Indications and Reoperation Rates for Total Elbow Arthroplasty: An Analysis of Trends in New York State

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Background: Total elbow arthroplasty was originally used to treat patients with arthritis. As familiarity with total elbow arthroplasty evolved, the indications were expanded to include other disorders. There continues to be a low number of total elbow arthroplasties performed each year in comparison with hip, knee, and shoulder arthroplasties, and few large studies have examined the indications and associated complications of total elbow arthroplasty. The purposes of this study were to evaluate the changes with time in the indications for total elbow arthroplasty and to examine the complications of this procedure in a large database.

Methods: The Statewide Planning and Research Cooperative System database from the New York State Department of Health, a census of all ambulatory and inpatient surgical procedures in the state of New York, was used to identify individuals who underwent primary total elbow arthroplasty during the time period of 1997 to 2006. These total elbow arthroplasties were evaluated for admitting diagnoses, sex and age of patient, readmission and complication data, and time to subsequent elbow surgery.

Results: From 1997 to 2006, there were 1155 total elbow arthroplasties performed in New York State. In 1997, 43% of the total elbow arthroplasties were associated with trauma and 48%, with inflammatory conditions. In 2006, this changed to 69% and 19%, respectively. Within ninety days after the primary total elbow arthroplasty, 12% of the patients were readmitted to the hospital with approximately one-half (5.6%) admitted for problems related to the total elbow arthroplasty. The overall revision rate was 6.4%. The revision rates for the traumatic, inflammatory arthritis, and osteoarthritis groups were 4.8%, 8.3%, and 14.7%, respectively. Of particular interest, 90.5% of the total elbow arthroplasties were performed by surgeons with no recorded experience in the database, which began collecting these data in 1986.

Conclusions: This study provides useful information regarding patients undergoing total elbow arthroplasty in New York State. During the study period, the most common indication for total elbow arthroplasty changed from inflammatory arthritis to trauma. Although the number of total elbow arthroplasties being performed each year has increased, there continues to be a high complication and revision rate.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Relatively few total elbow arthroplasties are performed in the United States each year. Because there is no nationwide database, most studies have been performed at single institutions with small numbers of patients. While informative, these smaller studies are unable to identify trends in outcomes across many surgeons and institutions.

A commentary by Srinath Kamineni, MD, FRCS(Orth), is linked to the online version of this article at jbjs.org.

There are few large studies describing the long-term survival of total elbow replacements and the associated complications. One recent study with use of the Norwegian Arthroplasty Register showed a decreasing number of total elbow arthroplasties being performed over time because of the declining needs of patients with inflammatory arthritis[1], with implant survival rates of 92% at five years and 85% at ten years from the date of implantation.

In the United States, Cook et al.[2] recently examined the perioperative complications associated with total elbow arthroplasty in patients with and without inflammatory arthritis. There have been few multicenter studies examining indications and outcomes for elbow arthroplasty[1-3].

In New York State, the Statewide Planning and Research Cooperative System (SPARCS) database consists of all ambulatory and inpatient surgical procedures performed in the State of New York. Because these data include unique patient identifiers, we tracked the patients' subsequent readmissions and operations performed in New York, allowing for evaluation of long-term complications and revision rates. We used this database to analyze the indications, incidence, causes for readmission, and revision rates for primary total elbow arthroplasties performed over the ten-year period of 1997 to 2006.

The aim of this study was to identify any changes in the indications for total elbow arthroplasty and complications associated with the procedure. These data may be helpful in directing implant design to improve the implant survival of total elbow arthroplasties and reducing the associated perioperative complications.

Materials and Methods

The SPARCS database[4] from the New York State Department of Health, a census of all hospital admissions and ambulatory surgery procedures within the state of New York, was used to identify primary total elbow arthroplasties performed in the state of New York on New York State residents over fifteen years of age. Since 1982, SPARCS has provided hospital discharge data for New York State. However, unique patient identifiers were introduced in 1997, allowing individual patients to be followed through multiple procedures and admissions. SPARCS also identifies the attending surgeon for each procedure, but does not record surgical procedures performed by each surgeon outside New York or while the surgeon was a resident or fellow.

The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes are used in the SPARCS database. Current Procedural Terminology (CPT) codes are not used for patients undergoing inpatient procedures. All patients undergoing a primary total elbow arthroplasty were identified as the first admission of an individual patient with a procedure code of ICD-9-CM 81.84 (total elbow replacement). Unique patient identifiers were then used to track all patients undergoing primary total elbow arthroplasty for (1) blood transfusions during the index admission, (2) complications within ninety days of surgery, (3) readmission for any cause within ninety days, (4) any revision total elbow arthroplasty, and (5) a second primary total elbow arthroplasty.

For analysis of revision total elbow arthroplasty and a second primary total elbow arthroplasty, the cohort was further limited by identifying patients without a previous admission for 81.80 (total shoulder replacement) or 81.81 (partial shoulder replacement) and without a concomitant ancillary diagnostic code of V43.61 (living with artificial shoulder), V43.62 (living with artificial elbow), or V43.63 (living with artificial wrist). Patients who had a previous upper-extremity arthroplasty were excluded in this way in order to confirm that a subsequent code of 81.97 (revision of joint replacement of the upper extremity) represented a revision of the index primary total elbow arthroplasty

rather than the revision of another previously implanted upper-extremity replacement and that a subsequent code of 81.84 represented a primary total elbow arthroplasty on the contralateral side. We conducted an internal audit of the code usage at our own institution, and revision total elbow arthroplasty was always coded as 81.97, while a second primary total elbow arthroplasty was always coded as 81.84. Because of the design of the statewide database, additional audits could not be performed at other institutions. Our institution performed 15.9% of the total elbow arthroplasties in the SPARCS database.

The surgical diagnosis for each patient was determined through the diagnosis codes used for the index admission. Patients with a diagnostic code reflecting rheumatoid, or inflammatory, arthritis (RA), trauma, or osteoarthritis (OA) were grouped into one of these three categories. Patients with diagnostic codes for more than one of the three categories were classified in this order: RA > trauma > OA. Therefore, a patient with an RA and trauma code would be considered an RA patient, while a patient with a trauma and OA code would be considered a trauma patient. This strategy was chosen because patients with rheumatoid arthritis, even if the total elbow arthroplasty was performed for trauma, are commonly more complicated than patients whose total elbow arthroplasty was performed for trauma alone. Conversely, in our experience, OA is used as a default diagnostic code for many orthopaedic procedures, and RA or trauma were considered more specific diagnoses for these patients. Patients without diagnostic codes for any of these three categories were classified as "oncology/other diagnosis." The surgical diagnoses for these patients outside the three primary categories varied widely, but included neoplasms, congenital malformations, and other rare conditions that require a total elbow arthroplasty.

Complications were identified through analysis of the index admission and all subsequent inpatient admissions within ninety days. Complications included mechanical complications of the implant, other complications related to the implant, infection of any origin, acute myocardial infarction, pulmonary embolism, and inhospital mortality (see Appendix). We were unable to identify patients who died out of hospital within ninety days of total elbow arthroplasty. Readmission for any reason within ninety days was also considered an adverse outcome.

Information was not available about the mechanism of injury for trauma cases, the duration of symptoms, or the severity of degeneration in the patients with rheumatoid arthritis or osteoarthritis because of the administrative nature of the database. The trauma subgroup was not confined to patients who only had isolated elbow trauma. However, data were available on patient age, sex, year of surgery, and comorbid conditions.

The Deyo modification of the Charlson Comorbidity Index was used to identify comorbidities[5,6]. This index controls for confounding by comorbidity status when administrative databases are used. It is a measure of seventeen specific comorbidities used to study patient outcomes.

Hospital identification numbers and physician license numbers are available in the SPARCS database for each inpatient admission. Cumulative surgeon volume was calculated on the basis of the number of cases the surgeon performed between 1986 (the first year for which we have complete data) and the case of interest.

Statistical Methods

Descriptive statistics consisted of means and standard deviations for continuous variables and frequency counts and percentages for discrete variables. Rates of readmission within ninety days and subsequent surgery within one year were calculated per 100 index cases. A Kaplan-Meier survival curve was generated to demonstrate implant survival by indication for surgery.

Multivariable modeling was performed with use of generalized estimate equations, accounting for clustering by hospital with regard to case mix. The generalized estimate equation models calculated odds ratios, 95% confidence intervals (95% CI), and p values. The outcomes for these models were readmission within ninety days, revision total elbow arthroplasty, and a second primary total elbow arthroplasty.

Source of Funding

TABLE I Comparison of Patients Who Had Total Elbow Arthroplasty by Diagnostic Group

	Overall	Trauma	Rheumatoid Arthritis	Osteoarthritis	Oncology or Other
All primary total elbow arthroplasties					
Total*	1155	719 (62.3)	283 (24.5)	76 (6.6)	77 (6.7)
Age† (yr)	58.3 ± 17.2	58.5 ± 18.2	57.4 ± 14.5	63.4 ± 12.4‡	54.0 ± 19.0
Female*	822 (71.1)§	485 (67.5)	240 (84.8)§	54 (71.1)	43 (55.8)
Male*	333 (28.8)	234 (32.5)	43 (15.2)	22 (28.9)	34 (44.2)
Deyo Comorbidity Index*					
0	815 (70.6)	502 (69.8)	207 (73.1)	53 (69.7)	53 (68.8)
1	245 (21.2)	147 (20.5)	66 (23.3)	21 (27.6)	11 (14.3)
≥2	95 (8.2)	70 (9.7)	10 (3.5)	2 (2.6)	13 (16.9)#
Physician career volume of total elbow arthroplasties**					
0	1045 (90.5)	665 (92.5)	241 (85.2)	70 (92.1)	69 (89.6)
1 to 19	55 (4.8)	38 (5.3)	11 (3.9)	3 (4)	3 (3.9)
≥20	55 (4.8)	16 (2.2)	31 (11)#	3 (4)	5 (6.5)

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation. ‡Significantly different (p < 0.05) from rheumatoid arthritis and oncology subgroups. §Significantly higher (p < 0.01) than males of corresponding group. #Significantly higher (p < 0.01) than other subgroups. **The values are given as the number of procedures, with the percentage in parentheses.

Results

From 1997 to 2006, a total of 1155 patients underwent 1216 total elbow arthroplasties in New York State. There was a significant yearly increase in the number of total elbow arthroplasties performed (p < 0.01), with ninety-three index total elbow arthroplasties performed in 1997 and 134 performed in 2006 (Fig. 1).

During the time period examined, there were 719 index total elbow arthroplasties performed for trauma, 283 performed for rheumatoid arthritis, seventy-six performed for osteoar-

thritis, and seventy-seven performed for oncology or other conditions (Table I, Fig. 2). The three most common principal diagnoses within the oncology group were secondary malignant neoplasm of bone and bone marrow (ICD-9 198.5), malignant neoplasm of scapula and long bones of upper limb (ICD-9 170.4), and other joint derangement not elsewhere classified involving an upper arm (ICD-9 71.82).

Of the 1155 index total elbow arthroplasties, 822 (71.1%) were performed in females and 333 (28.8%) were performed
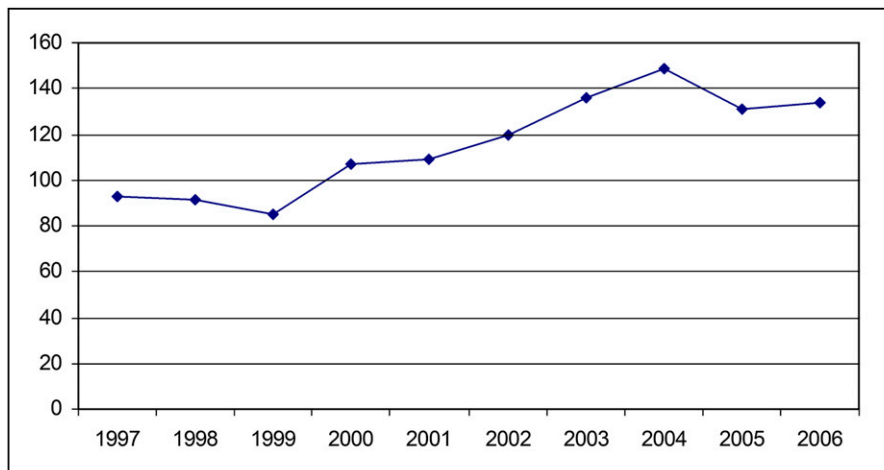

Fig. 1

The number of total elbow arthroplasties performed in New York State by year. There is a significant trend for a greater number of total elbow arthroplasties being performed over time (p < 0.01).
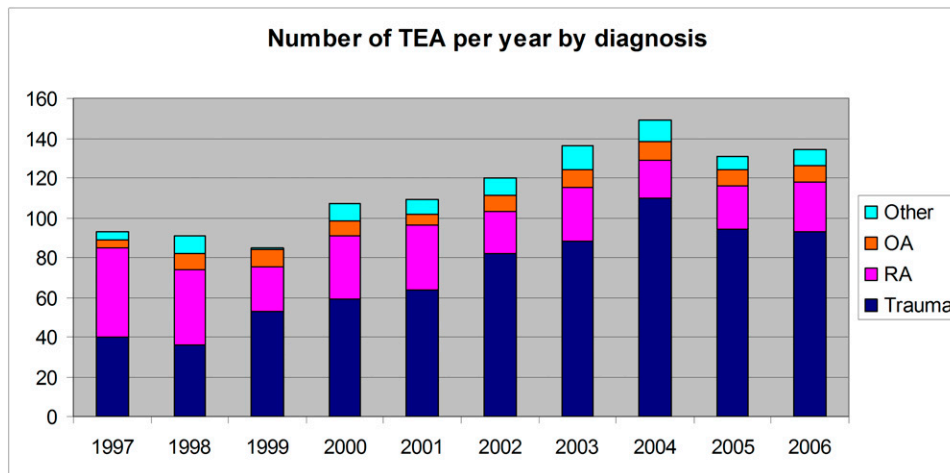
Fig. 2

The number of total elbow arthroplasties (TEA) per year by diagnosis. OA = osteoarthritis, and RA = rheumatoid arthritis.

in males. Females were significantly (p < 0.01) more likely to have a total elbow arthroplasty than were males, especially in the rheumatoid arthritis subgroup (p < 0.01). The average age (and standard deviation) of the patients was 58.3 ± 17.2 years. The rheumatoid arthritis patients were significantly younger than the osteoarthritis patients (average, 57.4 versus 63.4 years; p < 0.01).

During the study period, there was a significant increase in total elbow arthroplasties performed on patients for trauma from 43% to 69%, and a concomitant decrease in arthroplasties performed in patients with rheumatoid arthritis (p < 0.01) (see Appendix). The number of total elbow arthroplasties done in the osteoarthritis and oncology subgroups remained unchanged throughout this ten-year period. The calculated incidence of total elbow arthroplasty in New York State for the year 2000 (the only year for which census data are available) was 0.71 per 100,000 people over fifteen years of age[7]. The highest number of arthroplasties was performed in patients sixty to sixty-nine years old (see Appendix).

In this study, the majority of patients undergoing a total elbow arthroplasty were stratified as a Deyo Comorbidity Index of 0, indicating there were no medical comorbidities in these patients. Twenty-one percent of patients were categorized as having a Deyo index of 1, and 8% as having an index of ≥2. The oncology subgroup had a significantly higher percentage of patients with a Deyo index of ≥2 (p < 0.01; Table I), stratifying this group of total elbow arthroplasty patients as a higher risk group both for perioperative complications and overall mortality.

The surgeons who performed the arthroplasties were examined for the number of previous total elbow arthroplasties done from the time the database began collecting data in 1986. There were 373 surgeons in the total elbow arthroplasty dataset. The median duration from the time when a surgeon was first followed by the dataset to his or her first total elbow arthroplasty was 159 months (range, four to 295 months). Ninety percent of the total elbow arthroplasties were done by surgeons who had no documented cases of total elbow arthroplasty in

the database prior to the index case, although it is possible they performed total elbow arthroplasties prior to 1986 or outside New York State. Five percent of the total elbow arthroplasties were done by surgeons who had performed between one and nineteen total elbow arthroplasties previously, and another 5% were performed by surgeons who had done more than twenty total elbow arthroplasties. Only the patients in the rheumatoid arthritis subgroup were more likely to have had the surgery done by an experienced surgeon (p < 0.01).

During the index arthroplasty admission, 6.5% of patients required a transfusion of one or more units of blood (Table II). The rheumatoid arthritis subgroup had the lowest transfusion rate (2.5%), which was significantly lower than that for the other groups combined (p < 0.01), whereas the transfusion rate for the oncology subgroup was 16.9%, which was significantly higher than the other groups combined (p < 0.01).

Twelve percent of the patients were readmitted to the hospital within ninety days after the index procedure. Almost half of these readmissions were due to an implant-related complication (5.6%), with postoperative infection accounting for 3.1% (Table II). The likelihood of readmission within ninety days postoperatively was significantly increased for patients who were more than sixty-five years old (p < 0.05), who were in the oncology group (p < 0.05), or who had a comorbidity index of ≥2 (p < 0.01) (Table II). Major inpatient complications included myocardial infarction (four patients; 0.4%), pulmonary embolism (three patients; 0.3%), and death (seven patients; 0.6%) (Table II). All myocardial infarctions and pulmonary embolisms occurred in the traumatic group. All patients who died had been treated by surgeons with no previous experience performing total elbow arthroplasty, although this may be an artifact of having only a small number of surgeons with previous experience and the finding was not significant. Similarly, the revision rate was higher in patients treated by these surgeons compared with those treated by more experienced surgeons (6.8% versus 2.8%; p = 0.10). No difference was found for complications on the basis of surgeon volume.

TABLE II Complications After Total Elbow Arthroplasty by Diagnostic Group

	Overall* (N = 1155)	Trauma* (N = 719)	Rheumatoid Arthritis* (N = 283)	Osteoarthritis* (N = 76)	Oncology or Other* (N = 77)
Transfusion during index admission	75 (6.5)	50 (7)	7 (2.5)†	5 (6.6)	13 (16.9)‡
Complications within 90 days					
Mechanical complications	51 (4.4)	33 (4.6)	6 (2.1)§	2 (2.6)	10 (13)§
Other complications	13 (1.1)	8 (1.1)	3 (1.1)	1 (1.3)	1 (1.3)
Infection	36 (3.1)	18 (2.5)	14 (5)§	2 (2.6)	2 (2.6)
Myocardial infarction	4 (0.4)	4 (0.6)	0 (0)	0 (0)	0 (0)
Pulmonary embolism	3 (0.3)	3 (0.4)	0	0 (0)	0 (0)
Death within 90 days	7 (0.6)	4 (0.6)	0 (0)	1 (1.3)	2 (2.6)§
Overall complications**	112 (9.7)	68 (9.5)	23 (8.1)	6 (7.9)	15 (19.5)§
Readmission within 90 days	134 (11.6)	76 (10.6)	32 (11.3)	11 (14.5)	15 (19.5)§

*The values are given as the number of patients, with the percentage in parentheses. †Significantly lower rate ($p < 0.01$). ‡Significantly higher rate ($p < 0.01$). §Significant in simple logistic regression ($p < 0.05$). **Includes revision in upper extremity within ninety days.

Inflammatory arthritis (the RA group) was the most common diagnosis for patients undergoing a contralateral total elbow arthroplasty (Table III). Forty-seven patients (17.7%) in this diagnostic group underwent a total elbow arthroplasty on the contralateral elbow during the study period. The trauma subgroup had twelve patients (1.7%) and the OA subgroup had two patients (2.6%) who underwent a contralateral total elbow arthroplasty. The RA group included 77% of the contralateral total elbow arthroplasties performed during the analysis period. There were no contralateral total elbow arthroplasties performed in the oncology subgroup.

Of the 1155 patients, 1130 (98%) were able to be evaluated for revision elbow arthroplasty. Twenty-five patients were excluded as a result of having a previous upper extremity arthroplasty. The overall revision rate during the study period was 6.4%. There was a higher revision rate for patients with osteoarthritis and a lower rate for patients with traumatic diagnoses (Table III). Risk factors for revision identified by multivariable modeling include a diagnosis of osteoarthritis (odds ratio, 3.1; $p < 0.01$). There was evidence of a higher risk of revision in patients in the rheumatoid arthritis group compared with all other groups (odds ratio, 1.7) and in patients treated by lower-

TABLE III Contralateral and Revision Total Elbow Arthroplasty by Diagnostic Group

Subsequent Surgery	Overall (N = 1130)	Trauma (N = 715)	Rheumatoid Arthritis (N = 265)	Osteoarthritis (N = 75)	Oncology or Other (N = 75)
Additional primary total elbow arthroplasty*	61 (5.3)	12 (1.7)†	47 (16.6)†	2 (2.6)	0 (0)
Time to second primary arthroplasty *(days)*					
Mean and standard deviation	688.3 ± 715.0	788.1 ± 718.5	684.9 ± 727.3	169.5 ± 21.9	–
Median (range)	441.0 (45-3208)	535.5 (48-2338)	441.0 (45-3208)	169.5 (154-185)	–
Revision upper extremity arthroplasty*‡	72 (6.4)	34 (4.8)†	22 (8.3)	11 (14.7)†	5 (6.7)
Time to revision *(days)*					
Mean and standard deviation	849.2 ± 722.5	709.2 ± 802.7	1,075.1 ± 710.1	892.2 ± 498.2	712.4 ± 454.9
Median (range)	661.5 (7-2763)	390.5 (7-2763)	988.5 (14-2291)	900.0 (202-1570)	705.0 (100-1330)
Revision within 90 days*‡	8 (0.7)	6 (0.8)	2 (0.8)	0 (0)	0 (0)

*The values are given as the number, with the percentage in parentheses. †Significant in simple logistic regression ($p < 0.05$). ‡Restricted to patients without a previous upper extremity arthroplasty.

INDICATIONS AND REOPERATION RATES FOR TOTAL
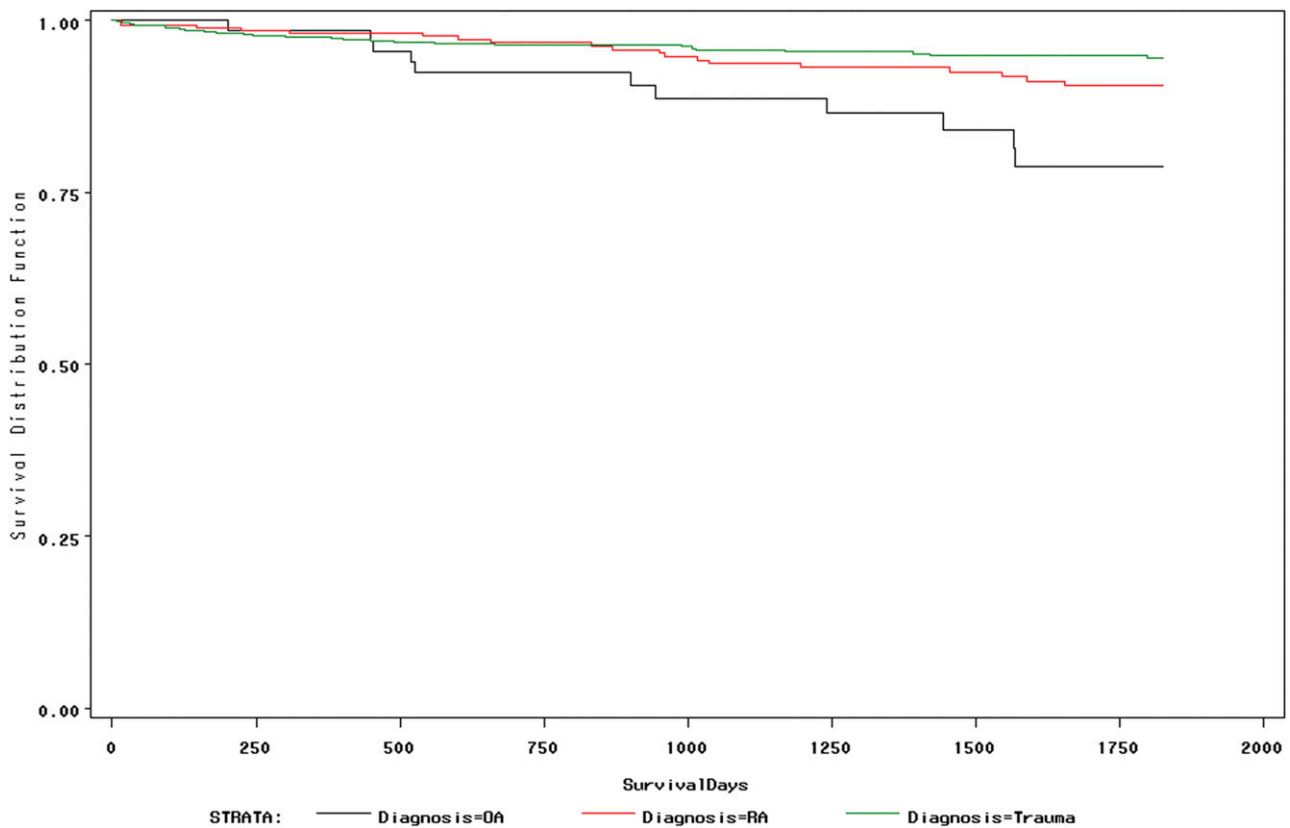ELBOW ARTHROPLASTY: AN ANALYSIS OF TRENDS

Fig. 3

Kaplan-Meier survivorship curves for the implants according to diagnosis, with revision arthroplasty used as the end point. OA = osteoarthritis, and RA = rheumatoid arthritis.

volume surgeons (odds ratio, 2.8) compared with higher-volume surgeons, although neither reached significance. Kaplan-Meier survival curves were constructed with use of revision arthroplasty as the end point (Fig. 3), and the five-year survival rates for the trauma, RA, and OA subgroups were 96%, 93%, and 85%, respectively.

Discussion

A recent study performed with use of the Norwegian Arthroplasty Registry found a decrease in the number of total elbow arthroplasties performed per year in that country[1]. However, in our study, the number of total elbow arthroplasties performed per year in New York State showed a significant upward trend from 1997 to 2006, with a 44% increase in the number of total elbow arthroplasties performed per year over the study period. The Norwegian study did demonstrate a small increase in number of total elbow arthroplasties performed for patients with traumatic conditions, but showed a 50% absolute decrease in the number of total elbow arthroplasties performed from 1994 to 2006, which the authors attributed to a decrease in the number of patients with rheumatoid arthritis.

We found a similar trend in our inflammatory arthritis subgroup. In 1997, inflammatory arthritis was the indication for total elbow arthroplasty in 48% of patients. This had decreased to 19% by 2006. Other studies evaluating the use of orthopaedic

surgery procedures in patients with rheumatoid arthritis have found similar declines[8-11]. These findings are likely due to important advances in the medical management of rheumatoid arthritis[12-15].

In New York State, the decrease in total elbow arthroplasties for inflammatory arthropathies was more than offset by an increase in the number of total elbow arthroplasties performed for traumatic conditions. Over the ten-year period, there was a 132% increase in the number of total elbow arthroplasties performed for trauma diagnoses. In 2003, Frankle et al.[16], in a retrospective review comparing total elbow arthroplasty with open reduction and internal fixation for acute treatment of distal humeral fractures in women over sixty-five years old, reported that the arthroplasty group had substantially better Mayo elbow scores than the group managed with open reduction and internal fixation. A recently published, multicenter, prospective randomized study comparing total elbow arthroplasty with open reduction and internal fixation for intra-articular humeral fractures also found that patients treated with total elbow arthroplasty had better outcomes at the time of the two-year follow-up[3]. These findings may result in a continuation of a large percentage of total elbow arthroplasties being done for complex elbow fractures, but the long-term fate of these arthroplasties is unknown.

A surprising finding of our study was that <10% of the arthroplasties were performed by a surgeon with previous

experience with the procedure as the primary surgeon. This is most likely a reflection of the rare indications for this procedure. The rheumatoid arthritis group had 15% of the total elbow arthroplasties performed by surgeons who had prior experience recorded in the database compared with 7.5% of those who had performed the procedure on patients in the traumatic subgroup. It is speculated that this difference is a result of the need for acute treatment in the trauma patients, whereas patients with inflammatory arthritis were more often referred to centers with experience in treating advanced inflammatory arthropathies of the elbow.

The outcomes of hip, knee, and shoulder arthroplasty have been examined with regard to the surgeon volume[17-25]. Those studies have demonstrated a correlation between low surgeon volumes and higher complication rates. We show evidence of a higher revision rate for inexperienced surgeons (6.8%) compared with experienced surgeons (2.8%). This finding did not reach significance ($p = 0.10$), but this may be due to the small number of arthroplasties (110) performed by experienced surgeons.

Reported rates of perioperative and long-term complications associated with primary total elbow arthroplasty have ranged from 29.9% to 43%[26,27]. However, there are very few reports of only perioperative complications. Recently, Cook et al.[2] used the Nationwide Inpatient Sample database to evaluate perioperative complications in patients with and without rheumatoid arthritis. They reported that the calculated perioperative mortality for 3617 subjects was <1%, and only the blood transfusion rate (2.8%) and a respiratory complications rate (1.1%) were >1%. The overall perioperative blood transfusion rate in our study was 6.5%, with the highest rates in the traumatic and oncology group. The inflammatory arthritis group had a blood transfusion rate of 2.5%, similar to the rate of 2.2% for rheumatoid patients reported by Cook et al.[2], and the overall transfusion rate of 2.9% reported by Duncan et al.[28]. The elevated transfusion rate in the traumatic subgroup may be influenced by the fact that some of those patients had multiple injuries at the time of the elbow trauma. The lower rates seen in the rheumatoid arthritis subgroup could be a reflection of the fact that the isolated disease process in these patients was addressed or could be due to a significantly higher rate of experienced surgeons performing the procedures in this subgroup.

The overall ninety-day complication rate in our study was 9.7%, with 8.8% of the complications related to infection or mechanical problems with the implant. The mechanical complication rate and death rate were higher in the oncology group. The high mechanical complication rate is most likely a reflection of the extensive tumor resections required for oncology patients and the increased mortality rate is a reflection of their disease processes. The overall ninety-day mortality, pulmonary embolism, and myocardial infarction rates were <1%. The 0.6% mortality rate and the 0.3% pulmonary embolism rate are equivalent to the reported rates of 0.6%[29] and 0.3%[30], respectively. The overall readmission rate, complication rate, and death rate decreased to 10.5%, 8.6%, and 0.4%, respectively, when calculated without including the oncology subgroup.

There was a significantly higher rate of infection at ninety days postoperatively in our patients with rheumatoid arthritis. Rates for infection have been reported to range from 0% to 8.1% for primary total elbow arthroplasty[27,31]. Our rate included both superficial and deep infections. Unfortunately, the design of the database did not allow us to determine the rates for superficial and deep infection separately.

Five and ten-year survival analyses have been reported for a variety of total elbow arthroplasty designs. Using revision as the end point, Little et al.[32] reported a five-year survival of 85% to 93% in rheumatoid arthritis patients. Other studies have found similar five-year survival rates[33-35]. A large Norwegian study examining all types of prostheses over a twelve-year time period for all diagnoses noted a five-year survival rate of 92% and a ten-year survival rate of 85%[1]. The five-year survival rate in our study was similar to the previous published rates, but we observed differences among our subgroups. Our revision values may be a slight underestimation since revisions on our cohort that were performed outside New York State were not identified.

Our findings were limited by the design of the database. Unfortunately, we were not able to include a surgeon's surgical history prior to 1986. A database with a longer history may have shown a significant difference in outcomes between high and low-volume surgeons. Additionally, data related to the manufacturer of the prosthesis were not available and we were not able to examine the influence of the prosthesis type on complications and survivability.

This study has limitations inherent to database studies. New York State law requires hospitals to submit 100% of their admission data to SPARCS within 180 days of the end of the fiscal year in which the admission took place. SPARCS also performs periodic audits to ensure data quality. As a reflection of these strict requirements for the database, other published orthopaedic studies have used SPARCS to report on the epidemiology of anterior cruciate ligament reconstructions[36], rotator cuff repair[37], and total shoulder arthroplasty[17].

In conclusion, our data show that the indications for total elbow arthroplasty in New York State have changed dramatically over a recent ten-year period, and the majority of surgeons performing total elbow arthroplasties have limited experience with this surgical procedure. The five-year revision rates are higher than rates seen for total hip and knee arthroplasty, and a significant number of perioperative complications are reported. Further investigations into implant design and possibly a higher referral rate to surgeons with greater experience with elbow arthroplasty may result in a reduction in the revision rates and perioperative complications.

Appendix

(eA) Tables showing the ICD-9 codes for complications and the distribution of total elbow arthroplasties by age groups as well as a graph showing the percentages of diagnoses for total elbow arthroplasties performed by year are available with the online version of this article as a data supplement at jbjs.org. ■

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