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Neurological outcomes in minimally invasive mitral valve surgery: risk factors analysis from the Mini-Mitral International Registry

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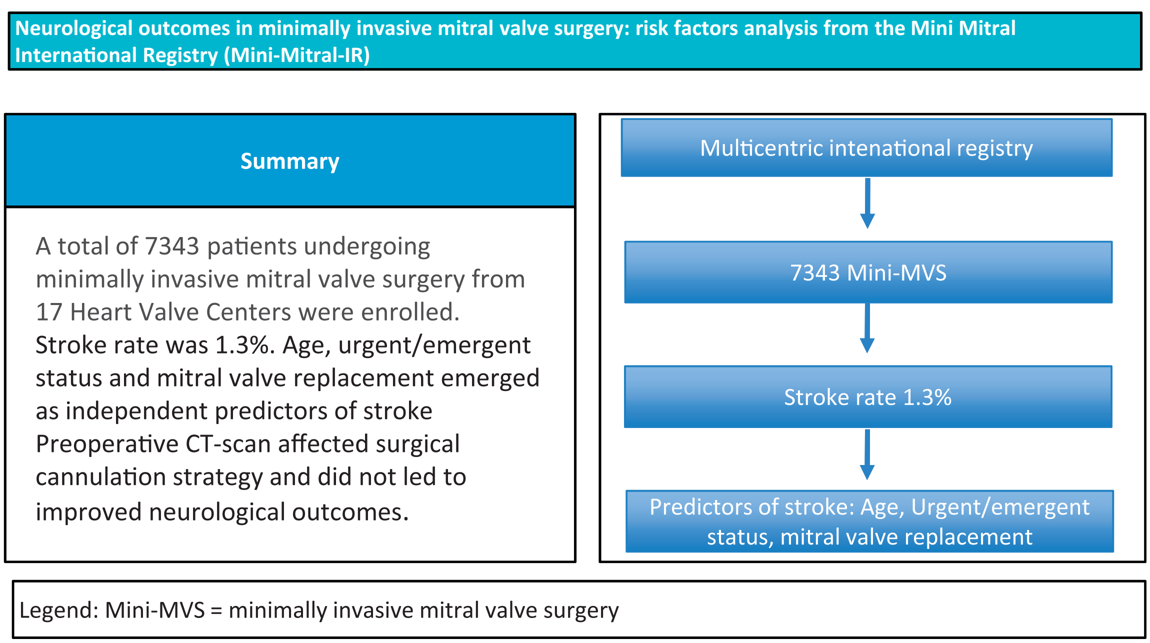

Abstract

OBJECTIVES: The aim of this study was to examine the incidence and predictors of stroke after minimally invasive mitral valve surgery (mini-MVS) and to assess the role of preoperative CT scan on surgical management and neurological outcomes in the large cohort of Mini-Mitral International Registry.

METHODS: Clinical, operative and in-hospital outcomes in patients undergoing mini-MVS between 2015 and 2021 were collected. Univariable and multivariable analyses were used to identify predictors of stroke. Finally, the impact of preoperative CT scan on surgical management and neurological outcomes was assessed.

RESULTS: Data from 7343 patients were collected. The incidence of stroke was 1.3% ($n = 95/7343$). Stroke was associated with higher in-hospital mortality (11.6% vs 1.5%, $P < 0.001$) and longer intubation time, ICU and hospital stay (median 26 vs 7 h, 120 vs 24 h and 14 vs 8 days, respectively). On multivariable analysis, age (odds ratio 1.039, 95% confidence interval 1.019–1.060, $P < 0.001$) and mitral valve replacement (odds ratio 2.167, 95% confidence interval 1.401–3.354, $P < 0.001$) emerged as independent predictors of stroke. Preoperative CT scan was made in 31.1% of cases. These patients had a higher risk profile and EuroSCORE II (median 1.58 vs 1.1, $P < 0.001$). CT scan influenced the choice of cannulation site, being ascending aorta (18.5% vs 0.5%, $P < 0.001$) more frequent in the CT group and femoral artery more frequent in the no CT group (97.8% vs 79.7%, $P < 0.001$). No difference was found in the incidence of postoperative stroke (CT group 1.5, no CT group 1.4%, $P = 0.7$).

CONCLUSIONS: Mini-MVS is associated with a low incidence of stroke, but when it occurs it has an ominous impact on mortality. Preoperative CT scan affected surgical cannulation strategy but did not led to improved neurological outcomes.

Keywords: Minimally invasive cardiac surgery • Heart valve surgery • Mitral valve surgery

ABBREVIATIONS

CI	Confidence interval
IQR	Interquartile range
mini-MVS	Minimally invasive mitral valve surgery
MMIR	Mini-Mitral International Registry
MVS	Mitral valve surgery
OR	Odds ratio

INTRODUCTION

Neurological injury is a devastating complication after cardiovascular surgery. The incidence of stroke following a cardiac operation ranges from 1.6% to 6% [1–4], and when it occurs it has serious consequences, influencing postoperative mortality rate and patients' quality of life [5]. In the past, an increasing risk of stroke following minimally invasive mitral valve surgery (mini-MVS) compared with standard sternotomy has been reported [6]. However, despite initial concerns about aortic injuries and particularly stroke, recent data from single-centre retrospective studies showed a stroke rate of 0.8–2% [7–9]. Furthermore, a recent meta-analysis showed that, despite longer operative times, mini-MVS, in comparison with sternotomy approach, reduces ICU and hospital stay and does not increase the risk of stroke [10].

In the present study, we aimed to examine the incidence and predictors of stroke in patients undergoing mini-MVS in the largest cohort of patients whose data were collected in the Mini-Mitral International Registry (MMIR) and to assess the role of preoperative CT scan on surgical management and neurological outcomes.

PATIENTS AND METHODS

Ethical statement

The study protocol was approved by the local institutional review board (no. 2020189, 30 July 2020). Consent of patients was waived for the retrospective phase, whereas was obtained for the patients enrolled prospectively.

Mini-Mitral International Registry and study population

The MMIR is an independent registry involving 17 international heart valve centres. Details of the registry have been published previously [11]. The Centres combined all consecutive patients who received minimally invasive mitral valve operations with or without associated procedures between 2015 and 2021. Perioperative characteristics and in-hospital outcomes of patients were collected according to the current European Society of Cardiology or ACC/AHA/HRS Guidelines [12], EuroSCORE II model [13] and Mitral Valve Academy Research Consortium end point definitions [14].

Study end points and outcome definitions

The primary end point was to evaluate the incidence and predictors of stroke in patients undergoing mini-MVS. Stroke was defined, according to the Mitral Valve Academy Research Consortium definition, as duration of a focal or global neurological deficit ≥24 or <24 h if available neuroimaging documents a new intracranial or subarachnoid haemorrhage or central nervous system infarction or the neurological deficit results in death.

The secondary end point was to assess the role of preoperative CT scan on surgical management and neurological outcomes.

Bleeding was defined as any postoperative haemorrhage requiring surgical revision.

Statistical analysis

Continuous variables were expressed as mean (standard deviation) and categorical variables as percentages. Where continuous variables did not follow a normal distribution, the median and interquartile range (IQR) were reported. In all cases, missing data were not defaulted to negative, and denominators reflect only cases reported. The association between covariates and stroke was tested using univariable and multivariable binary logistic regressions. The multivariable model included 18 pre- and intraoperative clinically relevant covariates: sex, age, diabetes, atrial fibrillation, endocarditis, peripheral arteriopathy, previous neurological injury, cerebrovascular arteriopathy, dialysis, previous cardiac surgery, reduced LVEF, urgent/emergent status, arterial cannulation site, myocardial protection, type of mitral valve surgery (MVS), type of valve prosthesis, concomitant tricuspid and atrial fibrillation surgery. The backward stepwise method was used to build the final model (adjusted R^2: 0.22).

Propensity score matching was used for subgroup analysis (CT scan versus no CT scan). The matched groups were compared using standard univariate statistical tests of association. Details on PS-matching and comparisons were reported in the Supplementary Material. The level of significance, α, was set at 5%. Statistical analysis was performed using Statistical Package for Social Sciences version 28.0 (IBM SPSS Inc., Chicago, IL, USA).

RESULTS

Demographic and baseline data

Perioperative characteristics and in-hospital outcomes of 7513 patients were collected. Patients with missing data on the key study variable—stroke (n = 28)—and those who received concomitant aortic valve or root/ascending aorta replacement (n = 142) were excluded. Subgroup analysis on preoperative CT scan included only patients with available CT scan data.

The analysis then included a total of 7343 patients. Baseline and preoperative characteristics of the populations are shown in Table 1. The median age was 65 years (55–73) with male predominance (n = 4239, 57.8%) and a median EuroSCORE II of 1.31% (0.81–2.73). A history of neurologic injury was present in 535 patients (7.4%) and an active endocarditis in 272 cases (3.7%), while 560 patients (7.7%) had prior cardiac surgery.

Perioperative data

Intraoperative variables are resumed in Table 2. The surgical approaches included: direct vision (28.5%), video-assisted (41%), fully endoscopic (27.4%) and robotic (0.7%). Conversion to full sternotomy occurred in 135 cases (1.9%). Femoral artery was the most used cannulation site for cardiopulmonary bypass (CPB) inflow (n = 6645, 92.8%). The main surgical procedure involved mitral valve repair in 5502 patients (74.9%) and mitral valve replacement in 1840 (25.1). In 1240 cases (16.9%), a concomitant tricuspid valve surgery was needed. The median CPB and cross-clamp time were 135 (107–172) and 84 min (64–109), respectively. Repeated cross-clamping was observed in 164 patients (2.3%).

In-hospital outcomes

In-hospital results are shown in Table 3. The overall mortality was 1.7%. The main postoperative complications included stroke (1.3%), bleeding (6%), low cardiac output (3.8%) and dialysis (1.8%). Median ventilation, ICU times and hospital stay were 8 h (IQR 5–13), 24 h (IQR 20–48) and 8 days (IQR 6–11), respectively.

Table 1: Patients' characteristics (n = 7343)

	N	%
Male	4239	57.8
Age, **median (IQR)**		65 (55–73)
NYHA class III–IV	3337	47.7
Hypertension	3896	58.1
Diabetes	653	8.9
Smoking	883	13.2
Obesity	1023	14.4
AF	2520	37.2
PM	234	3.2
Mitral valve regurgitation **(moderate–severe)**	6836	93.1
Mitral valve stenosis **(moderate–severe)**	511	7.6
Active endocarditis	272	3.7
Cerebrovascular arteriopathy	134	1.9
Peripheral arteriopathy	198	2.7
History of neurological injury	535	7.4
Pulmonary hypertension	2804	40
Dialysis	83	1.1
CAD	1001	14
Chronic lung disease	662	9
Previous cardiac surgery	560	7.7
Mitral valve surgery	322	4.4
Aortic valve surgery	164	2.2
CABG	149	2.1
Root/ascending aorta surgery	51	0.7
Other surgery	89	1.2
Reduced LVEF (≤50%)	1305	18
Preoperative CT scan	1750	31.1
Critical preoperative state	190	2.7
Urgent/emergent status	481	6.5
EuroSCORE II, median (IQR)		1.31 (0.81–2.73)

CABG: Coronary Artery Bypass Grafting; IQR: interquartile range; NYHA: New York Heart Association; AF: Atrial Fibrillation; PM: Pace Maker; CAD: coronary artery disease.

Neurological outcomes

The overall incidence of perioperative stroke was 1.3% (n = 95). In-hospital mortality in patients who had stroke was 11.6% (n = 11). On multivariable analysis age [odds ratio (OR) 1.039, 95% confidence interval (CI) 1.019–1.060, P < 0.001], urgent/emergent status (OR 2.095, 95% CI 1.137–3.857, P = 0.02) and mitral valve replacement (OR 2.167, 95% CI 1.401–3.354, P < 0.001) emerged as independent predictors of stroke (Table 4).

CT scan analysis

Patients with available CT scan data were 5626 (76.6%). A preoperative CT scan was made in the 31.1% of patients. These patients had a higher risk profile [median EuroSCORE II 1.58 (IQR 0.9–3.1) vs 1.1 (0.73–2.01), P < 0.001] compared with those who did not undergo CT scan (Table 5). When a preoperative CT scan was made, it influenced the choice of arterial cannulation site, being ascending aorta (18% vs 0.4%, P < 0.001) more frequent in the CT group and femoral artery more frequent in the no CT group (97.9% vs 80.2%, P < 0.001) (Table 6). The incidence of mortality (1.7% and 1.4%, P = NS) and stroke (1.5 vs 1.4%, P = NS) was not different between the CT and no CT groups (Table 7). Even after the propensity score analysis, no differences were found between the CT and no CT groups in terms of in-hospital mortality (1.3 vs 1.5%, P = NS) and stroke (1.2 vs 0.7%, P = NS).

Table 2: Operative data

	N	%
Surgical approach		
Direct vision	2089	28.5
Video assisted	3010	41
Totally endoscopic	2184	27.4
Robotic	54	0.7
Surgical access		
Anterolateral	5429	74
Transaxillary	918	12.5
Periareolar	695	9.5
Ministernotomy	298	4.1
Conversion to full sternotomy	135	1.9
Arterial cannulation site		
Femoral artery	6645	92.8
Axillary artery	137	1.9
Ascending aorta	328	4.6
Other	49	0.7
Myocardial protection		
Cardioplegia	7123	97.6
Ventricular fibrillation	149	2
Beating heart	26	0.4
Aortic cross-clamping type		
External clamp	6040	84.3
Endoclamp	1122	15.7
Type of surgery		
Mitral valve repair	*5502*	74.9
Mitral valve replacement	*1840*	25.1
Type of valve prosthesis		
Biological	*1341*	18.4
Mechanical	*460*	6.3
Concomitant tricuspid surgery	1240	16.9
Concomitant AF surgery	1301	17.7
LAAA closure	994	14.1
Repeated cross-clamping	164	2.3
CPB time, median (IQR)		135 (107–172)
Cross-clamp time, median (IQR)		84 (64–109)

AF: atrial fibrillation; CPB: cardiopulmonary bypass; IQR: interquartile range; LAA: left atrial appendage.

Table 3: In-hospital outcomes

	N	%
In-hospital mortality	122	1.7
Delirium	402	6.2
Intubation time (h), median (IQR)	8 (5–13)	
Bleeding requiring revision	420	6
New-onset AF	1063	15.8
Definitive PM implantation	453	6.2
Myocardial infarction	59	0.8
Low cardiac output syndrome	273	3.8
Dialysis	115	1.8
Vascular complications		
Major vasc. complications	*86*	*1.3*
Minor vasc. complications	*42*	*0.6*
Thoracic wound complications	104	1.4
Redo for early valve repair failure	59	0.9
ICU stay (h), median (IQR)	24 (20–48)	
Hospital stay (days), median (IQR)	8 (6–11)	

AF: atrial fibrillation; IQR: interquartile range; PM: Pace Maker.

Table 4: Multivariable analysis for stroke

Variable	*P*-value	OR/HR	95% CI
Age	<0.001	1.039	1.019–1.060
Urgent/emergent status	0.02	2.095	1.137–3.857
Reduced LVEF	–	–	–
Mitral valve replacement	<0.001	2.167	1.401–3.354

CI: confidence interval; OR: odds ratio.

DISCUSSION

In the present study, we evaluated the neurological outcomes and predictors of stroke after mini-MVS using data from the largest worldwide registry for mini-MVS. Moreover, we assessed the role of preoperative CT scan on surgical management and neurological outcomes.

The main results are as follows: (i) while the incidence of stroke in mini-MVS was very low, when it occurs had an ominus impact on mortality, (ii) advanced age, coronary artery disease, urgent emergent status and mitral valve replacement were significant predictors for stroke and (iii) preoperative CT scan performed in selected higher-risk patients affected surgical strategy and likely led to improved neurological outcomes.

Mini-MVS has been adopted for >30 years, since Carpentier reported the first successful case [15]. During these years, the minimally invasive techniques have greatly evolved and nowadays have become the routine approach in many specialized high-volume centres. However, there is still doubt about associated risk and detractors of the minimally invasive cardiac surgery claim that patients are exposed to a greater neurological risk. In 2010, a consensus statement of the International Society of Minimally Invasive Coronary Surgery stated that in patients with mitral disease, minimally invasive surgery could be an alternative to conventional surgery, but with an increasing risk of stroke [16]. Potential reasons for the increased risk of stroke included: incomplete or ineffective de-airing, retrograde aortic flow during CPB, use of CO_2 insufflation, air embolism, prolonged cross-clamp and CPB time and the use of endoaortic balloon. Recently, data from 2 large metanalyses disproved this assumption showing comparable results between mini-MVS and full sternotomy MVS [17, 18]. Our study confirmed that mini-MVS is associated with a very low incidence of neurologic injury. In MMIR, the overall incidence of stroke was 1.3% being only 1.1% in the isolated MVS. These results compare favourably with those reported by other international registries on conventional MVS [19]. These improvements may be explained by the evolution in terms of technology and surgeons' experience, which allowed to overcome some technical challenges like worse exposure and de-airing.

Although the incidence was very low, the occurrence of stroke remains a devastating complication after cardiac surgery. In MMIR, the mortality rate was 7 times higher in patients with postoperative stroke (11.6% vs 1.5%). On multivariable logistic regression, we have identified 3 preoperative and 1 intraoperative risk factors independently associated with the development of postoperative stroke: advanced age, urgent/emergent status and

Table 5: Patients' characteristics ($N = 5626$)

Characteristics	Overall cohort			Propensity-matched cohort		
	CT group ($n = 1750$), N (%)	No CT group ($n = 3876$), N (%)	Standardized mean difference	CT group ($n = 1185$), N (%)	No CT group ($n = 1185$), N(%)	Standardized mean difference
Male	977 (55.9)	2328 (60.2)	-15.6	504 (42.5)	479 (40.4)	6.4
Age, **median (IQR)**	65 (54–73)	64 (55–72)	8.4	64 (53–73)	64 (52–72)	3.6
NYHA class III–IV	820 (47.3)	1618 (42.5)	13.1	523 (44.1)	473 (39.9)	8.8
Hypertension	965 (58.5)	2243 (57.9)	2.2	687 (58)	667 (56.3)	5.3
Diabetes	201 (11.5)	265 (6.8)	14.3	92 (7.8)	100 (8.4)	-4.2
Smoking	252 (15.4)	422 (10.9)	16.8	143 (12.1)	169 (14.3)	-8.1
Obesity	217 (13.2)	570 (15)	-8.9	154 (13)	136 (11.5)	4.7
AF	707 (40.4)	1420 (36.7)	14.7	441 (37.2)	402 (33.9)	9.7
PM	81 (4.6)	80 (2.1)	11.8	33 (2.8)	28 (2.4)	3.1
Mitral valve regurgitation **(moderate–severe)**	1597 (91.3)	3631 (93.8)	-9.8	1118 (94.3)	1101 (92.9)	5.1
Mitral valve stenosis **(moderate–severe)**	216 (12.3)	195 (5)	23.6	86 (7.3)	72 (6.1)	3.6
Active endocarditis	79 (4.5)	124 (3.2)	7.8	51 (4.3)	45 (3.8)	2.5
Cerebrovascular disease	50 (2.9)	61 (1.6)	6.4	22 (1.9)	17 (1.4)	2.6
Peripheral arteriopathy	38 (2.2)	49 (1.3)	7.7	21 (1.8)	13 (1.1)	1.8
History of neurological injury	193 (11.8)	218 (5.6)	18.4	84 (7.1)	95 (8)	-2.4
Pulmonary hypertension	564 (32.3)	1490 (38.7)	-14.2	406 (34.3)	417 (35.2)	-2.6
Dialysis	27 (1.5)	32 (0.8)	9.8	14 (1.2)	11 (0.9)	2.1
CAD	237 (14.4)	485 (12.5)	7.7	141 (11.9)	114 (9.6)	5.3
Chronic lung disease	199 (11.4)	287 (7.4)	13.1	94 (7.9)	90 (7.6)	0.9
Previous cardiac surgery	106 (6.1)	158 (4.1)	7.8	58 (4.9)	44 (3.7)	3.6
Mitral valve surgery	42 (2.4)	90 (2.3)	2.3	23 (1.9)	24 (2)	-0.3
Aortic valve surgery	42 (2.4)	38 (1)	4.7	18 (1.5)	9 (0.8)	1.1
CABG	32 (2)	44 (1.1)	3.3	19 (1.6)	10 (0.8)	2.8
Root/ascending aorta surgery	18 (1)	15 (0.4)	2.4	10 (0.8)	3 (0.3)	1.2
Other surgery	22 (1.3)	32 (0.8)	2.1	15 (1.3)	13 (1.1)	0.9
Reduced LVEF (≤50%)	345 (20)	649 (17)	11.3	208 (17.6)	174 (14.7)	6.3
Critical preoperative state	54 (3.1)	94 (2.4)	6.5	30 (2.5)	30 (2.5)	–
Urgent/emergent status	124 (7.1)	234 (6)	5.2	75 (6.3)	75 (6.3)	–
EuroSCORE II, median (IQR)	1.58 (0.9–3.1)	1.1 (0.73–2.01)	14.9	1.41 (0.83–2.94)	1.29 (0.91–2.13)	9.4

AF: atrial fibrillation; CABG: coronary artery bypass grafting; IQR: interquartile range; NYHA: New York Heart Association.

Table 6: Operative data ($N = 5626$)

Characteristics	Overall cohort			Propensity-matched cohort		
	CT group ($n = 1750$), N (%)	No CT group ($n = 3876$), N (%)	P-value	CT group ($n = 1185$), N (%)	No CT group ($n = 1185$), N (%)	P-value
Surgical approach			<0.001			<0.001
Direct vision	795 (45.5)	989 (2.5)		467 (39.4)	342 (28.9)	
Video assisted	507 (29)	1697 (43.8)		347 (29.3)	433 (36.5)	
Totally endoscopic	401 (22.9)	1177 (30.4)		332 (28)	410 (34.6)	
Robotic	46 (2.6)	8 (0.2)		38 (3.2)	1 (0.1)	
Surgical access			<0.001			<0.001
Antrolateral	806 (46.1)	2939 (75.8)		615 (51.9)	788 (66.5)	
Transaxillary	570 (32.6)	348 (9)		298 (25.2)	152 (12.8)	
Periareolar	80 (4.6)	583 (15)		62 (5.2)	244 (20.6)	
Ministernotomy	293 (16.8)	5 (0.1)		210 (17.7)	1 (0.1)	
Conversion to full sternotomy	39 (2.2)	56 (1.4)	0.04	31 (2.6)	19 (1.6)	0.1
Arterial cannulation site			<0.001			<0.001
Femoral artery	1317 (80.2)	3791 (97.9)		955 (80.6)	1169 (98.6)	
Axillary artery	15 (0.9)	39 (1)		11 (0.9)	10 (0.8)	
Ascending aorta	296 (18)	17 (0.4)		212 (17.9)	4 (0.3)	
Other	14 (0.9)	27 (0.7)		7 (0.6)	2 (0.2)	
Myocardial protection			<0.001			<0.001
Cardioplegia	1719 (98.2)	3798 (98)		1170 (98.7)	1158 (97.7)	
Ventricular fibrillation	13 (0.7)	69 (1.8)		5 (0.4)	25 (2.1)	
Beating heart	18 (1)	7 (0.2)		10 (0.8)	2 (0.2)	
Aortic cross-clamping type			<0.001			0.006
External clamp	1658 (96.2)	3524 (92)		1121 (95.6)	1086 (93)	
Endoclamp	65 (3.8)	306 (8)		51 (4.4)	82 (7)	

Continued

Table 6: Continued

Characteristics	Overall cohort			Propensity-matched cohort		
	CT group (n = 1750), N (%)	No CT group (n = 3876), N (%)	P-value	CT group (n = 1185), N (%)	No CT group (n = 1185), N (%)	P-value
Type of surgery			<0.001			<0.001
Mitral valve repair	1202 (68.7)	3213 (82.9)		893 (75.4)	976 (82.4)	
Mitral valve replacement	548 (31.3)	662 (17.1)		292 (24.6)	209 (17.6)	
Concomitant tricuspid surgery	361 (20.6)	654 (16.9)	<0.001	230 (19.4)	186 (15.7)	0.02
Concomitant AF surgery	250 (14.3)	757 (19.5)	<0.001	184 (15.5)	159 (13.4)	0.2
LAA closure	270 (15.4)	592 (15.3)	0.8	191 (16.1)	157 (13.2)	0.03
Repeated cross-clamping	40 (2.3)	104 (2.7)	0.4	25 (2.1)	32 (2.7)	0.4
CPB time, median (IQR)	140 (114–176)	134 (103–178)	<0.001	142 (113–176)	133 (106–176)	<0.001
Cross-clamp time, median (IQR)	83 (64–109)	80 (59–107)	0.004	85 (65–111)	82 (61–106)	0.005

AF: atrial fibrillation; CPB: cardiopulmonary bypass; IQR: interquartile range; LAA: left atrial appendage.

Table 7: In-hospital results

Characteristics	Overall cohort			Propensity-matched cohort		
	CT group (n = 1750), N (%)	No CT group (n = 3876), N (%)	P-value	CT group (n = 1185), N (%)	No CT group (n = 1185), N (%)	P-value
In-hospital mortality	29 (1.7)	53 (1.4)	0.4	15 (1.3)	18 (1.5)	0.7
Stroke	26 (1.5)	53 (1.4)	0.7	14 (1.2)	8 (0.7)	0.2
Delirium	177 (10.1)	218 (5.6)	<0.001	103 (8.7)	60 (5.1)	<0.001
Intubation time (h), median (IQR)	8 (5–15)	7 (5–12)	<0.001	8 (5–14)	7 (5–12)	<0.001
Bleeding requiring revision	95 (5.5)	260 (6.7)	0.02	63 (5.3)	66 (5.6)	0.8
New-onset AF	270 (15.4)	567 (14.6)	0.4	191 (16.1)	189 (15.9)	0.9
Definitive PM implantation	53 (3)	72 (1.9)	0.008	39 (3.3)	24 (2)	0.07
Myocardial infarction	12 (0.7)	33 (0.8)	0.5	9 (0.8)	12 (1)	0.2
Low cardiac output syndrome	126 (7.7)	114 (2.9)	<0.001	79 (6.7)	41 (3.5)	<0.001
Dialysis	35 (1.8)	42 (1.1)	0.03	18 (1.5)	13 (1.1)	0.5
Vascular complications	29 (1.7)	78 (2)	0.05	20 (1.7)	27 (2.3)	0.1
Major vasc. complications	*15 (0.9)*	*59 (1.5)*		9 (0.8)	19 (1.6)	
Minor vasc. complications	*14 (0.8)*	*19 (0.5)*		11 (0.9)	8 (0.7)	
Thoracic wound complications	50 (2.9)	41 (1.1)	<0.001	7 (0.6)	17 (1.4)	0.06
Redo for early valve repair failure	12 (0.7)	35 (0.9)	0.6	12 (1)	7 (0.6)	0.3
ICU stay (h), median (IQR)	23 (18–48)	24 (19–48)	<0.001	23 (19.48)	24 (19–48)	0.2
Hospital stay (days), median (IQR)	9 (8–15)	8 (6–11)	<0.001	9 (7–14)	7 (6–10)	<0.001

AF: atrial fibrillation; IQR: interquartile range.

mitral valve replacement. These results are consistent with those reported in most series where age has been identified as a strong predictor of postoperative stroke due to the underlying conditions [20, 21]. Moreover, our findings get stronger what showed in a recent meta-analysis comparing MV repair over replacement, showing postoperative neurological complications in favour of repair over replacement [22]. Although in the past retrograde perfusion was associated with an increased risk of stroke and postoperative delirium [23], in the present study, the site of cannulation did not affect neurological outcomes.

Another topic of discussion is the need of preoperative CT scan screening in minimally invasive surgery. It is well known that it is very useful to assess preoperatively the chest anatomy and to identify the presence of peripheral vascular disease as well as potential contraindications, such as severely calcified aortopathy. Recent data showed that systematic preoperative CT scan screening seems to be associated with lower risk of postoperative stoke and need for dialysis after mini-MVS [24]. In MMIR, a preoperative CT scan was not routinely performed in all cases and was predominantly made in higher-risk patients. Performing CT scan in such selected patients resulted in similar incidence of mortality (1.7% and 1.4%, P = NS) and stroke (1.5% vs 1.4%, P = NS) between the CT group and the no CT group. However, CT scan influenced the choice of cannulation site, being ascending aorta more frequently cannulated in the CT group and femoral artery more frequently cannulated in the no CT group.

Limitations

Despite the strength of our multicentre international registry study, it is a retrospective observational analysis, with its intrinsic limitations. Moreover, indication and subsequent type of mini-MVS were assessed independently by each local institution that was responsible for the data collection and transmission. This study provides no information about the prevalence of mitral annulus calcification that it is a major risk factor for complications including stroke. The comparison of mortality in patients with and without stroke is merely descriptive and was not adjusted for confounders.

CONCLUSIONS

The present study showed that mini-MVS is associated with a low incidence of perioperative stroke, but when it occurs it has an ominous impact on mortality. Age, urgent/emergent status and mitral valve replacement emerged as independent predictors of stroke. In our experience, preoperative CT scan, performed in selected higher-risk patients, affected surgical cannulation strategy and did not led to improved neurological outcomes.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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DATA AVAILABILITY

All relevant data are available on request to the authors.

Author contributions

Giovanni Domenico Cresce: Investigation; Writing—original draft. **Paolo Berretta:** Data curation; Formal analysis. **Antonio Fiore:** Investigation. **Manuel Wilbring:** Investigation. **Marc Gerdisch:** Investigation. **Antonios Pitsis:** Investigation. **Mauro Rinaldi:** Investigation. **Nikolaos Bonaros:** Investigation. **Jorg Kempfert:** Investigation. **Tristan Yan:** Investigation. **Frank Van Praet:** Investigation. **Hoang Dinh Nguyen:** Investigation. **Carlo Savini:** Investigation. **Joseph Lamelas:** Investigation. **Tom C. Nguyen:** Investigation. **Pierluigi Stefano:** Investigation. Gloria Färber**:** Investigation. **Loris Salvador:** Conceptualization. **Marco Di Eusanio:** Conceptualization; Writing—review & editing.

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