Supplementary Online Content

Khera R, Pandey AP, Koshy T, et al. Role of hospital volumes in identifying low-performing and high-performing surgical valve centers in the United States. *JAMA Cardiol*. Published online November 8, 2017. doi:10.1001/jamacardio.2017.4003

This supplementary material has been provided by the authors to give readers additional information about their work.

Section A: Research Design

☑ Does the study limit its scope to the assessment of disease conditions and/or procedures in an inpatient setting?

☑ Does the study infer that captured encounters do not represent distinct patients, but rather hospitalization records?

☑ Does the study avoid diagnosis/procedure-specific volume assessments for units that are not a part of the sampling frame of the NIS, and are therefore not representatively sampled, including

  a) geographic units, like U.S. states

  b) healthcare facilities (after 2011)

  c) individual healthcare providers?

Section B: Data interpretation

☑ Does the study attempt to identify disease conditions or procedures of interest using administrative codes or their combinations that have been previously validated?

☑ Does the study limit its assessment to only in-hospital outcomes, rather than those occurring after discharge?

☑ Does the study limit assessment of outcomes to those accurately captured in the NIS, and avoid extrapolating non-specific secondary diagnoses to infer in-hospital events?

Section C: Data Analysis

☑ Does the study clearly account for the survey design of the NIS and its components - clustering, stratification, and weighting?

☑ Does the study adequately address changes in data structure over time (for trend analyses)?

eTable 1: National Inpatient Sample (NIS) study checklist.

eTable 2: Elixhauser comorbidities used in the risk-adjustment model in this study.

Heart failure	Peripheral vascular disease
Hypertension	Uncomplicated diabetes
Diabetes with chronic complications	Chronic pulmonary disease
Pulmonary circulation disease	Obesity
Weight loss	Paralysis
Other neurological disorders	Hypothyroidism
Renal failure	Fluid and electrolyte disorders
Liver disease	Alcohol abuse
Drug abuse	Psychoses
Depression	Peptic ulcer disease with bleeding
Chronic blood loss anemia	Iron deficiency anemia
Acquired immunodeficiency syndrome	Lymphoma
Metastatic cancer	Solid tumor without metastasis
Coagulopathy	Rheumatoid arthritis/collagen vascular disease

eTable 3: Correlation between procedure and unadjusted in-hospital mortality

Procedure	Spearman's rho	P-value
SAVR	-0.05	0.16
SAVR + CABG	0.09	0.01
MV repair	0.33	<.0001
MV replacement	0.13	0.0007

eTable 4: Trends in unadjusted median in-hospital mortality (and interquartile range) across deciles of procedure volume for isolated surgical aortic valve replacement (SAVR).

SAVR Volume Decile	SAVR volume	Mortality for isolated SAVR, % (unadjusted)				
		Median	Lower Quartile	Upper Quartile	Minimum	Maximum
1	2-13	6.2	0.0	11.4	0.0	50.0
2	13-20	4.2	0.0	7.7	0.0	16.7
3	20-27	3.2	0.0	6.3	0.0	29.4
4	27-33	3.8	1.9	7.1	0.0	15.7
5	33-43	3.2	1.5	6.3	0.0	14.8
6	43-53	2.9	2.2	5.3	0.0	17.1
7	53-68	3.7	1.0	5.3	0.0	15.7
8	68-87	3.8	1.7	5.6	0.0	11.4
9	57-136	3.7	2.3	5.2	0.0	12.5
10	136-1448	3.0	2.0	4.3	0.0	6.8

eTable 5: Trends in unadjusted median in-hospital mortality (and interquartile range) across deciles of procedure volume for surgical aortic valve replacement (SAVR) + coronary artery bypass grafting (CABG).

SAVR Volume Decile	SAVR volume	Mortality for SAVR + CABG, % (unadjusted)				
		Median	Lower Quartile	Upper Quartile	Minimum	Maximum
1	2-13	0.0	0.0	11.8	0.0	100.0
2	13-20	0.0	0.0	10.0	0.0	50.0
3	20-27	0.0	0.0	9.1	0.0	66.7
4	27-33	4.0	0.0	9.1	0.0	26.1
5	33-43	4.8	0.0	11.1	0.0	23.1
6	43-53	4.5	0.0	8.3	0.0	25.0
7	53-68	4.5	0.0	8.6	0.0	31.3
8	68-87	3.6	0.0	7.7	0.0	16.7
9	57-136	4.4	2.6	7.1	0.0	25.0
10	136-1448	4.1	2.5	5.9	0.0	10.7

eTable 6: Trends in unadjusted median in-hospital mortality (and interquartile range) across deciles of procedure volume for mitral valve (MV) repair.

MV Repair Volume Decile	MV Repair volume	Mortality for MV repair, % (unadjusted)				
		Median	Lower Quartile	Upper Quartile	Minimum	Maximum
1	1-2	0.0	0.0	0.0	0.0	50.0
2	2-3	0.0	0.0	0.0	0.0	100.0
3	3-5	0.0	0.0	0.0	0.0	66.7
4	5-7	0.0	0.0	6.3	0.0	100.0
5	7-9	0.0	0.0	7.1	0.0	33.3
6	9-12	0.0	0.0	5.1	0.0	16.7
7	12-16	0.0	0.0	8.3	0.0	28.6
8	16-23	0.0	0.0	4.3	0.0	11.8
9	24-39	2.3	0.0	4.8	0.0	16.0
10	40-657	1.9	0.0	3.3	0.0	10.5

eTable 7: Trends in unadjusted median in-hospital mortality (and interquartile range) across deciles of procedure volume for mitral valve (MV) replacement.

MV Replacement Volume Decile	MV Replacement volume	Mortality for MV replacement, % (unadjusted)				
		Median	Lower Quartile	Upper Quartile	Minimum	Maximum
1	1-3	0.0	0.0	20.0	0.0	100.0
2	3-5	0.0	0.0	20.0	0.0	50.0
3	5-7	0.0	0.0	16.7	0.0	40.0
4	7-9	5.2	0.0	14.3	0.0	40.0
5	9-13	3.8	0.0	11.1	0.0	28.6
6	13-16	6.3	0.0	10.0	0.0	27.3
7	16-19	6.3	0.0	8.3	0.0	21.4
8	19-25	6.6	3.4	10.3	0.0	23.1
9	25-40	5.6	2.5	9.5	0.0	33.3
10	40-398	5.5	2.9	8.0	0.0	25.8

eTable 8: Risk-standardized mortality rates (median and interquartile range) for operative procedures in this study

Procedures	Median RSMR	Interquartile range
Isolated SAVR	2.9	2.8 to 3.2
SAVR + CABG	4.8	4.5 to 5.6
MV repair*	2.7	2.6 to 3.0
MV replacement*	6.4	6.1 to 7.2

* with and without CABG

eTable 9: Association between volume and in-hospital mortality in the hierarchical risk-adjustment models for valve procedures, reported for a 10-unit increase in procedure volumes.

	Beta-coefficient for 10-unit increase in hospital procedure volume	Odds ratio for 10-unit increase in hospital procedure volume	P-value
SAVR, isolated	-0.00080	0.992	<.001
SAVR + CABG	-0.00078	0.992	<.001
MV repair*	-0.00531	0.948	<.001
MV replacement*	-0.00763	0.927	<.001

* with and without CABG

eTable 10: SAVR patient characteristics, 2011 to 2014

Characteristics	Calendar-years			
	2011	2012	2013	2014
Unweighted number	12476	11309	11694	11619
Weighted number (standard deviation)	57950 (5107)	56545 (2031)	58470 (2078)	58095 (2044)
Patient characteristics				
Female	38.1 (0.6)	36.4 (0.5)	35.4 (0.4)	34.4 (0.5)
Race				
White	75.8 (2.3)	77.9 (1.3)	78.9 (1.3)	78.8 (1.2)
Black	4.4 (0.5)	4.7 (0.3)	4.5 (0.3)	4.7 (0.3)
Other	10.1 (1.1)	11.1 (1.0)	9.9 (0.7)	10.1 (0.7)
Missing/Unknown	9.7 (2.3)	6.3 (1.0)	6.8 (1.2)	6.4 (1.0)
Comorbid conditions				
Heart failure	1.6 (0.2)	1.4 (0.1)	1.3 (0.1)	1.4 (0.1)
Valvular Heart Disease	0.9 (0.1)	0.8 (0.1)	1.0 (0.1)	0.9 (0.1)
Peripheral Vascular Disease	13.5 (0.9)	13.0 (0.4)	13.3 (0.5)	12.7 (0.4)
Chronic pulmonary disease	18.4 (0.5)	18.4 (0.4)	18.4 (0.4)	18.3 (0.4)
Pulmonary circulation disease	0.3 (0.05)	0.5 (0.1)	0.3 (0.1)	0.3 (0.05)
Hypertension	67.3 (0.6)	69.5 (0.5)	68.7 (0.6)	67.9 (0.5)
Obesity	15.3 (0.8)	16.6 (0.5)	18.2 (0.5)	19.3 (0.5)
Weight loss	4.6 (0.4)	4.6 (0.3)	4.6 (0.3)	3.9 (0.3)
Paralysis	1.5 (0.1)	1.7 (0.1)	1.5 (0.1)	1.3 (0.1)
Other neurological disorders	3.9 (0.2)	4.2 (0.2)	4.3 (0.2)	4.3 (0.2)
Diabetes w/o complications	23.8 (0.7)	25.9 (0.5)	25.3 (0.5)	24.0 (0.5)
Diabetes w/ chronic complications	4.4 (0.6)	4.1 (0.3)	4.7 (0.3)	5.2 (0.3)
Hypothyroidism	10.9 (0.3)	10.9 (0.3)	11.4 (0.3)	11.0 (0.3)
Renal failure	15.3 (0.6)	14.1 (0.4)	13.2 (0.4)	14.9 (0.3)
Fluid and electrolyte disorders	30.6 (1.7)	31.8 (1.1)	32.6 (1.0)	34.1 (0.9)
Liver disease	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	1.9 (0.1)
Alcohol abuse	1.8 (0.1)	2.0 (0.1)	2.4 (0.1)	2.4 (0.1)
Drug abuse	0.9 (0.1)	1.0 (0.1)	1.2 (0.1)	1.2 (0.1)
Psychoses	1.6 (0.2)	1.8 (0.1)	1.9 (0.1)	1.9 (0.1)
Depression	4.9 (0.3)	5.6 (0.2)	5.2 (0.2)	6.1 (0.2)
Chronic blood loss anemia	1.5 (0.3)	1.0 (0.1)	1.0 (0.1)	0.9 (0.1)
Peptic ulcer disease	0.0 (0.01)	0.0 (0.01)	0.0 (0.01)	0.0 (0.02)
Iron deficiency anemia (ANEMDEF)	16.9 (1.5)	15.2 (0.6)	14.6 (0.6)	13.2 (0.5)
AIDS	0.1 (0.02)	0.1 (0.03)	0.1 (0.02)	0.1 (0.02)
Lymphoma	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)
Metastatic cancer	0.2 (0.05)	0.2 (0.04)	0.1 (0.03)	0.2 (0.04)
Solid tumor without metastasis	1.2 (0.1)	1.2 (0.1)	1.1 (0.1)	1.0 (0.1)
Coagulopathy	27.5 (1.4)	28.6 (0.9)	30.3 (0.9)	30.7 (0.8)
Arthritis	2.5 (0.2)	2.7 (0.2)	2.6 (0.1)	2.5 (0.1)
Death	3.2 (0.2)	3.0 (0.2)	2.8 (0.2)	2.9 (0.2)

Numbers represent % and SE unless otherwise specified

<u>Abbreviations</u>: SD – standard deviation, SEM – standard error of mean, C.I. – confidence interval, ESRD – End-stage renal disease

eTable 11: MV repair and replacement patient characteristics, 2011 to 2014

Characteristics	Calendar-years			
	2011	2012	2013	2014
Unweighted number	5546	5060	5304	5434
Weighted number	25817 (2296)	25300 (1209)	26520 (1253)	27170 (1251)
Patient characteristics				
Female	47.1 (0.9)	45.4 (0.8)	46.5 (0.7)	46.4 (0.7)
Race				
White	70.4 (2.4)	72.8 (1.7)	72.5 (1.5)	71.8 (1.4)
Black	8.3 (0.7)	8.7 (0.6)	8.9 (0.5)	9.1 (0.6)
Other	11.6 (1.5)	12.3 (1.0)	12.0 (0.8)	12.1 (0.8)
Missing/Unknown	9.7 (2.4)	6.2 (1.6)	6.7 (1.4)	7.0 (1.3)
Comorbid conditions				
Heart failure	2.4 (0.2)	2.2 (0.2)	2.5 (0.2)	2.8 (0.2)
Valvular Heart Disease	1.6 (0.2)	1.7 (0.2)	1.3 (0.2)	1.7 (0.2)
Peripheral Vascular Disease	7.3 (0.6)	7.0 (0.4)	6.5 (0.4)	7.4 (0.4)
Chronic pulmonary disease	17.4 (0.8)	17.4 (0.6)	17.6 (0.6)	17.9 (0.6)
Pulmonary circulation disease	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)	0.9 (0.1)
Hypertension	52.8 (0.8)	55.1 (0.9)	55.9 (0.8)	54.9 (0.7)
Obesity	9.0 (0.6)	10.2 (0.5)	10.9 (0.6)	12.2 (0.5)
Weight loss	6.6 (0.7)	5.4 (0.4)	6.3 (0.5)	6.3 (0.5)
Paralysis	1.8 (0.2)	2.1 (0.2)	1.7 (0.2)	1.8 (0.2)
Other neurological disorders	3.8 (0.3)	4.2 (0.3)	3.6 (0.2)	4.2 (0.3)
Diabetes w/o complications	14.2 (0.8)	14.3 (0.6)	14.3 (0.6)	13.9 (0.6)
Diabetes w/ chronic complications	2.6 (0.4)	2.1 (0.2)	3.4 (0.3)	3.2 (0.3)
Hypothyroidism	9.6 (0.4)	9.7 (0.4)	10.4 (0.4)	9.2 (0.4)
Renal failure	13.1 (0.6)	12.1 (0.6)	11.8 (0.5)	13.2 (0.5)
Fluid and electrolyte disorders	32.8 (1.8)	33.4 (1.5)	34.9 (1.2)	38.6 (1.3)
Liver disease	1.6 (0.2)	1.1 (0.1)	1.7 (0.2)	1.3 (0.1)
Alcohol abuse	2.0 (0.2)	2.1 (0.2)	2.0 (0.2)	2.3 (0.2)
Drug abuse	1.3 (0.2)	1.6 (0.2)	1.6 (0.2)	2.0 (0.2)
Psychoses	2.1 (0.3)	1.8 (0.2)	2.3 (0.2)	2.2 (0.2)
Depression	6.4 (0.4)	5.6 (0.3)	6.2 (0.3)	5.9 (0.3)
Chronic blood loss anemia	1.7 (0.3)	0.7 (0.1)	0.8 (0.1)	0.9 (0.2)
Peptic ulcer disease	0 (0)	0.0 (0.02)	0 (0)	0.0 (0.02)
Iron deficiency anemia	17.1 (1.9)	14.1 (0.7)	13.8 (0.7)	12.4 (0.6)
AIDS	0.1 (0.04)	0.1 (0.06)	0.1 (0.05)	0.1 (0.05)
Lymphoma	0.5 (0.1)	0.6 (0.1)	0.6 (0.1)	0.4 (0.1)
Metastatic cancer	0.1 (0.04)	0.2 (0.06)	0.1 (0.05)	0.2 (0.1)
Solid tumor without metastasis	0.8 (0.1)	0.8 (0.1)	0.6 (0.1)	0.6 (0.1)
Coagulopathy	25.7 (1.6)	25.7 (1.0)	25.6 (0.9)	26.6 (0.8)
Arthritis	2.2 (0.2)	2.5 (0.2)	2.6 (0.2)	2.6 (0.2)
Death	3.8 (0.3)	3.9 (0.3)	3.7 (0.3)	3.6 (0.3)

Numbers represent % and SE unless otherwise specified

Abbreviations: SD – standard deviation, SEM – standard error of mean, C.I. – confidence interval, ESRD – End-stage renal disease
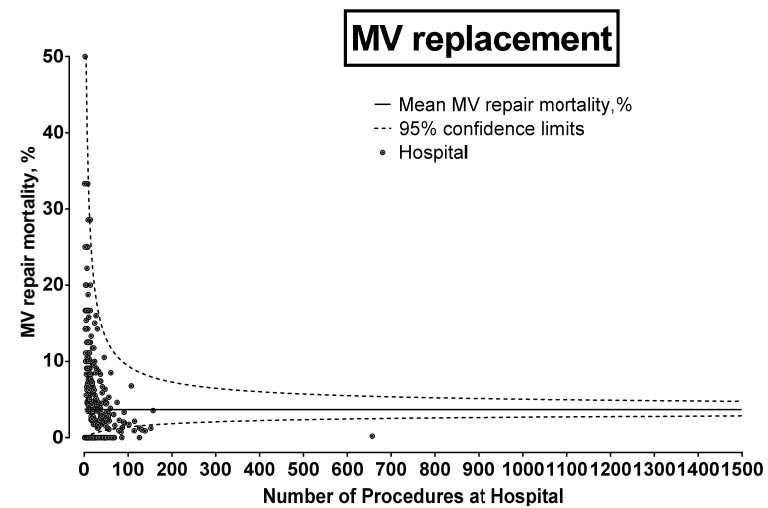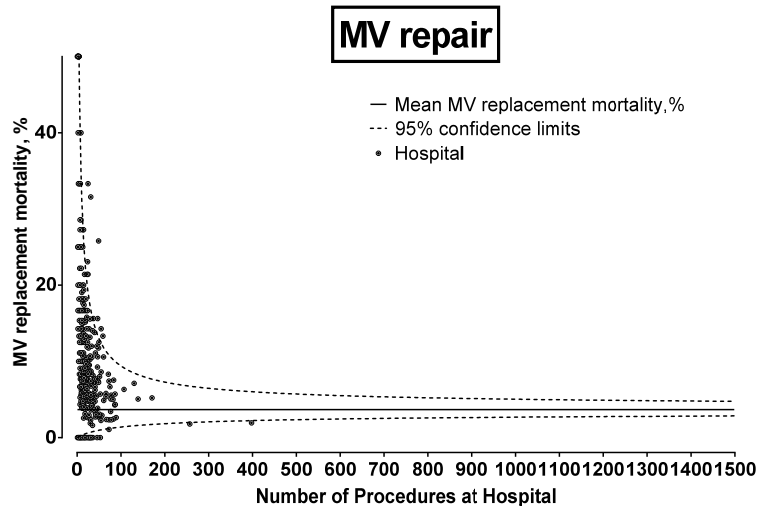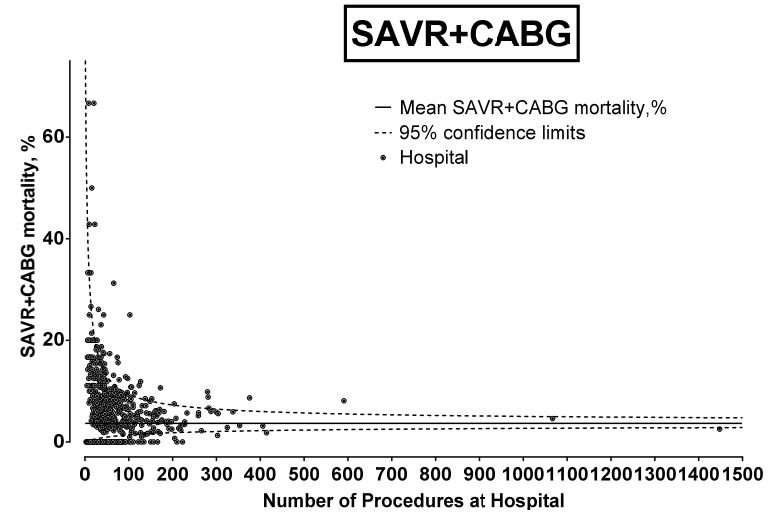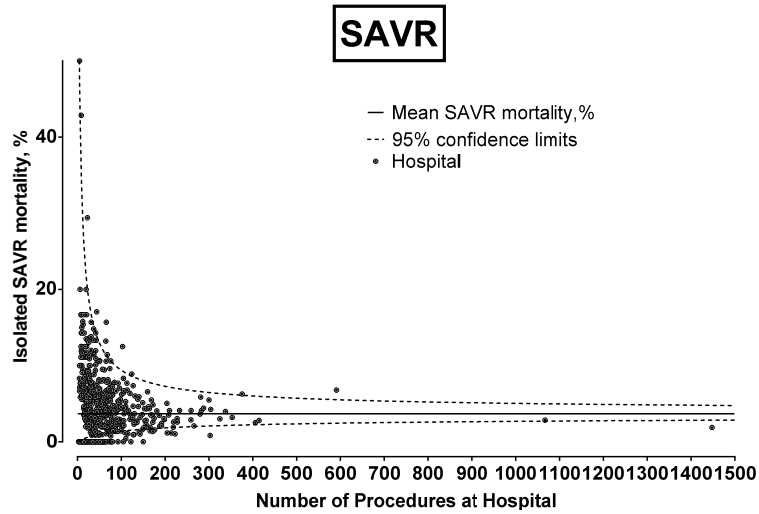
**eFigure 1**: Patient selection flowsheet
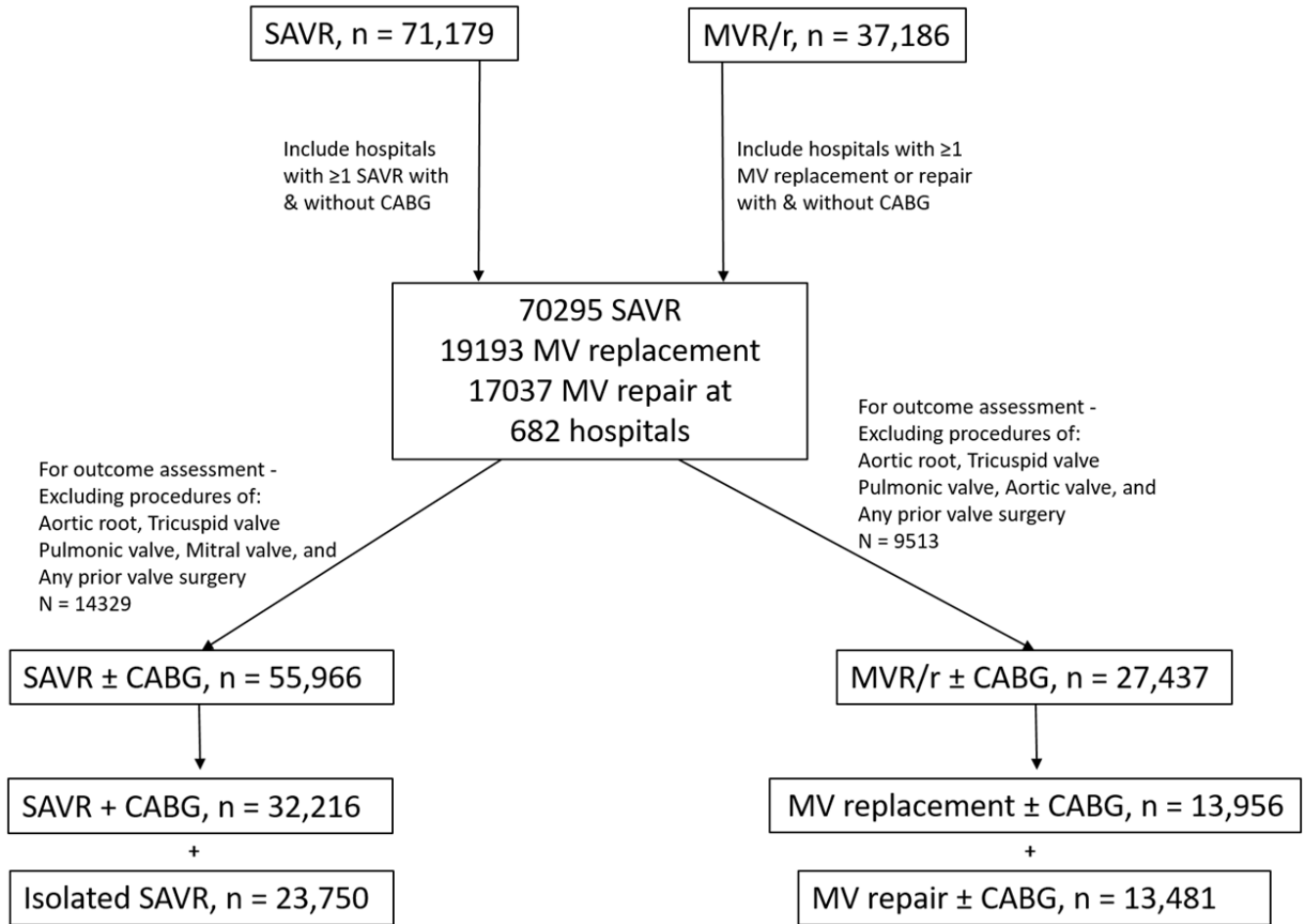
Abbreviations: SAVR: Surgical Aortic Valve Replacement, MV: Mitral valve, CABG: Coronary Artery Bypass Grafting

eFigure 2: Unadjusted in-hospital mortality by hospital volume. Horizontal line represents the mean mortality for each condition, the dotted lines represent the 95% confidence intervals as a binominal distribution around the mean volume for the procedure. The values between the confidence intervals represent those expected by chance alone.

SAVR

Legend:
— Mean SAVR mortality,%
--- 95% confidence limits
• Hospital

Y-axis: Isolated SAVR mortality, %
X-axis: Number of Procedures at Hospital

SAVR+CABG

Legend:
— Mean SAVR+CABG mortality,%
--- 95% confidence limits
• Hospital

Y-axis: SAVR+CABG mortality, %
X-axis: Number of Procedures at Hospital

MV repair

Legend:
— Mean MV replacement mortality,%
--- 95% confidence limits
• Hospital

Y-axis: MV replacement mortality, %
X-axis: Number of Procedures at Hospital

MV replacement

Legend:
— Mean MV repair mortality,%
--- 95% confidence limits
• Hospital

Y-axis: MV repair mortality, %
X-axis: Number of Procedures at Hospital

eFigure 3: Estimated National Procedural Volumes for (A) SAVR and (B) MVR Replacement and Repair (2005-2014).
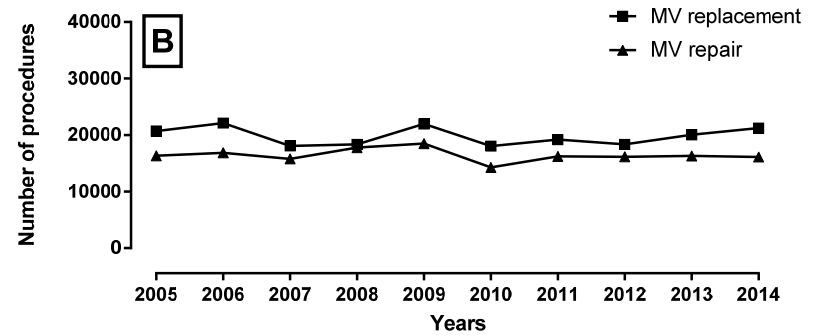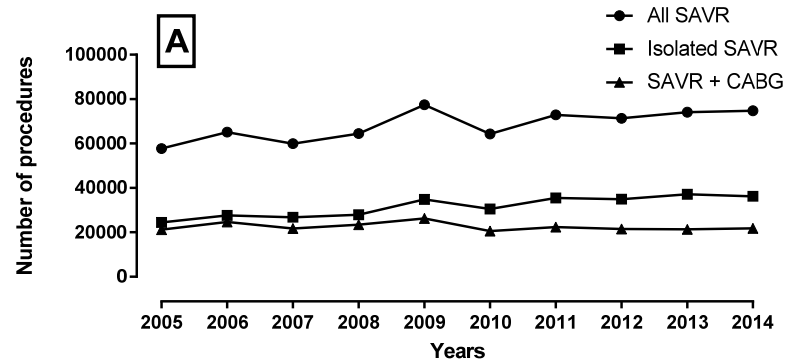
eFigure 4: Estimated In-Hospital Mortality Rates for (A) SAVR + CABG and Isolated CABG and (B) MV Replacement and Repair (2005-2014).