Rapid deployment or sutureless versus conventional bioprosthetic aortic valve replacement: A meta-analysis

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ABSTRACT

Objectives: This meta-analysis was conducted to compare the early and follow-up outcomes of aortic valve replacement using rapid deployment or sutureless (RD) valves (RDAVR group) with aortic valve replacement using conventional bioprostheses (CAVR group).

Methods: A literature search of 5 online databases was conducted. The primary outcomes were postoperative complications and the secondary outcomes included the aortic cross-clamp (ACC) and cardiopulmonary bypass (CPB) times and early mortality and all-cause mortality during follow-up.

Results: Twenty-one articles (RDAVR group = 1297 patients; CAVR group = 1488 patients) were selected. The pooled analyses showed that the ACC and CPB times were significantly shorter in the RDAVR group than in the CAVR group (mean difference, -26.34 ; 95% confidence interval [CI], -31.86 to -20.82 and mean difference, -25.33 ; 95% CI, -30.79 to -19.87 , respectively). The pooled risk ratios (RRs) of any paravalvular leak and permanent pacemaker (PPM) insertion were significantly higher in the RDAVR group than in the CAVR group (RR, 2.32; 95% CI, 1.53-3.51 and RR, 2.08; 95% CI, 1.49-2.90, respectively). The pooled analysis showed that the risk of a paravalvular leak grade ≥ 2 in the RDAVR group did not significantly differ between the RDAVR and CAVR groups (RR, 2.05; 95% CI, 0.71-5.93). The risk of PPM insertion remained significant when only studies reporting adjusted outcomes were pooled. The risks of other postoperative complications, early mortality, and all-cause mortality during follow-up were not significantly different between the RDAVR and CAVR groups.

Conclusions: RDAVR is associated with significantly shorter ACC and CPB times than CAVR, although this difference did not translate into improved postoperative outcomes, early mortality, and all-cause mortality during follow-up. Care might be needed when implanting RD valves because they are associated with a higher incidence of PPM insertion, regardless of the RD valve type. (J Thorac Cardiovasc Surg 2018;155:2402-12)

Pooled estimates of postoperative complications between RDAVR and conventional AVR.

Central Message

Rapid deployment or sutureless AVR is associated with shorter ACC and CPB times without differences in postoperative complications except for a higher occurrence of permanent pacemaker insertion.

Perspective

This study showed that aortic valve replacement using rapid deployment or sutureless valves was associated with shorter aortic cross-clamp and cardiopulmonary bypass times but also a greater occurrence of permanent pacemaker insertion. Surgeons should carefully select valve types according to the benefit and disadvantage of rapid deployment or sutureless valves and conventional valves.

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Received for publication Sept 17, 2017; revisions received Dec 14, 2017; accepted for publication Jan 11, 2018; available ahead of print March 13, 2018.

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0022-5223/\$36.00

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<https://doi.org/10.1016/j.jtcvs.2018.01.084>

Despite the development of transcatheter aortic valve implantation (TAVR) for elderly and high-risk patients, surgical aortic valve replacement (AVR) is still considered the treatment of choice for patients with severe aortic

Scanning this QR code will take you to the supplemental figures, table, and video for the article.

Abbreviations and Acronyms

ACC	= aortic cross-clamp
AVR	= aortic valve replacement
CAVR	= conventional aortic valve replacement
CI	= confidence interval
CPB	= cardiopulmonary bypass
CV	= conventional valve
HR	= hazard ratio
LBB	= left bundle branch
MD	= mean difference
MeSH	= medical subject heading
NRS	= nonrandomized study
PPM	= permanent pacemaker
PSM	= propensity score-matching
PVL	= paravalvular leak
RCT	= randomized controlled trial
RD	= rapid deployment or sutureless
RDAVR	= rapid deployment aortic valve replacement
RR	= risk ratio
ROB	= risk of bias
TAVR	= transcatheter aortic valve replacement

stenosis.^{1,2} Recently, rapid deployment or sutureless (RD) valves were introduced to overcome the limitations of TAVR as well as conventional surgical AVR.^{3,4} The theoretical advantages of RD valves include a short surgery time, the ease of insertion even in limited operating fields, and their optimal hemodynamic properties.^{3,5} However, whether the RD valves are truly beneficial is controversial.^{6,7} Therefore, this meta-analysis was conducted to compare the early and follow-up outcomes of AVR using RD valves with conventional bioprosthetic AVR.

METHODS**Data Source and Literature Search**

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.⁸ Full-text articles comparing the results of AVR using RD valves (RDAVR group) with those of standard AVR using conventional bioprostheses (CAVR group) were searched in the Medline, Embase, Cochrane Central Register of Controlled Trials, Web of Science, and Scopus databases on May 23, 2017. No restrictions were placed on the language or publication year. The following key words and medical subject heading (MeSH) terms were searched in Medline: ((“aortic valve” [MeSH Terms] OR “heart valve prosthesis implantation” [MeSH Terms]) OR ((“aortic valve replacement” [Title/Abstract] OR “aortic valve prosthesis” [Title/Abstract]) OR “aortic prosthesis” [Title/Abstract]) OR “prosthetic aortic valve” [Title/Abstract]) OR “aortic valve implantation” [Title/Abstract])) AND (“sutureless surgical procedures” [MeSH Terms] OR (“sutureless” [Title/Abstract] OR “rapid” [Title/Abstract])). The search strategies for other databases were adapted from this Medline strategy.

Study Selection

Study selection was independently performed by 2 reviewers (S.H.S. and H.Y.H.) on the basis of predefined selection criteria. Any disagreements between the reviewers were resolved through discussion. The study selection was performed through the following 2 levels of screening: the titles and abstracts of the searched studies were screened at the first level and the full texts were reviewed at the second level. Studies were included if they met the following criteria: (1) enrolled patients who underwent AVR; and (2) compared the clinical outcomes of RDAVR with those of CAVR. When duplicated publications with overlapping study populations were found, the most appropriate article for this comparison was selected on the basis of the confounding bias and the follow-up duration.

Data Extraction

The study characteristics and the patients' baseline data were extracted independently by 2 reviewers (S.H.S. and H.Y.H.). Data regarding study outcomes were also independently extracted by 2 reviewers (M.-J.J. and H.Y.H.). Any disagreements between reviewers were resolved through discussion by 3 authors (S.H.S., M.-J.J., and H.Y.H.). The corresponding author of 1 of the included studies⁷ was contacted via e-mail to clarify the outcome data.

Quality Assessment

The overall study quality was assessed independently by 2 reviewers (M.-J.J. and H.Y.H.) using the Cochrane Risk of Bias Tool for randomized controlled trials (RCTs) and the Risk of Bias In Non-Randomized Studies of Interventions for nonrandomized studies (NRSs).⁹ In the Risk Of Bias In Non-randomized Studies of Interventions, 7 domains of risk of bias (ROB) were assessed and the overall ROB was determined to be low, moderate, serious, or critical on the basis of the assessment of each domain. Any disagreements between reviewers were resolved through discussion by 3 authors (S.H.S., M.-J.J., and H.Y.H.).

Statistical Analysis

The primary outcomes were the incidence of paravalvular leak (PVL), the need for permanent pacemaker (PPM) insertion, and other postoperative complications such as acute renal failure, atrial fibrillation, bleeding reoperation, prolonged ventilation, and stroke. The secondary outcomes included aortic cross-clamp (ACC), cardiopulmonary bypass (CPB) times, mean transvalvular pressure gradient, early mortality, and all-cause mortality during follow-up. For the continuous outcomes, the results were presented as the mean differences (MDs) with 95% confidence intervals (CIs). For studies that reported median and interquartile or overall ranges, the mean values and standard deviations were estimated using a formula.¹⁰ Dichotomous outcomes were compared as risk ratios (RRs) with the 95% CIs. For all-cause mortality during follow-up, the hazard ratios (HRs) and 95% CIs were extracted directly from the studies or were calculated using other available statistical information (log rank tests or Kaplan-Meier curves).¹¹ For studies that only provided the numbers of events, RRs were calculated instead of the HRs. Statistical heterogeneity between the studies was assessed with the χ^2 test and the I^2 statistics. I^2 values of 25%, 50%, and 75% have been suggested to be indicators of low, moderate, and high heterogeneity, respectively.¹² A random-effects model with the DerSimonian and Laird method was used if substantial heterogeneity was found ($I^2 > 50\%$); otherwise, a fixed effects model was applied using the Mantel-Haenszel and inverse variance methods for binary and continuous outcomes, respectively. For all-cause mortality during follow-up, log-transformed HRs or RRs were pooled using the generic inverse variance method. Overall pooled estimates from all included studies were presented with those according to the type of RD valve, followed by pooled estimates from studies presenting adjusted results and 2 RCTs.

TABLE 1. Study characteristics

Study	Operative era	Country	Study type	Study population			Type of RD valve	Clinical follow-up		Statistical methods for adjustment
				Total	RD	CV		Duration, years	Completeness, %	
D'Onofrio et al ¹³	2008-2011	Italy	NRS	143	31	112	Perceval S	-	-	-
Shretha et al ⁴	2007-2012	Germany	NRS	120	50	70	Perceval S	2.4 ± 1.4	95.8	-
Gilmanov et al ¹⁴	2004-2014	Italy	NRS	266	133	133	Mixed†	2.9 ± 2.4	-	PSM
König et al ¹⁵	2012-2013	Germany	NRS	28	14	14	Perceval S	-	-	-
Pollari et al ¹⁶	2010-2013	Germany	NRS	164	82	82	Perceval S	1.1 ± 0.5	100	PSM
Muneretto et al ¹⁷	2007-2014	Italy and France	NRS	408	204	204	Perceval S	3.4 ± 2.3	95.8	PSM
Vola et al ¹⁸	2009-2013	France	NRS	83	41	42	3f Enable	2.1 ± 1.0	-	-
Andreas et al ⁶	2010-2014	Austria	NRS	248	116	132	Intuity	2.5 ± 1.3	100	-
Borger et al ¹⁹	2012-2013	Germany	RCT	94	46	48	Intuity	Up to 1	100	RCT
Bruno et al ²⁰	2012-2015	Italy	NRS	60	30	30	Intuity	-	-	PSM
Dalén et al ²¹	2005-2014	Multinational*	NRS	342	171	171	Perceval S	2.7 ± 2.1	100	PSM
Dedeilias et al ²²	2012-2014	Greece	RCT	50	25	25	Perceval S	0.7 ± 0.1	100	RCT
Forcillo et al ²³	2011-2015	Canada	NRS	195	65	130	Perceval S	-	-	PSM
Mataraci et al ²⁴	2009-2014	Turkey	NRS	46	21	25	Mixed‡	-	-	-
Shalabi et al ⁵	2011-2014	Israel	NRS	44	22	22	Perceval S	2.5 ± 1.9	100	Matching
Belluschi et al ²⁵	2012-2016	Italy	NRS	124	62	62	Perceval S	-	-	-
Bening et al ²⁶	2013-2015	Germany	NRS	68	43	25	Intuity	-	-	-
Ferrari et al ⁷	2014-2015	Switzerland	NRS	64	32	32	Intuity	Up to 1	100	-
Konertz et al ²⁷	2010-2015	Germany	NRS	52	16	36	Perceval S	-	-	-
Minami et al ²⁸	2007-2011	Belgium	NRS	104	52	52	Perceval S	Up to 1	100	-
Smith et al ²⁹	2008-2015	Australia	NRS	82	41	41	Mixed§	-	-	PSM

Perceval S valve from Sorin Group (Milan; Italy); Intuity from Edwards Lifescience Corp (Irvine, Calif); and 3f Enable from Medtronic ATS Medical (Minneapolis, Minn). RD, Rapid deployment or sutureless; CV, conventional valve; NRS, nonrandomized study; PSM, propensity score-matching; RCT, randomized controlled study. *Sweden, Finland, Italy, Germany, and Belgium. †Perceval S (n = 125) and Intuity (n = 6) and 3f Enable (n = 2). ‡Perceval S (n = 17) and Intuity (n = 4). §Intuity (n = 24) and 3f Enable (n = 27).

Meta-regression was performed to explore heterogeneity among the studies. Study characteristics, including the proportion of patients with a minimally invasive approach and the mean ACC and CPB times in the CAVR group, were considered covariates in the meta-regression of the MDs in the ACC and CPB times. A funnel plot and Egger test for asymmetry were applied to assess the possibility of publication bias among the studies. All analyses were performed using STATA version 12.0 (StataCorp, College Station, Tex). Two-sided *P* values < .050 were considered statistically significant.

RESULTS

Identification of Studies

The database searches identified 2046 articles. Among these articles, 2017 publications were excluded, because they clearly did not fulfill the selection criteria on the basis of the title and abstract. Full articles were obtained for the remaining 29 articles. After the scrutiny of these articles, 8 publications were excluded because of unmet inclusion criteria (n = 3) or duplicated data (n = 5). Therefore, a total of 21 studies were included in this review (Figure E1).^{4-7,13-29}

Study Characteristics and Patient Populations

Among the 21 studies with 2785 patients (RDAVR group = 1297 patients and CAVR group = 1488 patients),

2 studies presented the results of RCTs (n = 144), and 19 presented the outcomes of NRSs (n = 2641). Twelve studies exclusively used the Perceval S (Sorin Group; Milan; Italy),^{4,5,13,15-17,21-23,25,27,28} whereas the Edwards Intuity valve (Edwards Lifescience Corp; Irvine, Calif) was used exclusively in 5 studies.^{6,7,19,20,26} A minimally invasive approach through mini-sternotomies or right anterior thoracotomies were more frequently performed in the RDAVR group than in the CAVR group (69.1% vs 37.7%). Clinical follow-up was reported in 12 studies^{4-7,14,16-19,21,22,28} up to an average follow-up duration of 2.9 years (Table 1). On average or median, the patients were in their 70s, and 59% of the patients were female (Table 2).

Quality of the Included Studies

The overall ROB of 2 RCTs^{19,22} was graded as low; for the random number generation and allocation concealment domains, 1 study²² used a randomization strategy with a computer-assisted mathematic model and was rated low, whereas the other study¹⁹ was rated unclear. Neither of these studies reported information on blinding of the participants and personnel or blinding of the outcome

TABLE 2. Patient characteristics

Reference	Age, y		Female sex, %		EuroScore		Minimally invasive approach		Isolated AVR, %
	RD AVR	CAVR	RD AVR	CAVR	RD AVR	CAVR	RD AVR, %	CAVR, %	RD AVR
D'Onofrio et al ¹³	73.5 ± 12.6		94.2		18.3 ± 14.6		40*	0	100.0
Shretha et al ⁴	79.8 ± 4.5	77.4 ± 5.5	94.0	94.3	20.4 ± 10.7	16.7 ± 10.4	72	4.3	100.0
Gilmanov et al ¹⁴	75.3 (70.1-79.6)†	73.6 (68.1-78.7)†	44.4	42.9	5.83 (3.74-8.77)†	5.46 (3.53-8.17)†	100	100	100.0
König et al ¹⁵	78 ± 2.6	74 ± 4.4	85.7	35.7	7.4 ± 1.1	5.9 ± 2.2	0	0	82.1
Pollari et al ¹⁶	75.5 ± 5	74.5 ± 8.1	61.0	52.4	12.1 ± 4.9	10.9 ± 4.2	70	75.6	80.5
Muneretto et al ¹⁷	79 ± 4	80 ± 3	51.5	48.0	18.9 ± 5.9	19.2 ± 7.4	-	-	100.0
Vola et al ¹⁸	75.7 ± 6.3	75.3 ± 6.1	41.5	45.2	4.5 ± 3.1	4.1 ± 2.7	100	100	100.0
Andreas et al ⁶	75 ± 8	70 ± 9	61.2	31.1	9.3 ± 9.1	9.3 ± 10.1	59	38.7	100.0
Borger et al ¹⁹	73.0 ± 5.3	74.2 ± 5.0	41.3	56.3	6.4 ± 3.7	6.7 ± 3.6	100	0	100.0
Bruno et al ²⁰	72.7 ± 11.4	75.8 ± 9.6	63.3	60.0	-	-	100	100	100.0
Dalén et al ²¹	77.3 ± 5.1	77.4 ± 6.1	59.6	63.2	9.8 ± 5.5	9.6 ± 6.9	100	0	100.0
Dedeilias et al ²²	80 ± 3.3	79 ± 4.1	60.0	44.0	9.5 ± 5.5	9.9 ± 3.6	0	0	94.0
Forcillo et al ²³	83 ± 3	83 ± 3	20.0	53.1	4.4 (2.8-8.4)†	5.3 (3.1-9.0)†	18*	8*	48.7
Mataraci et al ²⁴	73.0 ± 8.4	76.2 ± 6.2	71.4	36.0	2.8 ± 1.5	3.4 ± 2.4	0	0	58.7
Shalabi et al ⁵	77 ± 6	79 ± 6	90.9	90.9	15 ± 16	14 ± 16	23	0	100.0
Belluschi et al ²⁵	79 (75-82)†	79 (76-81)†	62.9	62.9	8.5 (6.6-11.1)†	16.0 (9.1-27.7)†	65	0	75.8
Bening et al ²⁶	74.1 ± 6.6	74.2 ± 6.6	37.2	32.0	5.7 (3.9-9.0)†	5.0 (3.1-9.1)†	100	100	100.0
Ferrari et al ⁷	78 ± 5.6	72.5 ± 6	46.9	21.9	7.9 ± 0.06	4.2 ± 0.03	6.3	6.3	70.3
Konertz et al ²⁷	73 (58-83)‡	64, 35-80‡	81.3	25.0	-	-	100	100	100.0
Minami et al ²⁸	79.1 ± 3.5	78.5 ± 3.5	59.6	59.6	12.8 ± 7.8	9.7 ± 5.5	0	17.3	57.7
Smith et al ²⁹	76.5 ± 5.7	75.9 ± 6.1	51.2	58.5	-	-	0	0	48.8

RD, Rapid deployment or sutureless; AVR, aortic valve replacement; CAVR, conventional aortic valve replacement. *Proportion in entire group before matching. †Median with interquartile range. ‡Median with range.

assessors. The ROB of both studies was considered low for the other domains. Of the 19 NRSs, 11 studies^{4,6,7,13,15,18,24-28} were graded as overall severe ROB because of the presence of confounding biases, because the patients' baseline characteristics were not balanced across groups and appropriate adjustments for confounding factors were not used. The other 8 studies used propensity score matching^{14,16,17,20,21,23,29} or 1:1 matching⁵ and were rated overall moderate ROB, because the baseline characteristics were similar between groups, and the other ROB items were graded low (Table E1).

ACC and CPB Times

All of the studies compared the ACC and CPB times between the 2 groups. Pooled analyses revealed that the ACC and CPB times were shorter in the RDAVR than in the CAVR group, with differences of 25 minutes and 26 minutes, respectively (MD, -26.34; 95% CI, -31.86 to -20.82; $P < .001$ and MD, -25.33; 95% CI, -30.79 to -19.87; $P < .001$, respectively; Figure 1). These results were also similar when the ACC and CPB times were compared in the 10 studies showing adjusted results

(MD, -25.63; 95% CI, -30.63 to -20.63; $P < .001$ and MD, -25.33; 95% CI, -30.79 to -19.87, respectively), and in the 15 studies that included only patients who underwent isolated AVR (MD, -26.48; 95% CI, -32.74 to -20.23; $P < .001$ and MD, -24.19; 95% CI, -30.32 to -18.05, respectively). The meta-regression analyses revealed significant contributions of the ACC and CPB times in the CAVR group to the high heterogeneity of the MDs of the ACC and CPB times ($P < .001$ in each analysis); the studies with longer mean ACC and CPB times in the CAVR group had greater MDs for the ACC and CPB times, respectively (Figure 2).

Risk of Postoperative Complications: PVL

A pooled analysis of any PVL from 12 studies with 2377 patients^{4-7,13,15,17-21,28} showed a significantly higher risk of any PVL in the RDAVR group than in the CAVR group (RR, 2.32; 95% CI, 1.53-3.51; $I^2 = 25.6\%$; Figure 3). The risks of any PVL were insignificant when the pooled estimates were drawn from the adjusted results in 5 studies (RR, 1.25; 95% CI, 0.70-2.23; $I^2 = 0\%$; Figure 3). PVLs grade ≥ 2 (or moderate) were separately reported in 5

FIGURE 1. Mean difference (MD) of (A) aortic cross clamp (ACC) and (B) cardiopulmonary bypass (CPB) times between rapid deployment (RD) or sutureless aortic valve replacement (AVR) and conventional bioprosthetic AVR (CAVR) groups. CI, Confidence interval; SD, standard deviation.

studies.^{6,7,17,18,21} The pooled analysis showed that the incidence of a PVL grade ≥ 2 was not significantly different between the RDAVR and CAVR groups (RR, 2.05; 95% CI, 0.71-5.93; $I^2 = 0.0\%$; Figure 3).

Risk of Postoperative Complications: PPM Insertion

The risk of the need for PPM insertion after AVR was drawn from 17 studies with 2435 patients^{5-7,13-19,21-23,26-29} after the exclusion of 1 study that reported no patients with a PPM insertion.²⁰ The pooled analysis showed that the risk of PPM insertion was significantly higher in the RDAVR group than in the CAVR group (RR, 2.08; 95% CI, 1.49-2.90; $I^2 = 0\%$). The risk of PPM was also significant in pooled estimates from the adjusted results from 9 studies (Figure 4).

Risks of Other Postoperative Complications

The risks of acute renal failure, atrial fibrillation, bleeding reoperation, prolonged ventilation, and stroke were reported in 11,^{7,13,17-21,23,25,28,29} 9,^{5,7,14,16,20,23,26,29} 16,^{4,6,7,14-21,23,25-27,29} 6,^{14,17,19,23,28,30} and 16^{5,7,13-21,23,25-28} studies, respectively. The pooled analyses showed no significant differences in the risks of postoperative complications between the 2 groups (Figure E2).

Transvalvular Pressure Gradient of Prosthetic Valves

The transvalvular pressure gradient was presented in 13 studies.^{4,6,7,13,15,17-20,24,26-28} The pooled analyses showed no significant differences in the mean pressure gradient between the 2 groups in the overall (MD, -1.19; 95%

FIGURE 2. Metaregression analyses showed that longer aortic cross clamp (ACC) and cardiopulmonary bypass (CPB) times in the conventional aortic valve replacement (CAVR) groups were significantly associated with greater mean difference for (A) ACC and (B) CPB times, respectively, between the rapid deployment or sutureless aortic valve replacement groups.

FIGURE 3. Risk ratios (RRs) of any paravalvular leak (PVL) (A) from overall studies and (B) from adjusted or randomized studies. RDAVR, Rapid deployment or sutureless aortic valve replacement; CAVR, conventional aortic valve replacement; RD, rapid deployment; CI, confidence interval.

CI, -2.49 to 0.10 mm Hg) and adjusted results (MD, -0.83; 95% CI, -1.68 to 0.02 mm Hg; Figure E3).

Early Mortality and All-Cause Mortality During Follow-up

The early mortality rate was reported in all studies except one,²² but the RRs could not be calculated for 5 studies in

which the early mortality rate was 0%.^{5,15,20,27,28} Early mortality was defined as 30-day mortality and in-hospital death in 11 and 4 studies,^{7,14,24,25} respectively. The risk of early mortality was not significantly different between the RDAVR and CAVR groups (RR, 0.78; 95% CI, 0.50-1.22; $I^2 = 0\%$). The all-cause mortality during follow-up was also similar between the RDAVR and

FIGURE 4. Risk ratio (RR) of permanent pacemaker implantation after rapid deployment or suturesless aortic valve replacement (RDAVR) and conventional bioprosthetic aortic valve replacement (CAVR) (A) from overall studies and (B) from adjusted or randomized studies. CI, Confidence interval; RD, rapid deployment.

CAVR groups; the HR from 6 studies^{4,6,14,16,17,21} and RR from 5 studies^{7,18,19,22,28} were 0.92 (95% CI, 0.62-1.23) and 1.01 (95% CI, 0.44-2.34), respectively (Figure 5).

Publication Bias

There was no evidence of publication bias in the funnel plots of the primary or secondary outcomes. The Egger

FIGURE 5. Risk ratio (RR) of (A) early death and (B) hazard ratio (HR) or RR of all-cause mortality during follow-up after rapid deployment or sutureless aortic valve replacement (RDAVR) and conventional bioprosthetic aortic valve replacement (CAVR). CI, Confidence interval; RD, rapid deployment.

test also indicated that publication bias was nonsignificant for each outcome (Figure E4).

DISCUSSION

Our study showed 3 main findings. First, RDAVR resulted in overall reductions of 26 minutes and 25 minutes in the ACC and CPB times, respectively, compared with CAVR. Second, there were no differences in postoperative complications except for a higher risk of PPM implantation in the RDAVR group compared with the CAVR group. Third, early mortality and all-cause mortality during follow-up were similar between the 2 groups (Video 1).

One of the limitations related to RD valve insertion has been suggested to be a risk of PVL after surgery, and inadequate sizing and positioning are thought to be associated with PVL.^{18,31-33} Some surgeons have developed an aortic annular stabilization technique by performing circumferential aortic valve annuloplasty to adhere the annulus to the stent of the valve.³³ Insufficient decalcification of the annulus can be another cause of PVL in RDAVR.³⁴ The influence of PVL on late mortality is controversial. Some authors have insisted that PVL in RDAVR is mainly insignificant (grade 1 or mild) and thus has little influence on late mortality.¹⁹ In contrast, another study that presented the results of TAVR at 2 years suggested that even a mild degree of PVL could significantly worsen patient survival.³⁵ In the present meta-analysis, when pooling data from the adjusted results, the risks of any PVL and a PVL grade ≥ 2 did not significantly differ between the RDAVR and CAVR groups.

Another suggested limitation of RDAVR is its susceptibility to causing postoperative conduction disturbances that require PPM implantation. The left bundle branch (LBB) runs adjacent to the membranous septum, which is located at the base of the interleaflet triangle between the right and noncoronary cusps and the right fibrous trigone. In normal hearts, the valve leaflets are attached in a semilunar manner and therefore distant from the conduction pathway. However, in aortic stenosis conditions, the leaflets are fused, the valvular attachment approaches the ventriculoarterial junction, and the leaflet tissue moves close to the LBB.³⁶ All RD valves are designed to sit below the level of the aortic annulus, which contrasts with conventional stented bioprostheses that are designed for supra- or intra-annular positioning; thus, RD valves might increase the possibility of conduction disturbances. A previous study reported that the depth of the prosthesis implantation was a strong predictor of new PPM implantation as well as new LBB blockage after TAVR.³⁶ In addition to the prosthesis position, the outward force of the prosthesis has been suggested to be a contributory factor to conduction disturbances similar to TAVR valves.^{37,38} In the present study, the risk of PPM implantation after RDAVR was twofold greater than the

VIDEO 1. A presentation for meta-analysis of rapid deployment or sutureless versus conventional aortic valve replacement. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(18\)30364-7/fulltext](http://www.jtcvsonline.org/article/S0022-5223(18)30364-7/fulltext).

risk after CAVR. This result was consistent regardless of the RD valve type. Although sufficient evidence is not available regarding the influence of PPM implantation on late mortality,^{39,40} this issue could be a factor that offsets the benefits of RDAVR.

This meta-analysis presented the extent to which the ACC times could be reduced with RDAVR. Shortening the ACC time has been proven to be associated with better outcomes after cardiac surgery.^{30,31,41} A recent retrospective analysis of approximately 1000 patients who underwent surgical AVR showed that the ACC time was an independent predictor of cardiovascular morbidity after surgery with a 1.4% increase in the risk per minute of ACC time.⁴² In that study, the effect of a reduced ACC time was more relevant in high-risk patients, such as diabetic patients and those with left ventricular dysfunction. In the meta-analysis, the RDAVR group had a benefit of a 26-minute reduction in the ACC time. This decreased ACC time also resulted in a 25-minute reduction in the CPB time. However, this benefit did not result in decreased risk in postoperative complications, early mortality, and all-cause mortality during follow-up in the present meta-analysis. A relatively low risk of surgical complications after AVR and a relatively short follow-up duration might explain these findings.

In addition to the shortening of the surgery time, another advantage of the use of RDAVR is that this technique can facilitate minimally invasive approaches. Although favorable outcomes after minimally invasive AVR were reported even before the era of RD valves,⁴³⁻⁴⁵ the limited exposure of the surgical field in minimally invasive AVR increases the technical complexity for the surgeons, which leads to longer ACC times.^{43,44} Therefore, the benefits derived from minimally invasive approaches could be offset by the prolongation of the ACC and CPB times. In the present study, minimally invasive approaches were used for 69.1% of the patients in the RDAVR group compared with only 37.7% of the patients in the CAVR group. When considering the surgeons' learning curves

during their initial experiences with RD valves, improved early and long-term outcomes might be expected to accompany the advantages of minimally invasive approaches as well as shortening of the ACC and CPB times.

Study Limitations

Several limitations of this study should be recognized. First, only 2 of the 21 studies were RCTs. Although we separately showed results of pooled estimates from the adjusted analyses, confounding variables might have affected the results of our analysis. Second, the effect of learning curves on an institutional basis as well as for the individual training of surgeons could not be evaluated. Third, detailed information regarding aorta pathology and perivalvular involvement of disease, which might be important factors in determining the risk of PVL, could not be drawn from individual studies. Last, pooled analyses for the risks of postoperative complications were not drawn from all studies.

CONCLUSIONS

Aortic valve replacement with RD valves is associated with significantly shorter ACC and CPB times than conventional AVR, although these differences did not translate into improved postoperative complications and mortality early after surgery and during the follow-up. Care might be needed when implanting RD valves because they are associated with a higher incidence of PPM insertion, regardless of the RD valve type.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

The authors thank Dr Enrico Ferrari for confirming the data from his article via mail.

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Key Words: rapid deployment, sutureless, aortic valve replacement, meta-analysis

FIGURE E1. Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram.

FIGURE E2. Risk ratio (RR) of postoperative complications after rapid deployment or sutureless aortic valve replacement (RDAVR) and conventional bioprosthetic aortic valve replacement (CAVR). CI, Confidence interval; RCT, randomized controlled trial.

FIGURE E3. Mean difference (MD) of mean transvalvular pressure gradient after rapid deployment or sutureless aortic valve replacement (RDAVR) and conventional bioprosthetic aortic valve replacement (CAVR) (A) from overall studies and (B) from adjusted or randomized studies. SD, Standard deviation; CI, confidence interval; RD, rapid deployment.

FIGURE E4. Funnel plots of standard error using log hazard ratio showing the effect of rapid deployment or sutureless aortic valve replacement and conventional bioprosthetic aortic valve replacement on mean differences (MDs) of (A) aortic cross clamp (ACC) and (B) cardiopulmonary bypass (CPB) times, and risk ratios (RRs) of (C) paravalvular leak, (D) permanent pacemaker insertion, (E) early mortality, and (F) all-cause mortality during follow-up.

TABLE E1. Quality assessment of included studies

Quality assessment using Cochran Risk of Bias Tool for randomized controlled trials								
	Random sequence generation	Allocation concealment	Blinding of participants personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other sources of bias	Overall
Borger et al ¹⁹	Unclear	Unclear	Unclear	Unclear	Low	Low	Low	Low
Dedeilias et al ²²	Low	Low	Unclear	Unclear	Low	Low	Low	Low
Quality assessment according to Risk of Bias in Non-Randomized Studies of Interventions for nonrandomized studies								
Study	Bias due to confounding	Bias in selection of participants into the study	Bias in measurement of interventions	Bias due to departures from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall
D'Onofrio et al ¹³	Serious	Low	Low	Low	Low	Low	Low	Serious
Shretha et al ⁴	Serious	Low	Low	Low	Low	Low	Low	Serious
Gilmanov et al ¹⁴	Moderate	Low	Low	Low	Low	Low	Low	Moderate
König et al ¹⁵	Serious	Low	Low	Low	Low	Low	Low	Serious
Pollari et al ¹⁶	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Muneretto et al ¹⁷	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Vola et al ¹⁸	Serious	Low	Low	Low	Low	Low	Low	Serious
Andreas et al ⁶	Serious	Low	Low	Low	Low	Low	Low	Serious
Bruno et al ²⁰	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Dalén et al ²¹	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Forcillo et al ²³	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Mataraci et al ²⁴	Serious	Low	Low	Low	Low	Low	Low	Serious
Shalabi et al ⁵	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Belluschi et al ²⁵	Serious	Low	Low	Low	Low	Low	Low	Serious
Bening et al ²⁶	Serious	Low	Low	Low	Low	Low	Low	Serious
Ferrari et al ⁷	Serious	Low	Low	Low	Low	Low	Low	Serious
Konertz et al ²⁷	Serious	Low	Low	Low	Low	Low	Low	Serious
Minami et al ²⁸	Serious	Low	Low	Low	Low	Low	Low	Serious
Smith et al ²⁹	Moderate	Low	Low	Low	Low	Low	Low	Moderate