



Fig. E-1

APPENDIX

TOTAL SHOULDER ARTHROPLASTY (TSA)

Inclusion Criteria

- All procedures with the following procedure code:

81.80 – Total shoulder replacement

Exclusion Criteria

- Patients with diagnosis of shoulder bone infection:

730.01 – Acute osteomyelitis of shoulder region

730.11 – Chronic osteomyelitis of shoulder region

730.21 – Unspecified osteomyelitis

730.31 – Periostitis without mention of osteomyelitis

730.81 – Other infections involving bone in diseases classified elsewhere

730.91 – Unspecified infection of bone

996.60 – Infection or inflammatory reaction due to unspecified internal prosthetic device, implant, and graft

996.66 - Infection or inflammatory reaction due to internal joint prosthesis

996.67 – Infection or inflammation due to presence of unspecified orthopedic device, implant, and graft

- Patients with a primary diagnostic code that indicates that present surgery is for correction of a previous arthroplasty or complications of previous TSA :

996.4 – Mechanical complication of internal orthopedic device, implant, and graft

996.70 – Other complications of unspecified internal (biological) (synthetic) prosthetic device, implant, and graft

996.78 – Other complications of internal orthopedic (biological) (synthetic) prosthetic device, implant, and graft

996.79 - Other complications of internal (biological) (synthetic) prosthetic device, implant, and graft

- Patients with malignancies or pathological fractures of humerus, scapula, or glenoid:

170.4 – Malignant neoplasms of scapula and long bones of upper limb

196.3 – Secondary and unspecified malignant neoplasm of lymph nodes in axilla and upper limb

733.11 – Pathologic fracture of humerus

HEMIARTHROPLASTY (HA)

Inclusion Criteria

- All procedures with the following procedure code:

81.81 – Partial shoulder replacement

Exclusion Criteria

- Patients with diagnosis of shoulder bone infection:

730.01 – Acute osteomyelitis of shoulder region

730.11 – Chronic osteomyelitis of shoulder region

730.21 – Unspecified osteomyelitis

730.31 – Periostitis without mention of osteomyelitis

730.81 – Other infections involving bone in diseases classified elsewhere

730.91 – Unspecified infection of bone

996.60 – Infection of inflammatory reaction due to unspecified internal prosthetic device, implant, and graft

996.66 - Infection of inflammatory reaction due to internal joint prosthesis

996.67 – Infection or inflammation due to presence of unspecified orthopedic device, implant, and graft

- Patients with a primary diagnostic code that indicates that present surgery is for correction of a previous arthroplasty or complications of previous HA

996.4 – Mechanical complication of internal orthopedic device, implant, and graft

996.70– Other complications of unspecified internal (biological) (synthetic) prosthetic device, implant, and graft

996.78 - Other complications of internal orthopedic (biological) (synthetic) prosthetic device, implant, and graft

996.79 - Other complications of internal (biological) (synthetic) prosthetic device, implant, and graft

- Patients with malignancies or pathological fractures of humerus, scapula, or glenoid:

170.4 – Malignant neoplasms of scapula and long bones of upper limb

196.3 – Secondary and unspecified malignant neoplasm of lymph nodes in axilla and upper limb

733.11 – Pathologic fracture of humerus

FOR TSA AND HA

Main effect variables (independent variables)

- Surgeon volume
- Hospital volume

Main Outcomes (dependent variables)

- Mortality
- Length of stay
- Nonroutine disposition of patient on discharge
- Postoperative complications

998.59 - Postoperative wound infection

999.3 – Other infection

998.83 – Non-healing surgical wound

998.3 – Disruption of operation wound

415.19 - Pulmonary embolism pulmonary (artery or vein)

415.11 – Pulmonary embolism postoperative

997.2 – Thrombophlebitis during or resulting from a procedure

451.82, 451.83, 451.84 – Thrombophlebitis of upper extremity

999.2 – Other vascular complications

998.89 – Other specified complications of procedures, not elsewhere classified

998.9 – Unspecified complication of procedure, not elsewhere classified

Confounders

- Age
- Race
- Household income
- Deyo index
- Sex
- Hospital volume was used as confounder while evaluating surgeon volume outcomes

Stratification

- Patients with fracture of scapula, humerus, or glenoid due to injury:
 - 811.00, 811.01, 811.02, 811.03, 811.09, 811.10, 811.11, 811.12, 811.13, 811.19 – Fracture of scapula
 - 812.00 – 812.03, 812.09, 812.10-812.13, 812.19, 812.20, 812.21, 812.29, 812.30, 812.31, 812.40-812.44, 812.49, 812.50-812.54, 812.59 – Fracture of humerus
- Patients with a diagnosis of osteoarthritis:
 - 715.11 – Osteoarthritis, localized, primary of shoulder region
 - 715.12 – Osteoarthritis, localized, primary of upper arm
 - 715.21 – Osteoarthritis, localized, secondary of shoulder region
 - 715.22 - Osteoarthritis, localized, secondary of shoulder region
 - 715.31 – Osteoarthritis, localized, not specified whether primary or secondary of shoulder region
 - 715.32 – Osteoarthritis, localized, not specified whether primary or secondary of arm
 - 715.81 – Osteoarthritis involving, or with mention of more than one site, but not specified as generalized of shoulder region
 - 715.82 – Osteoarthritis involving, or with mention of more than one site, but not specified as generalized of arm
 - 715.91 – Osteoarthritis, unspecified whether generalized or localized of shoulder region
 - 715.92 - Osteoarthritis, unspecified whether generalized or localized of upper arm

Table E-1: Distribution by Hospital and Surgeon Procedure Volumes of Shoulder Arthroplasty from the Year 1988 through 2000, United States

FOR TOTAL SHOULDER ARTHROPLASTY[†]

Hospital Volume*	Surgeon Volume*			Total
	<2	≥2-<5	≥5	
<5	21.5%	15.7%	0.3%	37.5%
≥5-<10	7.5%	13.6%	7.8%	28.9%
≥10	4.5%	8.3%	20.8%	33.6%
Total	33.5%	37.6%	28.9%	100.0%

N=7373. Sample size differs from Table I and Table II due to missing primary surgeon identifiers in 41.3% of total shoulder replacement cases

*The volumes for surgeon and hospital represent only total shoulder replacement volume per year

†Percentages are expressed as the percent of total shoulder replacement procedures with a primary surgeon identifier (7373 records)

**FOR
HEMIARTHROPLASTY[†]**

Hospital Volume*	Surgeon Volume*			Total
	<2	≥2-<5	≥5	
<5	24.5%	15.0%	0.4%	39.9%
≥5-<10	11.5%	17.3%	4.3%	33.1%
≥10	6.0%	11.7%	9.4%	27.1%
Total	42.0%	44.0%	14.1%	100.1%

N=9505. Sample size differs from Table I and Table II due to missing primary surgeon identifiers in 45.5% of hemiarthroplasty cases

The total is not 100% due to rounding error

*The volumes for surgeon and hospital represent only hemiarthroplasty volume per year

†Percentages are expressed as the percent of hemiarthroplasty procedures with a primary surgeon identifier (9505 records)

Table E-2: Distribution of Hospital and Surgeon Shoulder Arthroplasty Volumes by Hospital Characteristics from the Year 1988 through 2000, United States

FOR TOTAL SHOULDER ARTHROPLASTY

Hospital Volume*	Hospital Bed Size**			Hospital Teaching Status**		Total Charges (mean) (in \$)
	Small	Medium	Large	Teaching	Non-teaching	
<5	14.6%	36.2%	49.3%	24.5%	75.5%	16462 [†]
≥5-<10	11.0%	25.1%	64.0%	38.1%	61.9%	15862 [†]
≥10	7.2%	15.7%	77.1%	54.5%	45.5%	16995

*Hospital volume represents only total shoulder replacement volume per year

**Percentages reflect percent of the respective hospital volume category

[†]Significantly different from mean charges for hospital volume ≥10 at 0.05 significance level

FOR HEMIARTHROPLASTY

Hospital Volume*	Hospital Bed Size**			Hospital Teaching Status**		Total Charges (mean) (in \$)
	Small	Medium	Large	Teaching	Non-teaching	
<5	16.1%	36.7%	47.1%	22.1%	77.9%	16211
≥5-<10	10.4%	28.0%	61.6%	37.4%	62.6%	16460
≥10	9.0%	23.4%	67.6%	52.2%	47.8%	16600

*Hospital volume represents only hemiarthroplasty volume per year

**Percentages reflect percent of the respective hospital volume category

Table E-3: Trends Analysis by Surgeon Volume for Patients Undergoing Shoulder Arthroplasty from the Year 1988 through 2000, United States, using Generalized Estimating Equations

Surgeon		
Outcome	Procedure Volume	Incremental Odds Ratio
FOR TOTAL SHOULDER ARTHROPLASTY		
Mortality	≥5	-
	≥2-<5	4.2
	<2	1.04
Postoperative complications	≥5	-
	≥2-<5	1.5
	<2	0.9
Nonroutine disposition of patient on discharge	≥5	-
	≥2-<5	0.9
	<2	1.1
FOR HEMIARTHROPLASTY		
Mortality	≥5	-
	≥2-<5	0.7
	<2	1.4
Postoperative complications	≥5	-
	≥2-<5	1.5
	<2	1.5
Nonroutine disposition of patient on discharge	≥5	-
	≥2-<5	1.3
	<2	0.99

Table E-4: Trends Analysis by Hospital Volume for Patients Undergoing Shoulder Arthroplasty from the Year 1988 through 2000, United States, using Generalized Estimating Equations

Hospital		
Outcome	Procedure Volume	Incremental Odds Ratio
FOR TOTAL SHOULDER ARTHROPLASTY		
Mortality	≥10	-
	≥5-<10	1.5
	<5	1.4
Postoperative complications	≥10	-
	≥5-<10	2.1
	<5	1.2
Nonroutine disposition of patient on discharge	≥10	-
	≥5-<10	1.1
	<5	1.1
FOR HEMIARTHROPLASTY		
Mortality	≥10	-
	≥5-<10	0.9
	<5	1.4
Postoperative complications	≥10	-
	≥5-<10	1.2
	<5	0.9
Nonroutine disposition of patient on discharge	≥10	-
	≥5-<10	1.2
	<5	0.9

Table E-5: Associations and Trends Between Surgeon Volume and Selected Outcomes after Stratification of Analysis by Diagnosis of Osteoarthritis and Fracture for Patients Undergoing Shoulder Arthroplasty from the Year 1988 through 2000, United States

Shoulder Arthroplasty from the Year 1980 through 2000, United States							
Surgeon							
	Procedure Volume	Outcome Rate	Adjusted Odds Ratio (95% Confidence Interval)	Incremental Odds Ratio	Outcome Rate	Adjusted Odds Ratio (95% Confidence Interval)	Incremental Odds Ratio
Outcome							
Diagnosis of Osteoarthritis					Diagnosis of Fracture*		
FOR TOTAL SHOULDER ARTHROPLASTY							
Postoperative complications	<2	1.78%	1.7 (0.7-3.9)	1.04	1.69%	0.7 (0.08-5.4)	1.3
	≥2-<5	1.43%	1.6 (0.8-3.5)	1.6	1.52%	0.5 (0.05-5.3)	0.4
	≥5	0.81%	1.0	-	1.39%	1.0	-
Nonroutine disposition of patient on discharge	<2	27.4%	1.1 (0.8-1.4)	1.1	50.8%	1.4 (0.8-2.3)	1.2
	≥2-<5	26.6%	1.01 (0.8-1.3)	1.01	51.8%	1.2 (0.7-2.0)	1.2
	≥5	25.3%	1.0	-	46.5%	1.0	-
FOR HEMIARTHROPLASTY							
Postoperative complications	<2	1.31%	1.3 (0.3-5.8)	0.9	2.26%	1.8 (0.8-3.7)	0.9
	≥2-<5	1.36%	1.5 (0.3-7.9)	1.5	1.60%	1.1 (0.5-2.4)	1.5
	≥5	0.43%	1.0	-	2.10%	1.0	-
Nonroutine disposition of patient on discharge	<2	26.5%	1.2 (0.8-1.8)	0.9	48.3%	1.1 (0.8-1.4)	0.9
	≥2-<5	30.3%	1.4 (0.99-2.0)	1.4	50.0%	1.1 (0.9-1.5)	1.4
	≥5	23.4%	1.0	-	45.5%	1.0	-

Table E-6: Associations and Trends Between Hospital Volume and Selected Outcomes after Stratification of Analysis by Diagnosis of Osteoarthritis and Fracture for Patients Undergoing Shoulder Arthroplasty from the Year 1988 through 2000, United States

Hospital							
Outcome	Procedure Volume	Outcome Rate	Adjusted Odds Ratio (95 % Confidence Interval)	Incremental Odds Ratio	Outcome Rate	Adjusted Odds Ratio (95 % Confidence Interval)	Incremental Odds Ratio
Diagnosis of Osteoarthritis					Diagnosis of Fracture*		
FOR TOTAL SHOULDER ARTHROPLASTY							
Postoperative complications	<5	1.67%	2.4 (1.4-4.3)	1.4	1.64%	1.8 (0.5-6.3)	0.8
	≥5-<10	1.38%	1.7 (0.9-3.2)	1.7	2.68%	2.2 (0.6-8.6)	2.3
	≥10	0.65%	1.0	-	0.92%	1.0	-
Nonroutine disposition of patient on discharge	<5	27.2%	1.2 (0.97-1.5)	1.1	54.9%	0.7 (0.5-1.1)	1.1
	≥5-<10	24.0%	1.1 (0.9-1.4)	1.1	46.5%	0.6 (0.4-1.0)	0.6
	≥10	23.7%	1.0	-	46.2%	1.0	-
FOR HEMIARTHROPLASTY							
Postoperative complications	<5	1.57%	1.8 (0.8-3.7)	1.3	1.52%	0.8 (0.4-1.3)	1.3
	≥5-<10	1.11%	1.3 (0.6-2.8)	1.3	1.86%	1.1 (0.6-1.8)	1.3
	≥10	1.16%	1.0	-	2.26%	1.0	-
Nonroutine disposition of patient on discharge	<5	25.6%	0.96 (0.8-1.2)	0.9	45.3%	0.9 (0.8-1.1)	0.9
	≥5-<10	27.3%	1.1 (0.9-1.4)	1.1	48.0%	1.1 (0.9-1.3)	1.1
	≥10	26.8%	1.0	-	48.9%	1.0	-

*Race was dropped from the models estimating adjusted odds ratios for postoperative complications in patients with a diagnosis of fracture after total shoulder replacement, since the convergence of the original full model (with race) was questionable and the generalized hessian matrix was not positive definite

Table E-7: Adjusted Estimates of Length of Stay by Surgeon and Hospital Volume for Patients Undergoing Shoulder Arthroplasty after Stratification of Analysis by Diagnosis of Osteoarthritis and Fracture from the Year 1988 through 2000, United States

Surgeon						
Procedure	Mean LOS*	Estimated LOS[†]	SD**	Mean LOS*	Estimated LOS[†]	SD**
Volume	(Days) [SD]**	(Days)	(Days)	(Days) [SD]**	(Days)	(Days)
Diagnosis of Osteoarthritis				Diagnosis of Fracture[§]		
FOR TOTAL SHOULDER ARTHROPLASTY						
<2	3.6 [2.6]	3.5 [‡]	0.6	6.8 [7.4]	6.3	1.2
≥2-<5	3.4 [2.3]	3.2	0.5	5.7 [4.9]	5.6	1.1
≥5	3.1 [1.9]	3.0	0.6	5.4 [5.8]	5.0	1.5
FOR HEMIARTHROPLASTY						
<2	3.6 [3.2]	3.3	0.6	7.1 [7.6]	6.7 ^{††}	1.4
≥2-<5	3.3 [2.2]	3.2	0.6	5.9 [5.6]	6.0	1.2
≥5	3.2 [2.2]	3.0	0.6	5.3 [4.2]	5.6	1.3
Hospital						
Procedure	Mean LOS*	Estimated LOS[†]	SD**	Mean LOS*	Estimated LOS[†]	SD**
Volume	(Days) [SD]**	(Days)	(Days)	(Days) [SD]**	(Days)	(Days)
Diagnosis of Osteoarthritis				Diagnosis of Fracture		
FOR TOTAL SHOULDER ARTHROPLASTY						
<5	3.7 [2.5]	3.5 [‡]	0.6	7.3 [9.3]	6.4 [‡]	1.2
≥5-<10	3.4 [2.0]	3.3***	0.6	5.7 [5.8]	5.6	1.1
≥10	3.1 [1.9]	2.9	0.5	5.3 [4.5]	5.0	1.1
FOR HEMIARTHROPLASTY						
<5	3.7 [2.9]	3.4 [‡]	0.6	6.8 [6.8]	6.9 [‡]	1.4
≥5-<10	3.5 [3.0]	3.3***	0.6	6.1 [6.0]	6.1 ^{††}	1.2
≥10	3.1 [2.0]	3.0	0.6	5.7 [5.5]	5.5	1.2

*LOS = Length of Stay

[†]Estimates were adjusted for smearing

**SD signifies the standard deviation from the mean

[§]Estimates for length of stay in patients with a diagnosis of fracture undergoing total shoulder arthroplasty were adjusted for scaling and not smearing since data was homoscedastic

[‡]signifies that variable for the respective surgeon and hospital volume category was significant at 0.001 significance level in the linear regression model with the lowest surgeon and hospital volume category as reference

^{††}signifies that variable for the respective surgeon and hospital volume category was significant at 0.01 significance level in the linear regression model with the lowest surgeon and hospital volume category as reference

***signifies that variable for the respective surgeon and hospital volume category was significant at 0.05 significance level in the linear regression model with the lowest surgeon and hospital volume category as reference