J Shoulder Elbow Surg (2023) 32, e216–e226

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Higher rates of mortality and perioperative complications in patients undergoing primary shoulder arthroplasty and a history of previous stroke

Erick M. Marigi, MD[a], Jose M. Iturregui, MD[b], Jean-David Werthel, MD[c], John W. Sperling, MD, MBA[a], Joaquin Sanchez-Sotelo, MD, PhD[a], Bradley S. Schoch, MD[b,*]

[a]*Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA*
[b]*Department of Orthopedic Surgery, Mayo Clinic Florida, Jacksonville, FL, USA*
[c]*Department of Orthopedic Surgery, Hopital Ambroise Paré, Boulogne-Billancourt, France*

Background: Cerebrovascular accidents (CVAs), or strokes, are the second most common cause of mortality and third most common cause of disability worldwide. Although advances in the treatment of strokes have improved survivorship following these events, there remains a limited understanding of the effect of a prior stroke and sequelae on patients undergoing shoulder arthroplasty (SA). This study aimed to determine the outcomes of patients with a history of stroke with sequela undergoing primary SA.
Methods: Over a 30-year time period (1990-2020), 205 primary SAs (32 hemiarthroplasties [HAs], 56 anatomic total shoulder arthroplasties [aTSAs], and 117 reverse shoulder arthroplasties [RSAs]) were performed in patients who sustained a previous stroke with sequela and were followed for a minimum of 2 years. This cohort was matched (1:2) according to age, sex, body mass index, implant, and year of surgery with patients who had undergone HA or aTSA for osteoarthritis or RSA for cuff tear arthropathy. Mortality after primary SA was individually calculated through a cumulative incidence analysis. Implant survivorship was analyzed with a competing risk model selecting death as the competing risk.
Results: The stroke cohort sustained 38 (18.5%) surgical and 42 (20.5%) medical perioperative complications. Compared with the control group, the stroke cohort demonstrated higher rates of any surgical complication (18.5% vs 10.7%; $P = .007$), instability (6.3 % vs 1.7%; $P = .002$), venous thromboembolism (3.4% vs 0.5%; $P = .004$), pulmonary embolus (2.0% vs 0%; $P = .005$), postoperative stroke (2.4% vs 0%; $P = .004$), respiratory failure (1.0% vs 0%; $P = .045$), any medical complication (20.5% vs 7.3%; $P < .001$), and 90-day readmission (16.6% vs 4.9%; $P < .001$). Additionally, RSA in the stroke cohort was associated with higher reoperation (8.5% vs 2.6%; $P = .011$) and revision rates (6.8% vs 1.7%; $P = .013$) compared with the matched cohort. Subsequent cumulative incidences of death at 1, 2, 5, 10, 15, and 20 years were 4.4% vs 3.4%, 10.7% vs 5.1%, 25.6% vs 14.7%, 51.6% vs 39.3%, 74.3% vs 58.6%, and 92.6% vs 58.6% between the stroke and matched cohorts, respectively ($P < .001$).
Conclusions: A preoperative diagnosis of a stroke in patients undergoing primary SA is associated with higher rates of perioperative complications and mortality when compared to a matched cohort. This information should be considered to counsel patients and surgeons to optimize care and help mitigate risks associated with the perioperative period.

This study was approved by Mayo Institutional Review Board (IRB 12-007498).

*Reprint requests: Bradley S. Schoch, MD, 4500 San Pablo Rd, Jacksonville, FL 32224, USA.
E-mail address: schoch.bradley@mayo.edu (B.S. Schoch).

https://doi.org/10.1016/j.jse.2022.10.014

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Cerebrovascular accident; stroke; shoulder arthroplasty; hemiarthroplasty; anatomic total shoulder arthroplasty; reverse total shoulder arthroplasty

Cerebrovascular accidents (CVAs), or strokes, are the second most common cause of mortality and third most common cause of disability worldwide.[51] Medical advances in the treatment of strokes have improved survivorship after these events; in the United States, there are an estimated 7 million stroke survivors, with a projected rise to 10 million by 2030.[43] However, stroke survivors are often left with debilitating neurologic sequela, leading to a decreased quality of life and depression.[37,40,47] Shoulder pain after a stroke is present in most cases with sequelae, with an estimated prevalence in 50% to 84% of survivors.[24,45,50] Hemiplegic shoulder pain is the most common pain disorder after stroke and one of the most common overall complications.[2,15] Although the etiologies are multifactorial, in the context of stroke sequelae symptoms are thought to be generated secondary to the injury and resulting spasticity, hypertonia, loss of muscle strength, rotator cuff injury, subluxation, unilateral negligence, or reflex sympathetic dystrophy.[45,50]

Nonoperative management remains the first-line treatment strategy of shoulder pain in stroke sequelae.[15,45,50] Often this is directed by the clinical presentation and underlying pathology of the glenohumeral joint with a goal of providing pain relief and restoration of shoulder function.[15,45,50] When these modalities fail and stroke survivors advance in age, those with recalcitrant shoulder pain secondary to glenohumeral arthritis or rotator cuff arthropathy may become candidates for shoulder arthroplasty (SA). A history of a stroke is a well-known risk factor for adverse cardiovascular events after elective noncardiac surgeries and for postoperative stroke following total hip and knee arthroplasty.[11,18,31,32] However, in the SA population, there are no known investigations that have evaluated the effect of a stroke with subsequent sequelae.

As the annual volume of SAs being performed continues to increase, it is important to develop a better understanding of the morbidity and mortality risks in patients with a stroke history undergoing SA.[13,20] Therefore, the purpose of this study was to determine the outcomes, including complications and survivorship, of patients with a history of stroke and sequela undergoing primary SA.

Materials and methods

Following institutional review board approval, a retrospective search of a prospectively recorded institutional Total Joint Registry Database was performed.[44] First, all adults who underwent a primary SA between January 1989 and July 2020 were identified (n = 10,930). Next, all SAs within this cohort with a history of a CVA or stroke prior to surgery were selected (n = 341). An electronic medical record review was subsequently performed collecting demographic data and clinical characteristics pertaining to strokes (date and age of first stroke, stroke etiology, laterality, and neurologic sequelae). Neurologic sequela was defined as any neurologic symptom (spasticity, hemiplegia, hemiparesis, paresthesias, allodynia, neuropathic pain, and subluxation) that developed secondary to the stroke that involved the extremities. Subsequent exclusions consisted of those without any permanent poststroke neurologic sequela (n = 72), a diagnosis of a transient ischemic attack instead of a CVA (n = 39), less than 2 years of clinical follow-up in a living patient (n = 18), and shoulder reconstructions performed for malignancy (n = 7).

Of note, there were 21 patients who died prior to 2 years of follow-up and were included for reporting of preoperative characteristics, complications, reoperations, and mortality rates. Patient survival and all-cause mortality events were captured through routine surveillance by our institutional Total Joint Registry Database and confirmed when needed through the use of a nationwide mortality database (Accurint by LexisNexis; LexisNexis, New York, NY, USA). In cases of database confirmation, a 6-month lag period was included in order to provide an appropriate interlude and promote accurate reporting.[52]

The final study cohort consisted of 205 primary shoulder replacements (32 hemiarthroplasties [HAs], 56 anatomic total shoulder arthroplasties [aTSAs], and 117 reverse shoulder arthroplasties [RSAs]) performed in 178 patients. Subsequently, the stroke cohort was matched (1:2) according to age, sex, body mass index, type of prosthesis, year of surgery, and indication for surgery. For patients who were unable to be matched based on the select criteria at the exact diagnosis, the indication parameters were expanded to include a control group of patients who had undergone HA or aTSA for OA or RSA for cuff tear arthropathy.

The stroke group included 87 males (42.4%) and 118 females (57.6%) with a mean age of 72.4 ± 9.6 and a body mass index (BMI) of 31.1 ± 7.4 (Table I). Strokes occurred at a mean of 8.7 ± 9.0 years prior to SA with a majority of stroke sequelae ipsilateral to the SA side (n = 85; 41.5%) (Table II). Notable differences between the stroke compared to matched cohort demonstrated a higher rate of diabetes mellitus (29.3% vs 15.1; $P < .001$), American Society of Anesthesiologists score (2.7 vs 2.2; $P < .001$), Charlson Comorbidity Index (6.0 vs 5.2; $P < .001$), anesthesia time (195 vs 186 minutes; $P = .028$), and length of stay (2.8 vs 2.0 days; $P < .001$).

Clinical outcomes collected were perioperative medical and surgical complications, subsequent reoperations, and revision surgery (subsequent removal and/or exchange of any components), readmissions within 90 days of surgery, and subsequent cumulative incidences of death at 1, 2, 5, 10, 15, and 20 years were compared between groups.

Table I Patient demographic and preoperative clinical characteristics

Variable	Stroke cohort (n = 205)	Matched cohort (n = 410)	*P* value
Age (y)	72.4 ± 9.6	72.3 ± 9.5	.942
Sex			.999
Male	87 (42.4)	174 (42.4)	
Female	118 (57.6)	236 (57.6)	
BMI	31.1 ± 7.4	30.4 ± 6.0	.506
Current tobacco use	13 (6.3)	23 (5.6)	.477
Diabetes mellitus	60 (29.3)	62 (15.1)	**<.001**
MRSA colonization	30 (14.6)	39 (9.5)	.070
ASA score	2.7 ± 0.5	2.2 ± 0.7	**<.001**
ASA class			**<.001**
≤2	73 (35.6)	249 (60.7)	
≥3	132 (64.4)	161 (39.3)	
CCI	6.0 ± 2.4	5.2 ± 2.2	**<.001**
CCI class			**.017**
0	0 (0.0)	2 (0.5)	
1-3	18 (8.8)	67 (16.3)	
4-5	93 (45.4)	198 (48.2)	
≥6	94 (45.9)	143 (34.9)	
Prior surgery	39 (19.0)	93 (22.7)	.298
Diagnoses			.963
Osteoarthritis	96 (46.8)	194 (47.3)	
Rotator cuff tear arthropathy	85 (41.5)	174 (42.4)	
Malunion or nonunion after PHFx	10 (4.9)	18 (4.4)	
Acute fracture	12 (5.9)	19 (4.6)	
Other	2 (1.0)	5 (1.2)	
Implant			.999
HA	32 (15.6)	64 (15.6)	
aTSA	56 (27.3)	112 (27.3)	
RSA	117 (57.1)	234 (57.1)	
Anesthesia time (min)	195 ± 62	186 ± 65	**.028**
Operative time (min)	111 ± 58	108 ± 60	.299
Length of stay (d)	2.8 ± 3.7	2.0 ± 1.4	**<.001**
Follow-up (y)	6.6 ± 4.5	6.1 ± 4.1	.238

BMI, body mass index; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *ASA*, American Society of Anesthesiologists; *CCI*, Charlson Comorbidity Index; *PHFx*, proximal humerus fracture; *HA*, hemiarthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *RSA*, reverse total shoulder arthroplasty.
Data are presented as mean ± standard deviation or n (%).
Bold values represent statistical significance ($P < .05$).

Statistical analysis

Statistical analyses were performed using BlueSky 7.4.0 software (BlueSky Statistics Inc., Chicago, IL, USA). Summary statistics were calculated for the demographic and clinical variables. Quantitative variables were reported as means, standard deviations, or ranges. Group numerical values were compared using the Student *t* test for parametric values and the Kruskal-Wallis for nonparametric distributions. Qualitative variables were reported as percentages and the chi-squared test was used to compare qualitative variables between groups. Mortality after SA were calculated through a cumulative incidence analysis. Subsequently, because of the elevated perioperative mortality and extended follow-up of the patients, the risk of reoperation and revision were assessed through a competing risk analysis, with all-cause mortality identified separately as the competing risk. For all data points, statistical significance was achieved when the *P* value was less than .05.

Results

Within the stroke cohort, a total of 38 (18.5%) and 42 (20.5%) SAs sustained at least 1 perioperative surgical and medical complication, respectively (Tables III and IV). When compared by implant type, HA had the highest rate of instability (15.6%), followed by aTSA (10.7%) and RSA (1.7%) (P = .005). When comparing the stroke and matched cohort, a higher rate of instability (6.3 % vs 1.7%; P = .002) and any surgical complication (18.5 % vs 10.7%; P = .007) were observed in the stroke cohort. Furthermore,

Table II Stroke characteristics and relationship to subsequent shoulder arthroplasty

Variable	Stroke cohort (n = 205)
Age at first stroke	63.7 ± 13.6
Stroke type	
Hemorrhagic	99 (48.3)
Ischemic	106 (51.7)
Time from last stroke to SA (y)	8.7 ± 9.0
Anticoagulation at the time of SA	
Aspirin alone	97 (47.3)
Single potent anticoagulant	28 (13.7)
Multiple anticoagulants	24 (11.7)
Antiplatelet agents other than aspirin	14 (6.8)
None	42 (20.5)
Stroke sequelae laterality in relation to SA	
Ipsilateral to SA side	85 (41.5)
Contralateral to SA side	70 (34.1)
Bilateral	12 (5.9)
Nonspecific	38 (18.5)

SA, shoulder arthroplasty.
Data are presented as mean ± standard deviation or n (%).

HA (15.6% vs 1.6%; $P = .015$) and aTSA (10.7% vs 2.7%; $P = .041$) had higher instability rates when compared to controls, whereas RSA (1.7% vs 1.3%; $P = .999$) had similar instability rates. All other individual complications occurred at similar rates to controls in HA, aTSA, and RSA.

Medically, the stroke cohort experienced a higher rate of venous thromboembolism (3.4% vs 0.5%; $P = .004$), pulmonary embolus (2.0% vs 0%; $P = .005$), postoperative stroke (2.4% vs 0%; $P = .004$), respiratory failure (1.0% vs 0%; $P = .045$), total medical complications (20.5% vs 7.8%; $P < .001$), and 90-day readmissions (16.6% vs 4.9%; $P < .001$). Of all 90-day readmissions, 45 (83.3%) and 9 (16.7%) readmissions were secondary to medical and surgical conditions, respectively. Among stroke patients specifically, 31 (91.2%) and 3 (8.8%) readmissions were secondary to medical and surgical conditions, respectively. A subanalysis by anticoagulation status demonstrated a higher rate of medical complications in patients with perioperative anticoagulation when compared to those without anticoagulation (23.9% vs 7.1%; $P = .017$).

The stroke cohort sustained 13 (6.3%) reoperations, with 11 (5.4%) in the form of revision surgery. When compared across implants, there were no differences in the rate of reoperations (3.1% vs 3.6% vs 8.5%; $P = .433$) or revision surgery (3.1% vs 3.6% vs 6.8%; $P = .685$) for HA, aTSA, and RSA, respectively (Table V). Similarly, no differences were observed in the overall rates of reoperations (6.3% vs 4.6%; $P = .369$) or revision surgery (5.4% vs 3.4%; $P = .248$) between the stroke and matched cohort.

A subanalysis of implant differences between cohorts demonstrated a higher reoperation (8.5% vs 2.6%; $P = .011$) and revision surgery (6.8% vs 1.7%; $P = .013$) in the RSA cohort of the stroke cohort compared to the matched cohort. When broken down by indication, only aseptic component loosening was higher in the stroke RSA group (2.6% vs 0%; $P = .014$) compared with the matched RSA cohort, whereas the other indications demonstrated no differences: PJI, 1.7% vs 0.4% ($P = .219$); instability, 1.7% vs 1.7% ($P > .999$); acromial or scapular spine fracture, 0.9% vs 0% ($P = .157$); periprosthetic fracture, 0.9% vs 0.4% ($P = .616$); and superficial wound complication, 0.9% vs 0% ($P = .157$). Additionally, no differences were observed in rates of complications, reoperations, or revisions across the stroke cohort sequela laterality in relation to the subsequent arthroplasty (Table VI).

Subsequent cumulative incidences of death at 1, 2, 5, 10, 15, and 20 years were 4.4% vs 3.4%, 10.7% vs 5.1%, 25.6% vs 14.7%, 51.6% vs 39.3%, 74.3% vs 58.6%, and 92.6% vs 58.6% between the stroke and matched cohorts, respectively ($P < .001$) (Fig. 1). Accounting for death as a competing risk, the cumulative incidence of reoperation or revision surgery demonstrated no differences between the stroke or matched cohort with rates of 5.9% vs 3.2%, 6.6% vs 6.5%, and 6.6 vs 6.5% at 2, 10, and 20 years, respectively ($P = .499$) (Fig. 2).

Discussion

As both the volume of stroke survivors and SA procedures continues to rise, it is important to develop a better understanding of the risks involved for patients with a history of stroke with sequelae undergoing SA.[13,20,33,43,48,49] In the present study, a preoperative stroke was identified in 2.9% of SAs, with 76.2% of shoulders also having neurologic sequelae. When compared to a matched cohort, SAs with previous strokes and neurologic sequelae experienced a higher rate of perioperative surgical (18.5%) and medical complications (20.5%). Additionally, the stroke cohort had significantly higher cumulative incidences of death across all postoperative time frames.

Within the general SA population, the rate of surgical complications has been diminishing over the recent past from 14.7% to 11%.[8] However, in the presence of select medical comorbidities, elevated rates of surgical complications have been described for certain conditions such as metabolic syndrome,[26] juvenile idiopathic arthritis,[27] Parkinson's disease,[29] and pulmonary hypertension.[28] Similarly, the stroke cohort in this study demonstrated a significantly higher surgical complication rate when compared to the matched cohort (18.5 % vs 10.7%; $P = .007$). When analyzing specific surgical complications, instability was the most common surgical complication in the stroke cohort and was significantly higher than the matched cohort (6.3 % vs 1.7%; $P = .002$). Furthermore,

Table III Postoperative surgical complications by implant type and across cohorts

Variable	HA (n = 32)	aTSA (n = 56)	RSA (n = 117)	P value*	Stroke cohort (n = 205)	Matched cohort (n = 410)	P value†
Instability	5 (15.6)	6 (10.7)	2 (1.7)	**.005**	13 (6.3)	7 (1.7)	**.002**
Periprosthetic fracture	2 (6.3)	0 (0)	6 (5.1)	.201	8 (3.9)	10 (2.4)	.310
Intraoperative	1 (3.1)	0 (0)	3 (2.6)		4 (2.0)	3 (0.7)	
Postoperative	1 (3.1)	0 (0)	3 (2.6)		4 (2.0)	7 (1.7)	
Aseptic component loosening	0 (0)	1 (1.8)	3 (2.6)	.646	4 (2.0)	4 (1.0)	.314
Glenoid	0 (0)	1 (1.8)	1 (0.9)		2 (1.0)	4 (1.0)	
Humerus	0 (0)	0 (0)	2 (1.7)		2 (1.0)	0 (0)	
Deep infection	1 (3.1)	0 (0)	2 (1.7)	.474	3 (1.5)	3 (0.7)	.384
Acromial or scapular spine fracture	0 (0)	0 (0)	2 (1.7)	.468	2 (1.0)	5 (1.2)	.788
Arthrofibrosis	0 (0)	1 (1.8)	1 (0.9)	.700	2 (1.0)	0 (0)	.050
Neural palsy or neuropathy	1 (3.1)	0 (0)	1 (0.9)	.350	2 (1.0)	2 (0.5)	.478
Superficial wound complication	0 (0)	0 (0)	2 (1.7)	.468	2 (1.0)	9 (2.2)	.282
Progressive glenoid arthrosis	1 (3.1)	0 (0)	0 (0)	.066	1 (0.5)	2 (0.0)	.157
Rotator cuff failure	0 (0)	1 (1.8)	0 (0)	.263	1 (0.5)	2 (0.5)	.999
Total surgical complications	10 (31.3)	9 (16.1)	19 (16.2)	.131	38 (18.5)	44 (10.7)	**.007**

HA, hemiarthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *RSA*, reverse total shoulder arthroplasty.
Data are presented as number (percentage).
Bold values represent statistical significance ($P < .05$)
* *P* values between implant types of stroke patients.
† *P* values between the stroke and matched cohorts.

when categorized by implants within the stroke cohort, HA had the highest rate of instability (15.6%) followed by aTSA (10.7%) and RSA (1.7%) ($P = .005$).

In review of the literature, the described incidence of postoperative instability and dislocation after SA varies widely from 1.4% to 38%.[3,9,10,38] However, rates of postoperative instability after RSA in our stroke cohort are similar to the lower end of recently described values in the literature between 0.5% and 5.0%.[3,8,30] In aTSA, previous studies have estimated rates of instability to range from 5% historically to 1% in more contemporary investigations.[8] Regardless, the instability rate among the stroke cohort for aTSA in our study was substantially higher at 10.7% compared with our controls and the recent literature. Described etiologies for instability in aTSA are typically a combination of factors including glenoid bone deficiency, posterior capsular redundancy, axillary nerve injury, component malposition, rotator cuff deficiency, and specifically failure of the subscapularis repair.[8,46]

Although all of these must be considered when performing an aTSA, clinicians should also pay close attention to the preoperative status of the shoulder in stroke patients because of this elevated risk and in order to assess for poststroke shoulder subluxation.[22,34] Shoulder subluxation in stroke patients has been described as one of the most common secondary musculoskeletal problems and is thought to occur from neurologic dysfunction of shoulder girdle musculature leading to inferior glenohumeral joint displacement.[1,22,34] Over time, this can lead to capsular redundancy and pain. In stroke patients presenting to surgeons with concerns of glenohumeral pathology, consideration of specialized therapy and specific shoulder orthoses to reduce subluxation can be considered in addition to standard nonoperative modalities.[1,22,34,39] With respect to implant selection, perhaps these neurologic changes in the shoulder girdle, in the form of increased muscle tone and altered strength, are better tolerated in the setting of an RSA as demonstrated by lower instability when compared to an aTSA or HA.

Although there were higher complications, patients with a previous stroke and neurologic sequelae experienced reoperations (6.3% vs 4.6%; $P = .369$) and revision surgery (5.4% vs 3.4%; $P = .248$) at rates overall similar to those of the matched cohort. This was sustained even when death between the cohorts was accounted for as a competing risk in the cumulative incidence analysis ($P = .499$). When evaluating specific indications, instability was the most frequent complication and indication for reoperation in the stroke cohort. Although 6.3% of stroke patients presented with instability after SA, only 2.0% underwent a reoperation. Furthermore, when instability was compared to the matched group as an indication for reoperation, it appeared to occur at a similar rate (2.0% vs 1.5%; $P = .738$). This may suggest a possible benefit of nonoperative management of instability in these stroke patients; however, this treatment path could have been necessitated for a variety of reasons. When compared by implant type, HA had the highest rate of instability (15.6%) followed by aTSA

Table IV Postoperative medical complications of the stroke cohort by anticoagulation status at the time of surgery and comparison between the stroke vs. matched cohort

Variable	AC at surgery (n = 163)	No AC at surgery (n = 42)	*P* value	Stroke cohort (n = 205)	Matched cohort (n = 410)	*P* value
Nonmortality complications	39 (23.9)	3 (7.1)	.017	42 (20.5)	30 (7.3)	**<.001**
Anemia requiring transfusion	14 (8.6)	1 (2.4)	.315	15 (7.3)	19 (4.6)	.170
Venous thromboembolism	6 (3.7)	1 (2.4)	>.999	7 (3.4)	2 (0.5)	**.004**
Pulmonary embolus	4 (2.5)	0 (0.0)	.584	4 (2.0)	0 (0.0)	**.005**
Deep venous thrombosis	2 (1.2)	1 (2.4)	.499	3 (1.5)	2 (0.5)	.204
Myocardial infarction	4 (2.5)	0 (0.0)	.584	4 (2.0)	2 (0.5)	.082
Healthcare-associated pneumonia	3 (1.8)	1 (2.4)	>.999	4 (2.0)	3 (0.7)	.179
Acute heart failure	1 (0.6)	0 (0.0)	>.999	1 (0.5)	0 (0.0)	.157
Sepsis	1 (0.6)	0 (0.0)	>.999	1 (0.5)	0 (0.0)	.157
Seizures	1 (0.6)	0 (0.0)	>.999	1 (0.5)	0 (0.0)	.157
Cerebrovascular accident / stroke	5 (3.1)	0 (0.0)	.586	5 (2.4)	0 (0.0)	**.004**
Respiratory failure / ARDS	2 (1.2)	0 (0.0)	>.999	2 (1.0)	0 (0.0)	**.045**
Arrhythmia	2 (1.2)	0 (0.0)	>.999	2 (1.0)	4 (1.0)	.999
90-d mortality				1 (0.5)	2 (0.5)	.999
Total medical complications (90-d mortality included)	40 (24.5)	3 (7.1)	.011	43 (21.0)	32 (7.8)	**<.001**
90-d readmissions	27 (16.6)	7 (16.7)	>.999	34 (16.6)	20 (4.9)	**<.001**

ARDS, acute respiratory distress syndrome; *AC*, anticoagulation.
Data are presented as number (percentage).
Bold values represent statistical significance ($P < .05$).

(10.7%) and RSA (1.7%) ($P = .005$). When comparing the stroke and matched cohort, a higher rate of instability (6.3 % vs 1.7%; $P = .002$). However, when analyzed by implant type, the RSA stroke cohort did have a higher rate of both reoperation (8.5% vs 2.6%; $P = .011$) and revision surgery (6.8% vs 1.7%; $P = .013$) compared with controls. In comparison to the literature, these rates are still within the expected range for primary RSA with given estimates of 2.4%-8.5%.[3,16,23,36] Medical complications in the general SA population have been observed at rates ranging from 2.8% to 6.7%.[6,14] In elderly patients >80 years old, the rate of medical complications after revision SA rises to 8%.[4] In the present study, patients with a history of a stroke with neurologic sequelae had a significantly higher medical complication rate when compared to the matched cohort (20.5% vs 7.8%; $P < .001$) and the general population described in the literature.[6,14] Likewise, a higher 90-day readmission rate in the stroke cohort was observed when compared to the matched cohort (16.6% vs 4.9%; $P < .001$). When further compared to the literature, a 90-day readmission rate has been estimated to occur between 4.5%-8.8% and 6%-11.2%.[25,41] This is especially high in the context of a previous publication from our institution that found a 1.8% readmission rate for primary SAs.[19] Additionally, the authors observed that 68% of their 90-day readmissions were attributed to medical conditions.[19] Similarly, the present study observed that 83.3% of the 90-day readmissions were related to medical conditions, with 91.2% of those attributed to the stroke cohort. Thus, care teams should continue to provide adequate postoperative care instructions and be aware of the higher propensity of medical readmissions in stroke patients.

With respect to specific perioperative medical diagnoses, a 0.2% rate of perioperative strokes have been reported in an observational study of 18,745 patients undergoing primary or revision total hip or knee arthroplasty at a mean follow-up of 62 months.[32] Although the present study had a 0% rate of perioperative strokes in our matched cohort of primary shoulders, the stroke cohort had a significantly higher rate at 2.4% ($P = .004$). All of these cases had anticoagulation held and were restarted in preparation of the SA after a dedicated preoperative evaluation. Regardless, 3 of the 5 cases occurred within the 90-day postoperative period. Venous thromboembolic events, including pulmonary embolus, also occurred at a significantly higher rate in the stroke cohort compared with matched controls (3.4% vs 0.5%; $P = .004$). When compared by anticoagulation status at surgery, we also observed a higher rate of medical complications in patients with perioperative anticoagulation compared with those without anticoagulation (23.9% vs 7.1%; $P = .017$). In a review of the literature, Bohsali et al[8] observed a 0.3% venous thromboembolism rate in 19,262 SAs and Kolz et al[21] reported a 0.41% rate in 5906 shoulders. Hence in stroke patients,

Table V Postoperative surgical reoperations inclusive of revisions by implant type and across cohorts

Variable	HA (n = 32)	aTSA (n = 56)	RSA (n = 117)	*P* value*	Stroke cohort (n = 205)	Matched cohort (n = 410)	*P* value†
Instability	0 (0.0)	2 (3.6)	2 (1.7)	.626	4 (2.0)	6 (1.5)	.738
Periprosthetic fracture	0 (0.0)	0 (0.0)	1 (0.9)	>.999	1 (0.5)	2 (0.5)	>.999
Aseptic component loosening	0 (0.0)	0 (0.0)	3 (2.6)	.731	3 (1.5)	2 (0.5)	.340
Deep infection	1 (3.1)	0 (0.0)	2 (1.7)	.548	3 (1.5)	3 (0.7)	.406
Acromial or scapular spine fracture‡	N/A	N/A	1 (0.9)	N/A	1 (0.9)	0 (0.0)	.333
Superficial wound complication	0 (0.0)	0 (0.0)	1 (0.9)	>.999	1 (0.5)	1 (0.2)	>.999
Progressive glenoid arthrosis§	0 (0.0)	N/A	N/A	N/A	0 (0.0)	2 (3.1)	.551
Rotator cuff failure‖	0 (0.0)	0 (0.0)	N/A		0 (0.0)	3 (1.7)	.553
All-cause reoperations	1 (3.1)	2 (3.6)	10 (8.5)	.433	13 (6.3)	19 (4.6)	.369
All-cause revisions	1 (3.1)	2 (3.6)	8 (6.8)	.685	11 (5.4)	14 (3.4)	.248

HA, hemiarthroplasty; *N/A*, not applicable; *aTSA*, anatomic total shoulder arthroplasty; *RSA*, reverse total shoulder arthroplasty.
Data are presented as number (percentage).
* *P* values between implant types of stroke patients.
† *P* values between the stroke and matched cohorts.
‡ Proportions calculated based on RTSA alone.
§ Proportions calculated based on HA alone.
‖ Proportions calculated based on HA and aTSAs.

Table VI Postoperative surgical complications and reoperations inclusive of revisions by stroke sequelae laterality

Variable	Bilateral (n = 12)	Contralateral (n = 70)	Ipsilateral (n = 85)	Unspecified (n = 38)	*P* value
Surgical complications	2 (16.7)	13 (18.6)	19 (22.4)	6 (15.8)	.876
Instability	1 (8.3)	0 (0.0)	3 (3.5)	0 (0.0)	.111
Periprosthetic fracture	0 (0.0)	1 (1.4)	0 (0.0)	0 (0.0)	.585
Aseptic component loosening	0 (0.0)	0 (0.0)	3 (3.5)	0 (0.0)	.423
Deep infection	0 (0.0)	0 (0.0)	1 (1.2)	2 (5.3)	.237
Acromial or scapular spine fracture*	0 (0.0)	1 (2.7)	0 (0.0)	0 (0.0)	.590
Superficial wound complication	0 (0.0)	0 (0.0)	1 (1.2)	0 (0.0)	>.999
Progressive glenoid arthrosis†	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	N/A
Rotator cuff failure‡	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	N/A
All-cause reoperations	1 (8.3)	2 (2.9)	8 (9.4)	2 (5.3)	.328
All-cause revisions	1 (8.3)	2 (2.9)	7 (8.2)	1 (2.6)	.388

N/A, not applicable.
Data are presented as number (percentage).
* Proportions calculated based on reverse total shoulder arthroplasty alone.
† Proportions calculated based on hemiarthroplasty alone.
‡ Proportions calculated based on hemiarthroplasty and anatomic total shoulders.

special attention should be placed on the anticoagulation status of patients to mitigate the risks of venous thromboembolic events and postoperative strokes. Furthermore, stroke patients with perioperative anticoagulation may be at a higher risk for medical complications and therefore would benefit from careful perioperative medical monitoring.

Mortality following SA has become an increasingly researched topic, with most data focusing on the short term.[5,12,17] One year postoperatively, mortality rates after SA in the general population have been reported between 1.0% and 3.8%.[5,12,17] However, in certain populations such as trauma, malignancy, PJI, or conditions like pulmonary hypertension, elevated rates have been observed.[7,28,35] Similarly, the present study observed an elevated rate of mortality at all time points when compared to controls. At the 1-year mark, the stroke cohort experienced a mortality rate of 4.4%, which was within the reported range of mortality in stroke patients.[7,28,35,42] These results seem to indicate that strokes with neurologic sequelae are a potential risk factor for mortality within the first year after

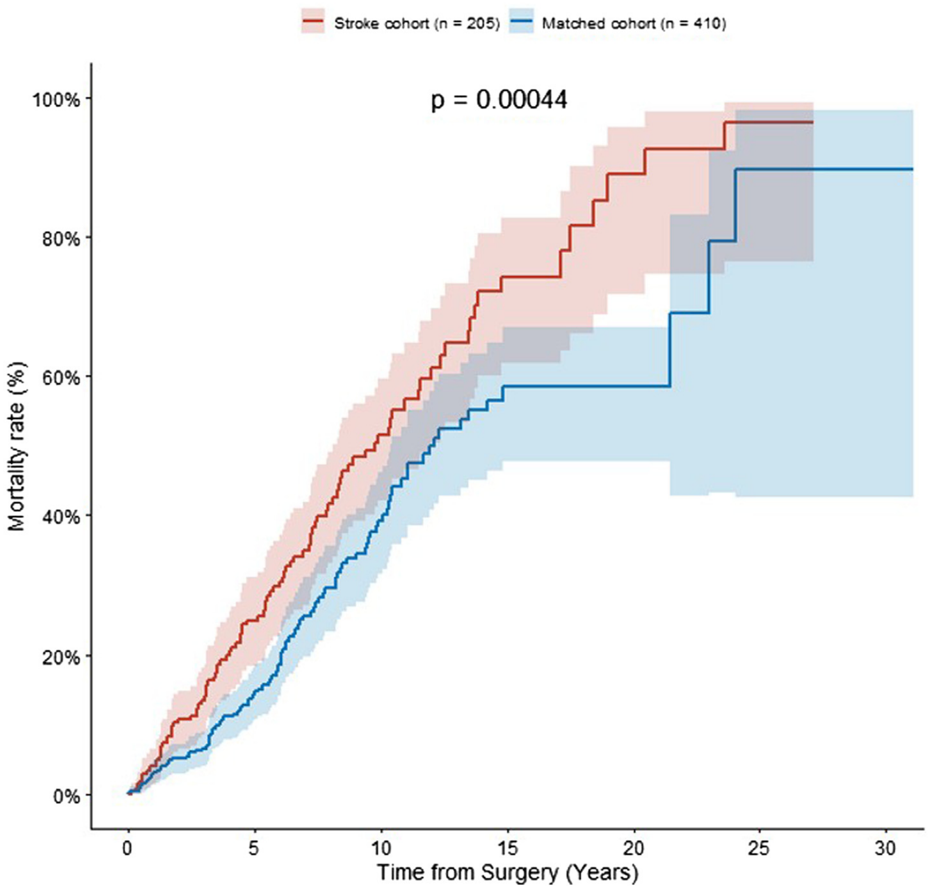

Figure 1 Kaplan-Meier curve demonstrating the cumulative mortality of the Stroke and Matched cohorts.

primary SA when compared to controls, thus highlighting the importance of thorough medical perioperative management in these patients.

The findings of this study should be interpreted with consideration of the following limitations. First, this is a retrospective review of an institutional database that prospectively collects data over an extended time frame, which limits inclusion into our study and allows for selection bias. This may potentially lead to an underestimation of the severity of disease because of reporting only on the patients who were deemed medically fit for surgery despite being candidates. Additionally, because of limitation in documentation, there may have been patients who sustained a stroke with subsequent neurologic sequelae that may have been excluded. Finally, approximately 2.8% of the SAs performed at our institution were performed in patients with a prior stroke, resulting in a relatively smaller sample size. Therefore, a power analysis was not performed, but a matched cohort was created to provide better group comparisons. Regardless, because of the smaller cohort sizes of subanalyses, the analysis may be underpowered and the observed differences between groups may not be valid. Moreover, matching was not performed on the basis of associated medical comorbidities (ie, history of myocardial infarction, heart failure, chronic kidney disease); therefore, there remains potentially confounding variables in the medical analysis of our stroke patients and matched group.

Conclusion

A preoperative diagnosis of a stroke with subsequent neurologic sequelae undergoing primary SA is associated with elevated rates of perioperative complications and mortality when compared to a matched cohort of arthroplasty patients with no prior stroke. This information should be considered to counsel patients and surgeons to optimize care and help mitigate risks associated with a perioperative period.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or

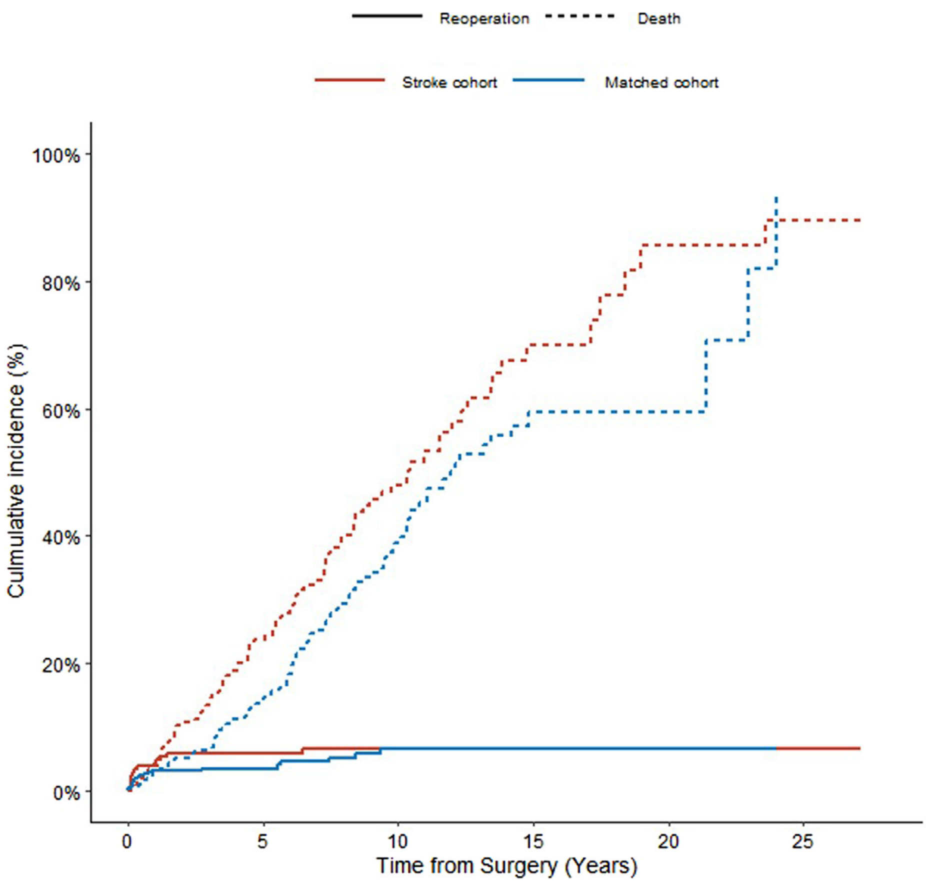

Figure 2 Cumulative incidence of any reoperation or revision with all-cause mortality as the competing risk.

other benefits from any commercial entity related to the subject of this article.

References

1. Ada L, Foongchomcheay A, Canning C. Supportive devices for preventing and treating subluxation of the shoulder after stroke. Cochrane Database Syst Rev 2005;2005:CD003863. https://doi.org/10.1002/14651858.CD003863.pub2
2. Adey-Wakeling Z, Arima H, Crotty M, Leyden J, Kleinig T, Anderson CS, et al. Incidence and associations of hemiplegic shoulder pain poststroke: prospective population-based study. Arch Phys Med Rehabil 2015;96:241-7.e241. https://doi.org/10.1016/j.apmr.2014.09.007
3. Aibinder W, Schoch B, Parsons M, Watling J, Ko JK, Gobbato B, et al. Risk factors for complications and revision surgery after anatomic and reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2021;30:e689-701. https://doi.org/10.1016/j.jse.2021.04.029
4. Alentorn-Geli E, Clark NJ, Assenmacher AT, Samuelsen BT, Sánchez-Sotelo J, Cofield RH, et al. What Are the Complications, Survival, and Outcomes After Revision to Reverse Shoulder Arthroplasty in Patients Older Than 80 Years? Clin Orthop Relat Res 2017;475:2744-51. https://doi.org/10.1007/s11999-017-5406-6
5. Amundsen A, Rasmussen JV, Olsen BS, Brorson S. Mortality after shoulder arthroplasty: 30-day, 90-day, and 1-year mortality after shoulder replacement–5853 primary operations reported to the Danish Shoulder Arthroplasty Registry. J Shoulder Elbow Surg 2016;25:756-62. https://doi.org/10.1016/j.jse.2015.09.020
6. Anakwenze OA, O'Donnell EA, Jobin CM, Levine WN, Ahmad CS. Medical Complications and Outcomes After Total Shoulder Arthroplasty: A Nationwide Analysis. Am J Orthop (Belle Mead NJ) 2018;47. https://doi.org/10.12788/ajo.2018.0086
7. Austin DC, Townsley SH, Rogers TH, Barlow JD, Morrey ME, Sperling JW, et al. Shoulder periprosthetic joint infection and all-cause mortality: a worrisome association. JB JS Open Access 2022;7:e21.00118. https://doi.org/10.2106/jbjs.Oa.21.00118
8. Bohsali KI, Bois AJ, Wirth MA. Complications of Shoulder Arthroplasty. J Bone Joint Surg Am 2017;99:256-69. https://doi.org/10.2106/jbjs.16.00935
9. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res 2016;102:S33-43. https://doi.org/10.1016/j.otsr.2015.06.031
10. Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 2007;89:516-20. https://doi.org/10.1302/0301-620x.89b4.18435
11. Christiansen MN, Andersson C, Gislason GH, Torp-Pedersen C, Sanders RD, Føge Jensen P, et al. Risks of Cardiovascular Adverse Events and Death in Patients with Previous Stroke Undergoing Emergency Noncardiac, Nonintracranial Surgery: The Importance of Operative Timing. Anesthesiology 2017;127:9-19. https://doi.org/10.1097/aln.0000000000001685

12. Dacombe P, Harries L, McCann P, Crowther M, Packham I, Sarangi P, et al. Predictors of mortality following shoulder arthroplasty. J Orthop 2020;22:179-83. https://doi.org/10.1016/j.jor.2020.04.005
13. Farley KX, Wilson JM, Kumar A, Gottschalk MB, Daly C, Sanchez-Sotelo J, et al. Prevalence of shoulder arthroplasty in the united states and the increasing burden of revision shoulder arthroplasty. JB JS Open Access 2021;6:e20.00156. https://doi.org/10.2106/jbjs.Oa.20.00156
14. Fehringer EV, Mikuls TR, Michaud KD, Henderson WG, O'Dell JR. Shoulder arthroplasties have fewer complications than hip or knee arthroplasties in US veterans. Clin Orthop Relat Res 2010;468:717-22. https://doi.org/10.1007/s11999-009-0996-2
15. Fitterer JW, Picelli A, Winston P. A Novel Approach to New-Onset Hemiplegic Shoulder Pain With Decreased Range of Motion Using Targeted Diagnostic Nerve Blocks: The ViVe Algorithm. Front Neurol 2021;12:668370. https://doi.org/10.3389/fneur.2021.668370
16. Gill DRJ, Page BRS, Graves SE, Rainbird S, Hatton A. A comparison of revision rates for osteoarthritis of primary reverse total shoulder arthroplasty to primary anatomic shoulder arthroplasty with a cemented all-polyethylene glenoid: analysis from the Australian Orthopaedic Association National Joint Replacement Registry. Clin Orthop Relat Res 2021;479:2216-24. https://doi.org/10.1097/corr.0000000000001869
17. Inacio MC, Dillon MT, Miric A, Anthony F, Navarro RA, Paxton EW. Mortality after shoulder arthroplasty. J Arthroplasty 2014;29:1823-6. https://doi.org/10.1016/j.arth.2014.04.006
18. Jørgensen ME, Torp-Pedersen C, Gislason GH, Jensen PF, Berger SM, Christiansen CB, et al. Time elapsed after ischemic stroke and risk of adverse cardiovascular events and mortality following elective noncardiac surgery. JAMA 2014;312:269-77. https://doi.org/10.1001/jama.2014.8165
19. Kennon JC, Songy CE, Marigi E, Visscher SL, Larson DR, Borah BJ, et al. Cost analysis and complication profile of primary shoulder arthroplasty at a high-volume institution. J Shoulder Elbow Surg 2020;29:1337-45. https://doi.org/10.1016/j.jse.2019.12.008
20. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Joint Surg Am 2011;93:2249-54. https://doi.org/10.2106/jbjs.J.01994
21. Kolz JM, Aibinder WR, Adams RA, Cofield RH, Sperling JW. Symptomatic thromboembolic complications after shoulder arthroplasty: an update. J Bone Joint Surg Am 2019;101:1845-51. https://doi.org/10.2106/jbjs.18.01200
22. Koyuncu E, Nakipoğlu-Yüzer GF, Doğan A, Ozgirgin N. The effectiveness of functional electrical stimulation for the treatment of shoulder subluxation and shoulder pain in hemiplegic patients: a randomized controlled trial. Disabil Rehabil 2010;32:560-6. https://doi.org/10.3109/09638280903183811
23. Lehtimäki K, Rasmussen JV, Mokka J, Salomonsson B, Hole R, Jensen SL, et al. Risk and risk factors for revision after primary reverse shoulder arthroplasty for cuff tear arthropathy and osteoarthritis: a Nordic Arthroplasty Register Association study. J Shoulder Elbow Surg 2018;27:1596-601. https://doi.org/10.1016/j.jse.2018.02.060
24. Lindgren I, Gard G, Brogårdh C. Shoulder pain after stroke - experiences, consequences in daily life and effects of interventions: a qualitative study. Disabil Rehabil 2018;40:1176-82. https://doi.org/10.1080/09638288.2017.1290699
25. Mahoney A, Bosco JA 3rd, Zuckerman JD. Readmission after shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:377-81. https://doi.org/10.1016/j.jse.2013.08.007
26. Marigi E, Marigi I, Crowe MM, Ortiguera CJ, Ledford CK, Werthel JD, et al. Primary reverse shoulder arthroplasty in patients with metabolic syndrome is associated with increased rates of deep infection. J Shoulder Elbow Surg 2021;30:2032-40. https://doi.org/10.1016/j.jse.2020.12.025
27. Marigi EM, Lee D, Marigi I, Werthel JD, Barlow JD, Sperling JW, et al. Shoulder arthroplasty in patients with juvenile idiopathic arthritis: long-term outcomes. J Shoulder Elbow Surg 2021;30:2703-10. https://doi.org/10.1016/j.jse.2021.06.014
28. Marigi EM, Marigi I, Sperling JW, Sanchez-Sotelo J. Primary and revision shoulder arthroplasty in patients with pulmonary hypertension: an underlying condition associated with high perioperative mortality and complications. Semin Arthroplasty 2021;31:772-82. https://doi.org/10.1053/j.sart.2021.05.005
29. Marigi EM, Shah H, Sperling JW Jr, Hassett LC, Schoch BS, Sanchez-Sotelo J, et al. Parkinson's disease and shoulder arthroplasty: a systematic review. JSES Int 2022;6:241-6. https://doi.org/10.1016/j.jseint.2021.11.004
30. Marigi EM, Tams C, King JJ, Crowe MM, Werthel JD, Eichinger JK, et al. Shoulder arthroplasty after prior anterior shoulder instability surgery: a matched cohort analysis. Eur J Orthop Surg Traumatol 2022;1:1-9. https://doi.org/10.1007/s00590-022-03233-y
31. Menendez ME, Greber EM, Schumacher CS, Lowry Barnes C. Predictors of Acute Ischemic Stroke After Total Knee Arthroplasty. J Surg Orthop Adv 2017;26:148-53.
32. Mortazavi SM, Kakli H, Bican O, Moussouttas M, Parvizi J, Rothman RH. Perioperative stroke after total joint arthroplasty: prevalence, predictors, and outcome. J Bone Joint Surg Am 2010;92:2095-101. https://doi.org/10.2106/jbjs.I.00940
33. Murena L, Hoxhaj B, Fattori R, Canton G. Epidemiology and Demographics of Reverse Shoulder Arthroplasty. In: Reverse Shoulder Arthroplasty. Cham, Switzerland: Springer International Publishing; 2019. p. 59-67. https://doi.org/10.1007/978-3-319-97743-0_4
34. Nadler M, Pauls M. Shoulder orthoses for the prevention and reduction of hemiplegic shoulder pain and subluxation: systematic review. Clin Rehabil 2017;31:444-53. https://doi.org/10.1177/0269215516648753
35. Nielsen KP, Amundsen A, Olsen BS, Rasmussen JV. Good long-term patient-reported outcome after shoulder arthroplasty for cuff tear arthropathy. JSES Int 2022;6:40-3. https://doi.org/10.1016/j.jseint.2021.08.002
36. Nwakama AC, Cofield RH, Kavanagh BF, Loehr J. Semiconstrained total shoulder arthroplasty for glenohumeral arthritis and massive rotator cuff tearing. J Shoulder Elbow Surg 2000;9:302-7.
37. Owolabi MO, Akarolo-Anthony S, Akinyemi R, Arnett D, Gebregziabher M, Jenkins C, et al. The burden of stroke in Africa: a glance at the present and a glimpse into the future. Cardiovasc J Afr 2015;26:S27-38. https://doi.org/10.5830/cvja-2015-038
38. Parada SA, Flurin PH, Wright TW, Zuckerman JD, Elwell JA, Roche CP, et al. Comparison of complication types and rates associated with anatomic and reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2021;30:811-8. https://doi.org/10.1016/j.jse.2020.07.028
39. Qian Q, Hu X, Lai Q, Ng SC, Zheng Y, Poon W. Early stroke rehabilitation of the upper limb assisted with an electromyography-driven neuromuscular electrical stimulation-robotic arm. Front Neurol 2017;8:447. https://doi.org/10.3389/fneur.2017.00447
40. Rasouli MR, Tabatabaee RM, Maltenfort MG, Chen AF. Acute stroke after total joint arthroplasty: a population-based trend analysis. J Clin Anesth 2016;34:15-20. https://doi.org/10.1016/j.jclinane.2016.03.034
41. Schairer WW, Zhang AL, Feeley BT. Hospital readmissions after primary shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:1349-55. https://doi.org/10.1016/j.jse.2013.12.004
42. Sennfält S, Norrving B, Petersson J, Ullberg T. Long-term survival and function after stroke. Stroke 2019;50:53-61. https://doi.org/10.1161/STROKEAHA.118.022913
43. Skolarus LE, Burke JF. Towards an understanding of racial differences in post-stroke disability. Curr Epidemiol Rep 2015;2:191-6. https://doi.org/10.1007/s40471-015-0047-3
44. Smith AM, Barnes SA, Sperling JW, Farrell CM, Cummings JD, Cofield RH. Patient and physician-assessed shoulder function after arthroplasty. J Bone Joint Surg Am 2006;88:508-13. https://doi.org/10.2106/jbjs.E.00132

45. Souza IG, Souza RF, Barbosa FDS, Scipioni K, Aidar FJ, Zanona AF. Protocols used by occupational therapists on shoulder pain after stroke: systematic review and meta-analysis. Occup Ther Int 2021; 2021:8811721. https://doi.org/10.1155/2021/8811721
46. Sperling JW, Hawkins RJ, Walch G, Zuckerman JD. Complications in total shoulder arthroplasty. J Bone Joint Surg Am 2013;95:563-9. https://doi.org/10.2106/00004623-201303200-00012
47. Sprigg N, Selby J, Fox L, Berge E, Whynes D, Bath PM. Very low quality of life after acute stroke: data from the efficacy of nitric oxide in stroke trial. Stroke 2013;44:3458-62. https://doi.org/10.1161/strokeaha.113.002201
48. Trofa D, Rajaee SS, Smith EL. Nationwide trends in total shoulder arthroplasty and hemiarthroplasty for osteoarthritis. Am J Orthop (Belle Mead NJ) 2014;43:166-72.
49. Westermann RW, Pugely AJ, Martin CT, Gao Y, Wolf BR, Hettrich CM. Reverse shoulder arthroplasty in the united states: a comparison of national volume, patient demographics, complications, and surgical indications. Iowa Orthop J 2015;35:1-7.
50. Wilson RD, Chae J. Hemiplegic shoulder pain. Phys Med Rehabil Clin N Am 2015;26:641-55. https://doi.org/10.1016/j.pmr.2015.06.007
51. World Health Organization. Global Health Estimates: Life expectancy and leading causes of death and disability. Available at: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates. Accessed March 28, 2022
52. Zmistowski B, Karam JA, Durinka JB, Casper DS, Parvizi J. Periprosthetic joint infection increases the risk of one-year mortality. J Bone Joint Surg Am 2013;95:2177-84. https://doi.org/10.2106/jbjs.L.00789