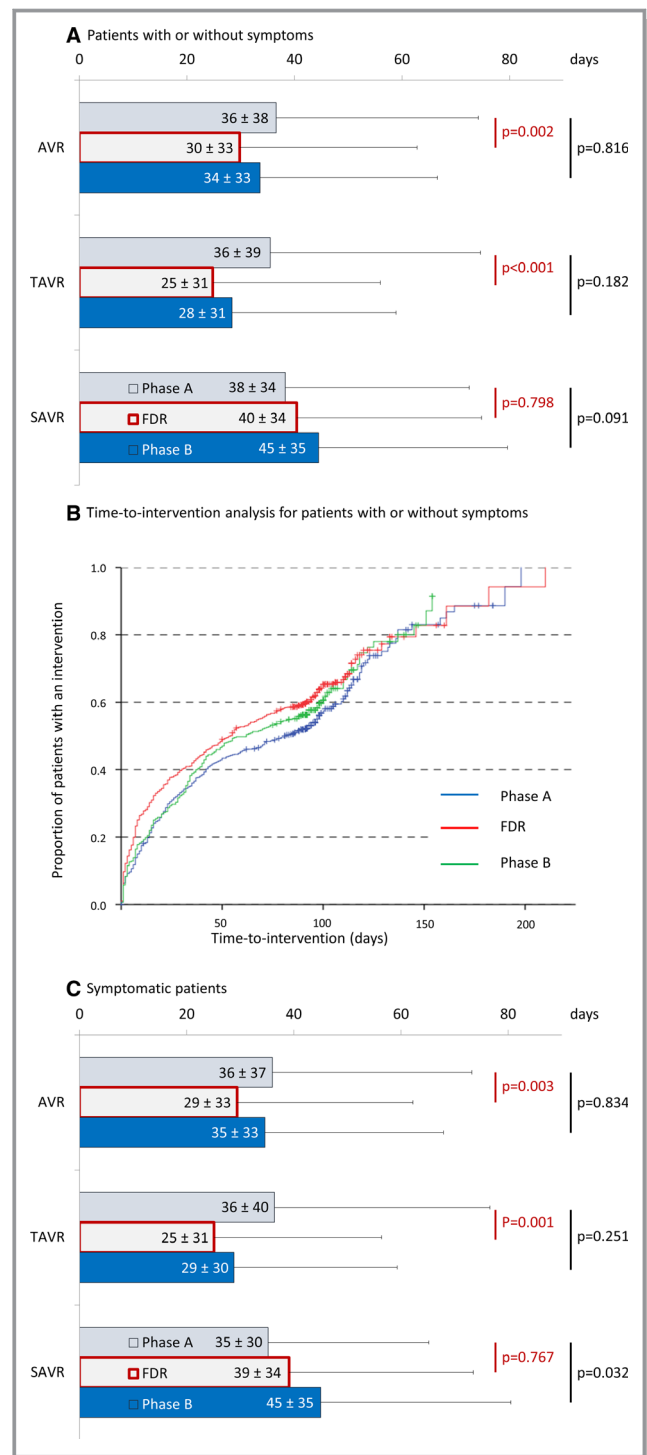
Figure 4. Time to intervention or planned date according to treatment option and study phase in patients with or without symptoms (**A** and **B**) and in symptomatic patients (**C**). FDR indicates facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

0.257, respectively) (Figure 4B). If the time-to-event analysis is repeated for the TAVI and SAVR groups, the results reproduce the prior findings using the *t* test. While there is a significant effect of FDR on the rate of TAVI (P=0.011 log-rank

P=0.001 Breslow), there is no such effect for SAVR alone (*P*=0.066 log-rank, *P*=0.134 Breslow). Comparisons of observational phase B to A are again not statistically significant.

FDR: A Legacy Effect?

Once FDR was discontinued, there was little "legacy effect." Comparing observation phase B with observation phase A, there was neither a difference in the number of AVRs planned (332/479, 69% versus 464/696, 67%) nor in the number of AVR performed within 3 months (54.9% versus 51.3%, *P*=0.223) (Table 2 and Figure 3B). Overall, time to intervention was not different between phase B and phase A (34±33 versus 36±38 days, *P*=0.816) (Figure 4A).

Facilitated Data Relay: An International Comparison

Results were then investigated to determine whether there was a difference in effect of FDR between countries. Within each of the countries studied, there was an increase in the number of AVR procedures performed (Table 3), and, as a result, a consistent reduction in the time to intervention (Table 4). Within each single country, there was no significant difference in the effect of FDR, presumably because of lower power. The data from individual countries, however, together with sensitivity analysis revealed 3 important further

differences. First, the percentage of cases planned (Figure S1) and then actually performed (Figure S2) within 3 months differs between countries, with a much higher percentage of definitive treatment delivered in a timely fashion (Figure S3) within 3 months in Germany compared with the United Kingdom. Second, sequentially excluding 1 country and restricting analysis to the 4 remaining countries, much of the effect of FDR appears to be delivered by analyses that include the United Kingdom and the impact loses significance when the United Kingdom was excluded. Third, there was a strong increase in the rate of AVR performance in Italy, which further increased in the second observational phase for AVR and SAVR in particular.

Discussion

In patients diagnosed with severe AS on echocardiography, 1 in 5 patients wait >3 months from time of diagnosis to intervention. This delay to intervention occurred despite >80% of patients being symptomatic, with the majority of these having severe limitations, classified as New York Heart Association or Canadian Cardiovascular Society class III or IV. Moreover, the delay to intervention occurred in hospitals in which both SAVR and TAVR were available on-site, where one might expect intervention to occur in a timelier fashion. A simple, low cost, and easily applicable FDR intervention

Table 2. Treatment Actually Performed After 3 Months

	Observation A (n=696)	FDR (n=825)		Observation B (n=479)	
	n (%)	n (%)	*P* vs Phase A	n (%)	*P* vs Phase A
Total					
AVR performed within 3 mo	357 (51.3)	487 (59.0)	0.002	263 (54.9)	0.223
If AVR not performed					
Date of AVR set	41 (5.9)	32 (3.9)	0.067	23 (4.8)	0.419
Date of AVR not set	66 (10)	64 (8)	0.231	46 (10)	0.945
TAVR					
TAVR performed within 3 mo	239 (34.3)	334 (40.5)	0.014	173 (36.1)	0.530
If TAVR not performed					
Date of TAVR set	29 (4.2)	17 (2.1)	0.017	14 (2.9)	0.264
No date of TAVR set	38 (5.5)	31 (3.8)	0.112	24 (5.0)	0.735
SAVR					
SAVR performed within 3 mo	118 (17.0)	153 (19)	0.419	90 (18.8)	0.418
If SAVR not performed					
Date of SAVR set	12 (1.7)	15 (2)	0.890	9 (1.9)	0.844
No date of SAVR set	28 (4)	33 (4)	0.982	22 (4.6)	0.634

Comparisons were analyzed using Pearson χ^2 or Fisher exact test. AVR indicates aortic valve replacement; BAV, balloon aortic valvuloplasty; FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.
Number of patients in whom BAV was performed within 3 months: 5/696 (0.7%) during observation phase A; 6/825 (0.7%) during intervention (facilitated data relay) phase; and 7/479 (1.5%) during observation phase B.

Table 3. Treatment Planned, and Treatment Actually Performed After 3 Months: Country-Specific Analysis

	Total	Observation A n (%)	Facilitated Data Relay n (%)	*P* vs Phase A	Observation B n (%)	*P* vs Phase A
Germany	n=520	n=191	n=209		n=120	
AVR						
Planned	472 (90.8)	169 (88.5)	191 (91.4)	0.333	112 (93.3)	0.158
Performed	449 (86.3)	164 (85.9)	181 (86.6)	0.830	104 (86.7)	0.842
TAVR						
Planned	390 (75.0)	137 (71.7)	153 (73.2)	0.741	100 (83.3)	0.019
Performed	374 (71.9)	134 (70.2)	147 (70.3)	0.969	93 (77.5)	0.156
SAVR						
Planned	82 (15.8)	32 (16.8)	38 (18.2)	0.707	12 (10.0)	0.096
Performed	75 (14.4)	30 (15.7)	34 (16.3)	0.878	11 (9.2)	0.097
UK	n=478	n=178	n=114		n=186	
AVR						
Planned	247 (51.7)	92 (51.7)	62 (54.4)	0.652	93 (50.0)	0.748
Performed	135 (28.2)	48 (27.0)	42 (36.8)	0.075	45 (24.2)	0.544
TAVR						
Planned	143 (29.9)	51 (28.7)	41 (36.0)	0.189	51 (27.4)	0.794
Performed	83 (17.4)	27 (15.2)	29 (25.4)	0.030	27 (14.5)	0.861
SAVR						
Planned	104 (21.8)	41 (23.0)	21 (18.4)	0.347	42 (22.6)	0.918
Performed	52 (10.9)	21 (11.8)	13 (11.4)	0.918	18 (9.7)	0.513
France	n=356	n=107	n=202		n=47	
AVR						
Planned	271 (76.1)	83 (77.6)	150 (74.3)	0.520	38 (80.9)	0.648
Performed	241 (67.7)	71 (66.4)	133 (65.8)	0.928	37 (78.7)	0.123
TAVR						
Planned	150 (42.1)	42 (39.3)	83 (41.1)	0.754	25 (53.2)	0.108
Performed	133 (37.4)	33 (30.8)	76 (37.6)	0.235	24 (51.1)	0.017
SAVR						
Planned	121 (34.0)	41 (38.3)	67 (33.2)	0.366	13 (27.7)	0.202
Performed	108 (30.3)	38 (35.5)	57 (28.2)	0.186	13 (27.7)	0.340
Italy	n=327	n=108	n=145		n=74	
AVR						
Planned	242 (74.0)	77 (71.3)	105 (72.4)	0.845	60 (81.1)	0.133
Performed	198 (60.6)	51 (47.2)	91 (62.8)	0.014	56 (75.7)	<0.001
TAVR						
Planned	169 (51.7)	60 (55.6)	78 (53.8)	0.781	31 (41.9)	0.070
Performed	133 (40.7)	38 (35.2)	68 (46.9)	0.062	27 (36.5)	0.857
SAVR						
Planned	73 (22.3)	17 (15.7)	27 (18.6)	0.550	29 (39.2)	<0.001
Performed	65 (19.9)	13 (12.0)	23 (15.9)	0.389	29 (39.2)	<0.001

Table 3. Continued

	Total	Observation A n (%)	Facilitated Data Relay n (%)	P vs Phase A	Observation B n (%)	P vs Phase A
Others	n=319	n=112	n=155		n=52	
AVR						
Planned	147 (46.1)	43 (38.4)	75 (48.4)	0.105	29 (55.8)	0.037
Performed	84 (26.3)	23 (20.5)	40 (25.8)	0.317	21 (40.4)	0.008
TAVR						
Planned	47 (14.7)	16 (14.3)	27 (17.4)	0.492	4 (7.7)	0.230
Performed	23 (7.2)	7 (6.3)	14 (9.0)	0.405	2 (3.8)	0.720
SAVR						
Planned	100 (31.3)	27 (24.1)	48 (31.0)	0.218	25 (48.1)	0.002
Performed	61 (19.1)	16 (14.3)	26 (16.8)	0.582	19 (36.5)	0.001

Comparisons were analyzed using Pearson χ^2 or Fisher exact test. No adjustment for multiple testing was made, because the analyses are meant to explore the country-specific effect, but with lower statistical power compared with the main analysis. AVR indicates aortic valve replacement; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

resulted in a greater proportion undergoing treatment within 3 months, mainly because of faster delivery of TAVR. FDR did not affect the rate of AVR. Delay to delivery of treatment differs between the countries included, with fewer receiving treatment within 3 months of a decision in the United Kingdom and a particular improvement with FDR in Italy.

Delay between the diagnosis of severe AS and an appropriate intervention is responsible for patients dying while waiting for an intervention and can increase perioperative and late complications.[11,12] Given the impact of unduly delayed intervention, the introduction of methods such as FDR that do reduce delays in management should be mandated. This is particularly important in patients with severe AS who have advanced disease at a stage when full recovery can no longer be guaranteed.[6–8,17] In the current study, 52% of patients had severely limiting symptoms and 27% had an ejection fraction of ≤50% at the time of enrollment. Since the prognosis is poor for such patients with severe AS who do not receive appropriate treatment,[18–20] a failure to deliver outcome-modifying treatment in 1 in 5 patients within 3 months suggests that there is an urgent need to improve quality of care. It is also noteworthy that consistently across all phases of the study, no decision was made regarding management of these high-risk patients in 3% to 4% of cases. Given the risk of sudden cardiac death, irreversible myocardial damage, and development of congestive heart failure, which directly impact outcome, any intervention that can speed up management pathways should lead to improved outcomes, and in large populations, may reduce mortality.

There is a consensus that the best care for patients with valvular heart disease is provided by a specialist heart valve service.[21,22] One study showed that symptoms were detected earlier among patients with severe AS followed up in a structured valve clinic compared with those referred from other services, which facilitated optimized timing of surgery.[23] Such services do not have to be physician-led. For example, the introduction of a sonographer-led heart valve clinic increased the proportion of patients with valvular disease managed according to best-practice guidelines from 41% to 92%.[24] In our study, a simple communication by a nurse resulted in faster delivery of treatment in centers that had fully capable facilities available and which one would expect should already deliver the highest quality of care. A nurse was used in the study; however, the FDR communication itself highlighted the diagnosis, the indications for intervention, and asked for options regarding management, and so could potentially be carried out automatically or by nonmedical staff. All healthcare systems are currently under financial constraint and FDR is a low-cost intervention that was shown in this study to improve timeliness of care in AS.

There is evidence that this type of quality improvement strategy, which involves the transmission of clinical data using a means other than an existing automated system, is effective in other medical conditions.[25] A systematic review of quality-improvement strategies for the management of hypertension found that FDR of clinical data was associated with median reductions in systolic and diastolic blood pressure of 8.0 and 1.8 mm Hg, and a 25% increase in the proportion of patients achieving target systolic blood pressure.[26] The results of the current study indicate that an FDR strategy can increase the rate of delivery of TAVR to patients with severe AS. A trend towards an increase in the number of surgical AS

Table 4. Time to Intervention: Country-Specific Analysis

	Total	Observation A Mean±SD	FDR Mean±SD	P vs Phase A	Observation B Mean±SD	P vs Phase A
Total						
AVR	33.0±34.7	36.45±37.6	29.9±33.0	0.002	34.0±33.0	0.816
TAVR	29.2±34.2	35.5±39.1	24.8±31.2	<0.001	28.4±30.5	0.182
SAVR	40.7±34.5	38.3±34.2	40.4±34.4	0.798	44.5±35.1	0.091
Germany						
AVR	24.6±29.2	23.6±25.7	23.1±30.2	0.119	28.5±32.1	0.347
TAVR	21.4±28.2	22.2±25.6	17.4±28.4	0.004	26.3±30.6	0.373
SAVR	40.3±29.1	29.5±25.7	47.1±25.9	0.003	47.7±39.0	0.072
UK						
AVR	50.9±41.5	54.2±45.5	47.0±35.4	0.615	50.4±41.8	0.606
TAVR	53.2±42.9	60.5±50.9	50.3±37.8	0.605	47.9±37.3	0.410
SAVR	47.2±39.2	45.0±35.0	39.3±28.6	0.667	53.8±47.8	0.968
France						
AVR	22.0±26.2	22.2±22.1	22.9±29.5	0.242	18.3±20.0	0.209
TAVR	20.7±25.8	23.4±20.9	21.5±29.8	0.078	14.4±15.5	0.053
SAVR	23.6±26.7	21.2±23.3	24.7±29.3	0.965	25.5±25.4	0.672
Italy						
AVR	35.9±34.7	54.8±44.7	29.1±30.2	<0.001	26.1±15.6	0.005
TAVR	35.1±35.1	53.5±44.0	26.7±27.3	<0.001	23.8±20.1	<0.007
SAVR	37.7±33.9	59.1±48.4	35.8±37.3	0.071	28.3±9.3	0.115
Others						
AVR	62.8±34.8	65.3±41.3	60.4±33.7	0.886	64.9±28.1	0.820
TAVR	60.6±41.0	72.2±58.8	53.9±25.4	0.786	50.5±20.5	0.693
SAVR	63.7±32.4	61.5±28.9	63.4±36.8	0.668	66.3±28.8	0.676

Comparisons were analyzed using Mann–Whitney U test. No adjustment for multiple testing was made, because the analyses are meant to explore the country-specific effect, but with lower statistical power compared with the main analysis. AVR indicates aortic valve replacement; FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

interventions being pursued was also seen during the FDR phase, although this did not achieve statistical significance. This study provides proof of concept and offers the possibility that similar benefit could be gained by automated communications containing the same information and sent to the referrer (for example, by e-mail generated by the echocardiographer or the machine itself), to minimize delays.

The reasons for the difference in the effect of FDR on the rate of delivery of TAVR and SAVR are unknown but could possibly relate to the increased awareness of the role of TAVR in patients who are at high surgical risk or for whom surgery is contraindicated (such as very elderly patients with comorbidities). A potential explanation is that there is a fixed capacity for SAVR in a given hospital and merely adding patients to the wait list does not result in a higher throughput. On the contrary, the potential turnover of patients undergoing

TAVR may be more flexible because it requires fewer resources and allows for a higher rate of AVR performance and a substantial shortening of the time to intervention. While an increase in TAVR performance capacity may contribute to this, it is unlikely to have a played a role in our setting because enrollment in each institution was limited to 3 months for observation A, 6 months for FDR, and 3 months for observation B. The fact that there are differences between countries included in this study suggest that other factors may also have an impact, which could include issues of logistics and infrastructure that appear to be much less of a problem in Germany and Italy than in the United Kingdom. All the centers involved in this study had the capability of delivering SAVR and TAVR, and it is not known whether the effect of FDR might be different in centers without direct access to these interventions. Given the adverse effect that

delays can have on outcomes for patients with severe AS (as illustrated by the mortality rate of 6% within 3 months noted across each phase of the study), these results suggest that additional measures may be necessary to further reduce delays in the delivery of intervention.[27]

There were limitations to the IMPULSE registry. As an observational, cross-sectional study, the outcomes after valve intervention beyond 3 months were not recorded. Furthermore, although treatment decisions were documented, the actual treatment that each patient underwent may have differed. Finally, despite a total number of patients of n=2171, the study was not powered to detect a difference in outcomes such as mortality. Future study at the population level will determine whether FDR altered appropriateness of intervention. The strengths of the IMPULSE registry include its prospective design and that it is the largest prospective registry to date that documents clinical characteristics and management of contemporary patients.

Conclusions

In conclusion, a significant proportion of patients diagnosed with severe AS on echocardiography wait >3 months from time of diagnosis to intervention. This delay to intervention occurred despite the majority being symptomatic and mostly with severe limitation. A simple, low-cost FDR process may improve treatment pathways for patients diagnosed with severe AS, by increasing the rate of intervention performed within 3 months and decreasing the time to TAVR. Although the effect of FDR was seen, the data from this study also highlighted differences in the delivery of aortic valve intervention to patients, with many more experiencing delay in the United Kingdom compared with Germany. Although FDR did not alter the overall rate of intervention, this process could be improved and has the potential to reduce perioperative and postoperative morbidity, while decreasing the number of patients dying on the waiting list for AVR. Future studies are now needed to formally demonstrate the impact of FDR on outcome.

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Author Contributions

Frey, Steeds, Messika-Zeitoun, Kurucova, Thoenes, and Bramlage were involved in the conception and design of the study. Steeds, Lutz, and Bramlage drafted the manuscript and all other authors revised the article for important intellectual content. All authors gave final approval of the version to be published.

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SUPPLEMENTAL MATERIAL

Figure S1. Country specific analysis - Proportion of AVR (total), TAVR or SAVR planned within 3 months during the three study phases.
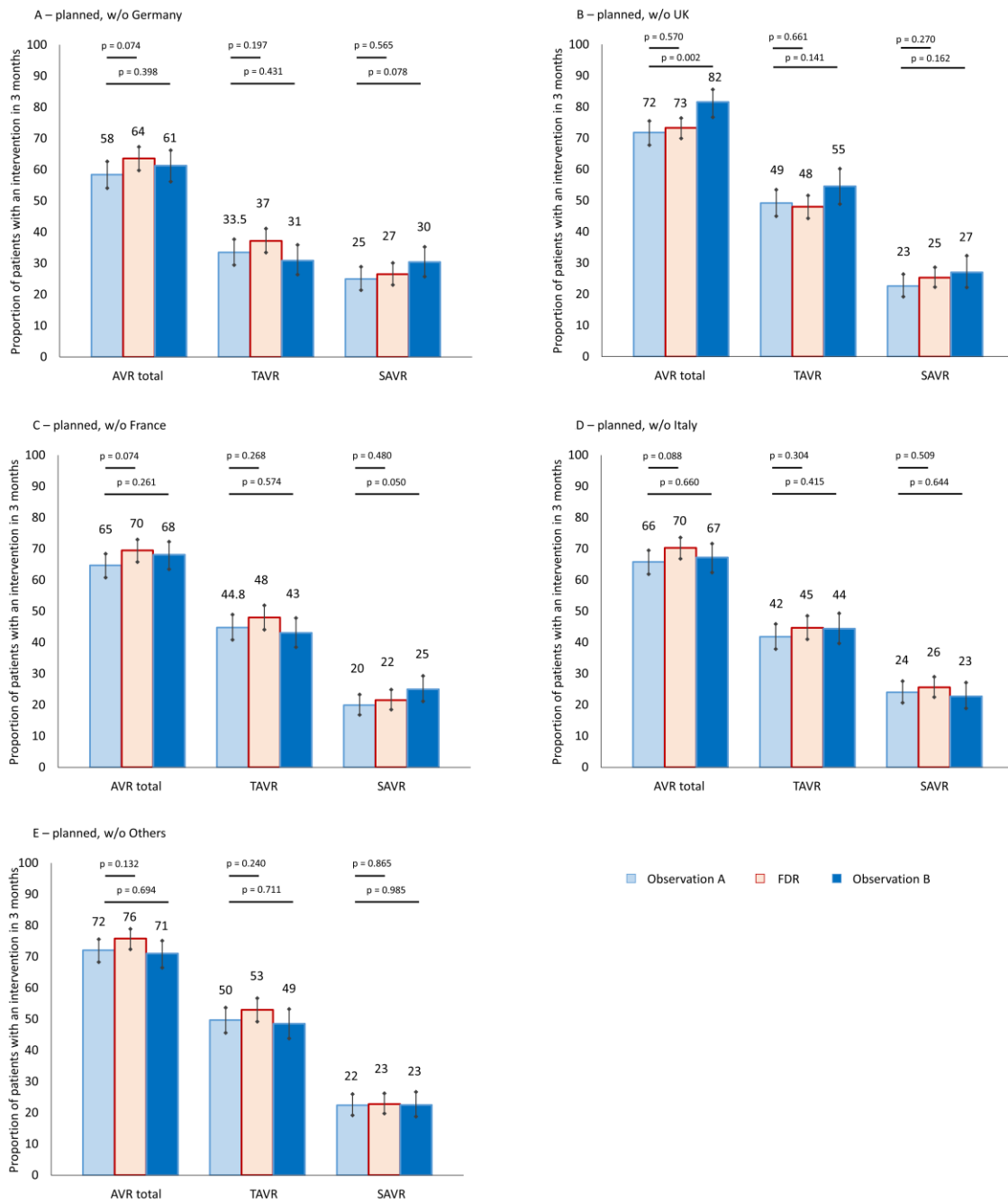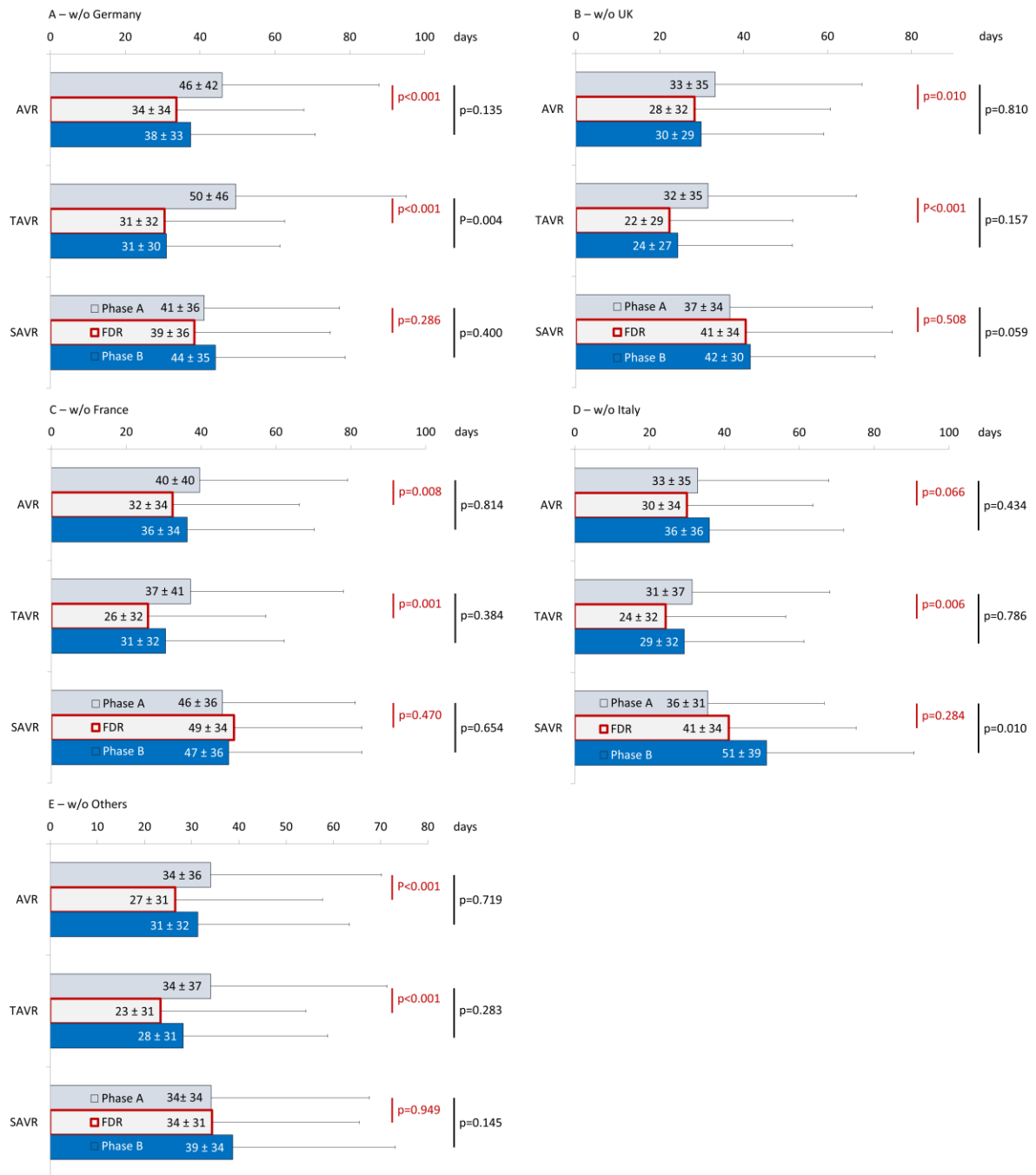

AVR, aortic valve replacement; FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

Figure S2. Country specific analysis - Proportion of AVR (total), TAVR or SAVR performed within 3 months during the three study phases.
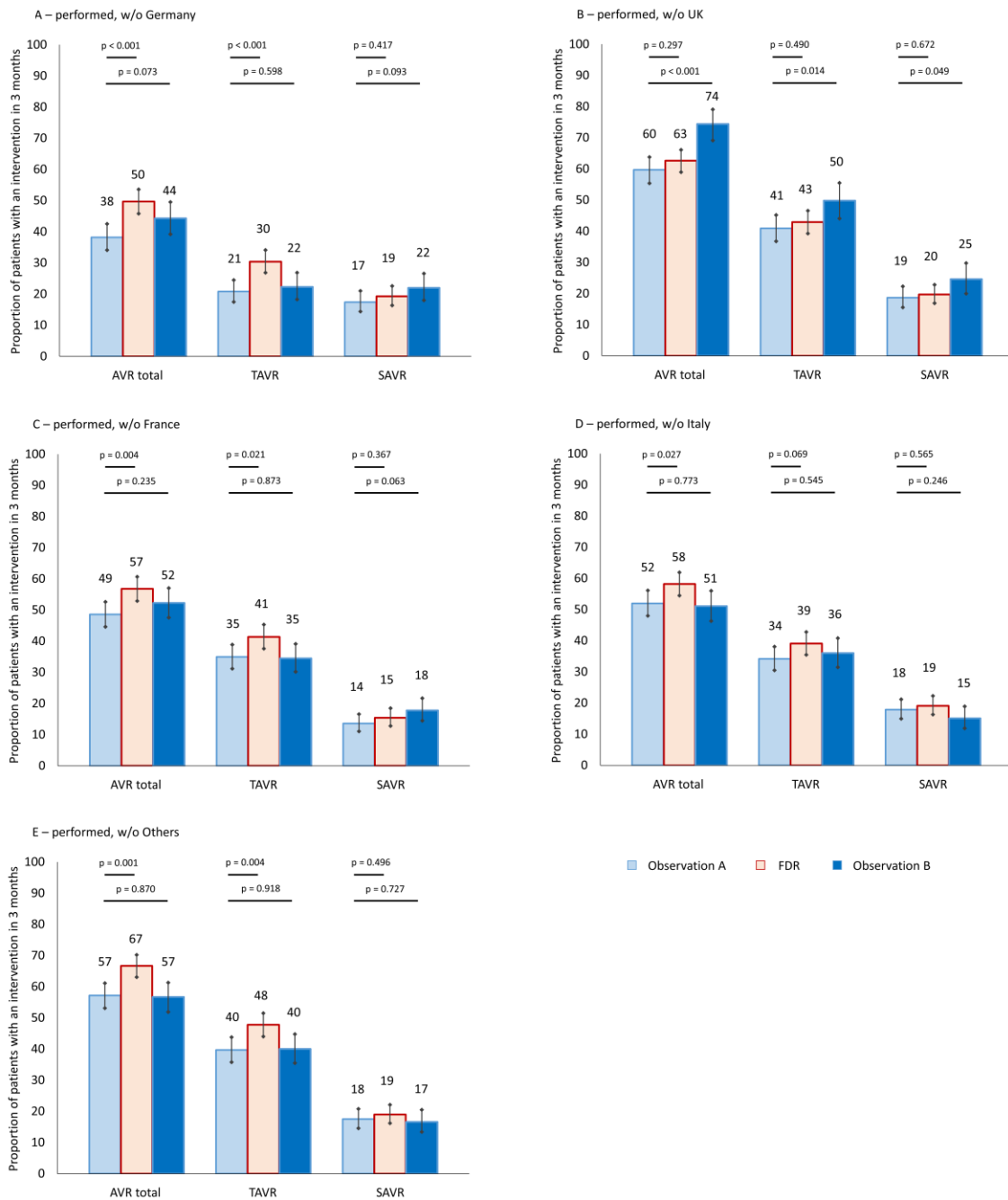
AVR, aortic valve replacement; FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

Figure S3. Country specific analysis (Exclusion of countries) – Time to intervention.

FDR, facilitated data relay; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement