■ SHOULDER & ELBOW

Total elbow arthroplasty in England

ANALYSIS OF NATIONAL JOINT REGISTRY AND HOSPITAL EPISODE STATISTICS DATA

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Aims

The aim of this study was to review the provision of total elbow arthroplasties (TEAs) in England, including the incidence, the characteristics of the patients and the service providers, the types of implant, and the outcomes.

Methods

We analyzed the primary TEAs recorded in the National Joint Registry (NJR) between April 2012 and December 2022, with mortality data from the Civil Registration of Deaths dataset. Linkage with Hospital Episode Statistics-Admitted Patient Care (HES-APC) data provided further information not collected by the NJR. The incidences were calculated using estimations of the populations from the Office for National Statistics. The annual number of TEAs performed by surgeons and hospitals was analyzed on a national and regional basis.

Results

A total of 3,891 primary TEAs were included. The annual incidence of TEA was between 0.72 and 0.82 per 100,000 persons before 2020 and declined to 0.4 due to a decrease in elective TEAs during the COVID-19 pandemic, with a slight recovery in 2022. Older patients, those of white ethnicity and females, were more likely to undergo TEA. Those who underwent elective TEA had a median wait of between 89 (IQR 41 to 221) and 122 days (IQR 74 to 189) in the years before 2021, and this increased to 183 days (IQR 66 to 350) in 2021. The number of TEAs performed by surgeons per annum remained unchanged, with a median of two (IQR 1 to 3). The median annual number of TEAs per region was three to six times higher than the median annual case load of the highest volume hospital in a region. Patients in the lowest socioeconomic group had a higher rate of serious adverse events and mortality (11%) when undergoing TEA for acute trauma.

Conclusion

In England, TEA is more common in older age groups, those of white ethnicity, and females. The COVID-19 pandemic affected the incidence of elective TEA and waiting times, and the provision of TEA has not yet recovered. The Getting it Right First Time recommendation of centralizing services to one centre per region could result in up to a six-fold increase in the number of TEAs being performed in some centres.

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Introduction

Total elbow arthroplasty (TEA) may be used to treat patients with severe osteoarthritis (OA), and distal humeral fractures which are not amenable to reconstruction.[1] Data about TEA are prospectively captured in the National Joint Registry (NJR) in England, which provides a valuable resource to inform service planning and measure the impact of changes to delivery. There are currently no published data dealing with the incidence of TEA in England, and limited assessment of the patients, implants, and healthcare services involved in TEA beyond the NJR annual reports.[2]

TEAs are less commonly undertaken than arthroplasties of the hip, knee, shoulder, and ankle.[2] The NHS England Getting It Right First Time (GIRFT) programme aims to improve the quality of care for patients undergoing low-volume procedures, such as TEA, by centralizing these procedures to specialized centres.[3] The NHS

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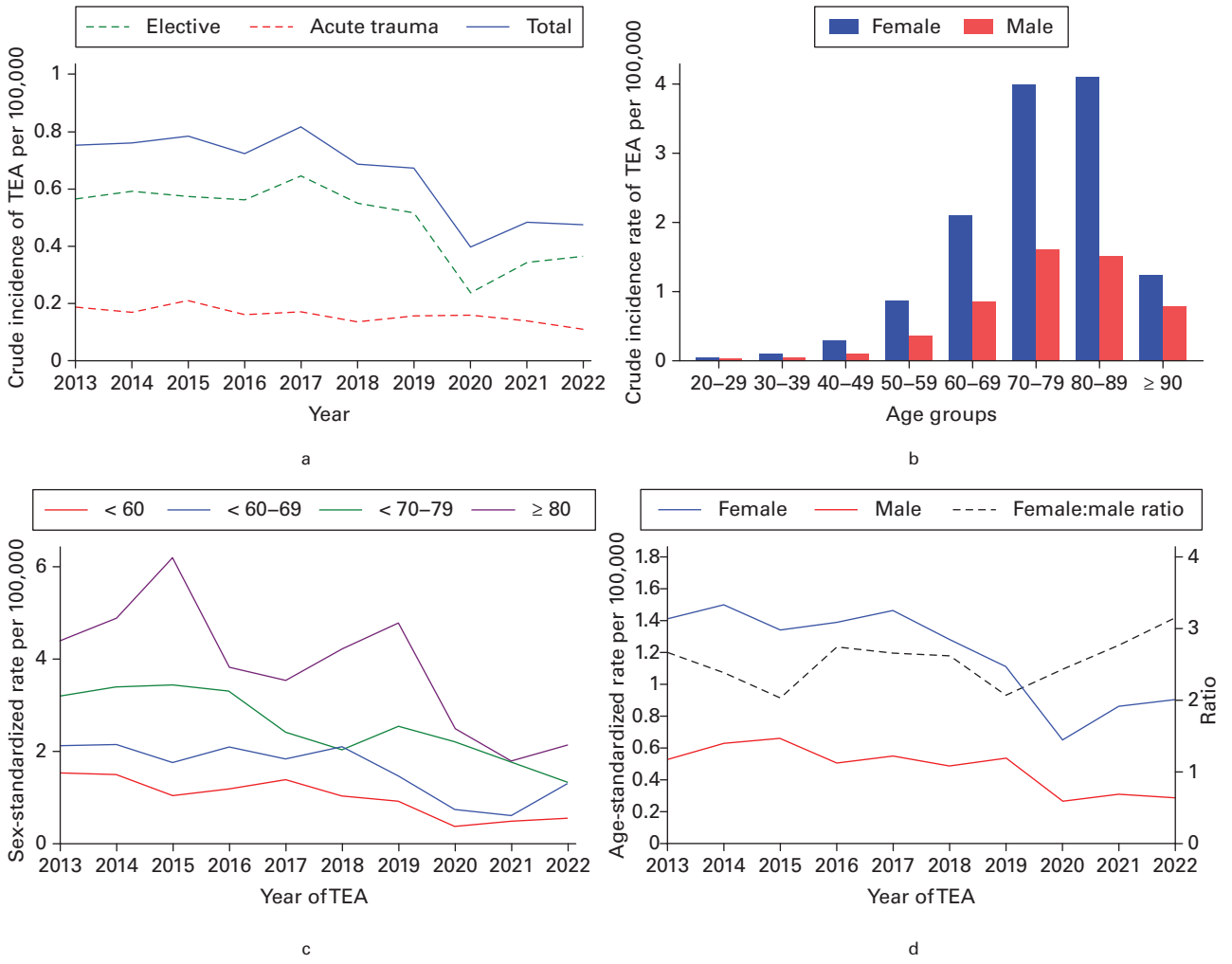

Fig. 1

Incidence of total elbow arthroplasty (TEA) in England. a) The crude incidence of TEA for the whole population and per indication. b) The crude incidence of TEA for the study period per age group and sex. c) Sex-standardized incidence per age group. d) Age-standardized incidence per sex.

worked with the British Elbow and Shoulder Society (BESS) to develop a "hub and spoke" referral model, which involves having one or two regional centres providing primary and revision TEAs in each NHS region in England, Wales, and Northern Ireland.[4] They proposed that resources, knowledge, and experience in this area should be channelled in order to improve outcomes and training.

Before implementing any service changes, an assessment of the current and recent past practices of TEA is required to provide a baseline for comparison and to enable assessment of the impact of change. The aim of this study was to provide an overview of TEAs undertaken in England, focusing on the characteristics of the patients, the types of implant, and the services that offer TEA.

Methods

Data from the National Joint Registry (NJR), which covers England, Wales, Northern Ireland, the Isle of Man, and Guernsey, were analyzed. The findings and methodology are reported in accordance with the RECORD statement.[5] The study was registered at ClinicalTrials.gov (NCT06355011) and a detailed protocol has been published.[6] In this section, a summary of the methodology which was used in the study is provided.

The study included primary TEAs recorded by the NJR between 1 April 2012 and 31 December 2022. Further data were collected by linking the NJR data to the NHS England Hospital Episode Statistics-Admitted Patient Care (HES-APC) data[7] and the Civil Registration of Deaths dataset.[8] The linked data involved all HES-APC episodes between 23 October 1996 and 31 March 2022, including admissions unrelated to the TEA. Unlinked episodes were used to obtain information about readmissions and patients' comorbidities. Estimations of the populations from the Office for National Statistics (ONS)[9] were used to calculate the incidence of TEA.

All patients aged between 18 and 100 years who had a primary TEA in England recorded in the NJR were included. Those who did not consent to participate in research, had invalid

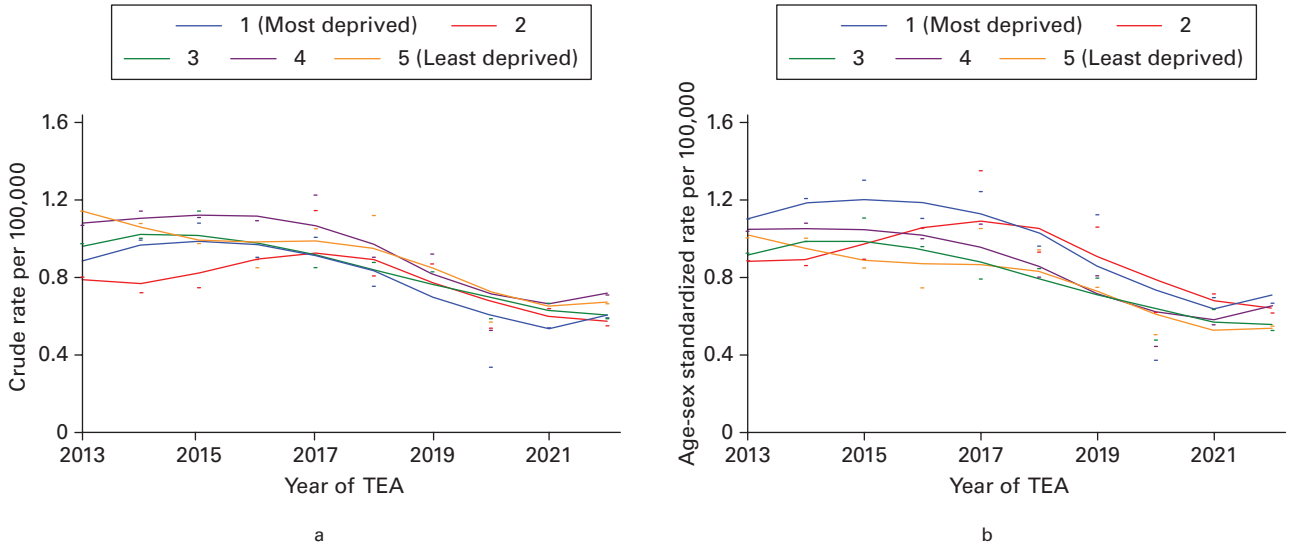

Fig. 2

a) Crude and b) adjusted annual incidence of total elbow arthroplasty by socioeconomic group. Dots represent the incidence rates. Lines are from a locally weighted scatterplot smoother with a bandwidth of 0.8.

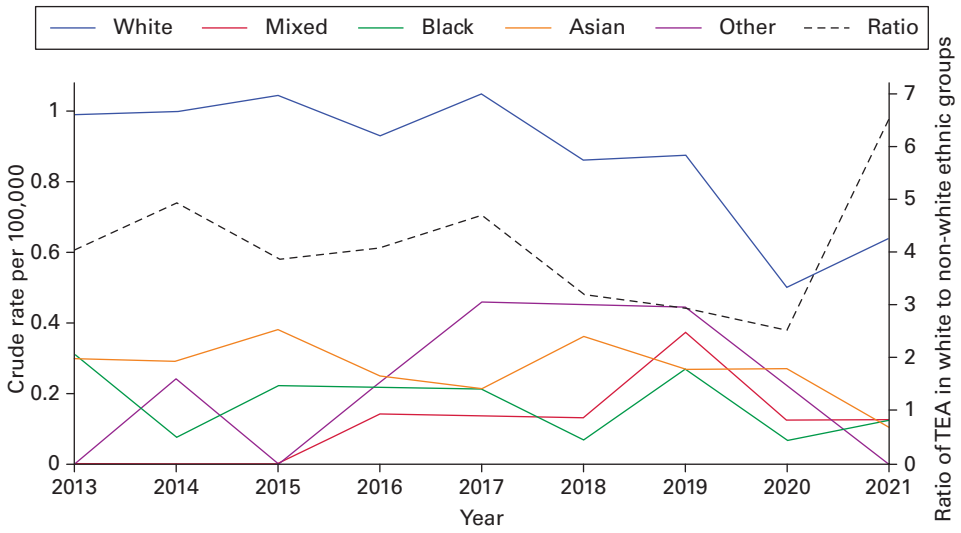

Fig. 3

Total elbow arthroplasty (TEA); incidence by ethnic group.

identification numbers, were untraceable after surgery, or had duplicate records were excluded. The quality of the data about the remaining procedures was checked to confirm that they matched the list of implants and that the patterns of primary and revision TEAs were consistent. The confirmed procedures required compatible humeral and ulnar components. HES-APC episodes with obvious errors or with inconsistent dates were excluded.

The primary aim was to analyze the volume and rates of the provision of primary TEA, while examining the year-to-year changes. Secondary outcomes were the waiting times for elective procedures, the postoperative recovery, and significant adverse events occurring within 30 or 90 days of the TEA.

Statistical analysis. A descriptive analysis of patients' characteristics, the types of implants which were used, and the number of TEAs performed by surgeons and hospitals was conducted. This included a summary and stratified analysis for acute traumatic and elective procedures, and the median number of TEAs performed by surgeons and hospitals nationally and regionally. The potential annual number of TEAs after GIRFT recommendations was also calculated by assuming one centre per region using the old ten regional health authorities in England.

Table I. The characteristics of patients who underwent total elbow arthroplasty in England.

Variable	Elective	Acute trauma	Total
Procedures, n (%)	2,944 (76)	947 (24)	3,891 (100)
Mean age at operation, yrs (SD)	67 (12)	77 (8.8)	70 (12)
Mean BMI, kg/m² (SD)*	28.3 (5.9)	27.9 (6.6)	28.2 (6)
Surgery to dominant arm, n (%)			
Yes	1553 (53)	388 (41)	1,941 (50)
No	931 (32)	319 (34)	1,259 (32)
Unknown	460 (16)	240 (25)	700 (18)
Sex, n (%)			
Female	2,081 (71)	797 (84)	2,878 (74)
Male	863 (29)	150 (16)	1,013 (26)
Ethnicity, n (%)			
Asian	74 (3)	14 (1)	88 (2)
Black	21 (1)	< 4 (< 1)	22 (1)
Mixed	8 (< 1)	0 (0)	8 (< 1)
White	2,364 (80)	790 (83)	3,154 (81)
Other	7 (< 1)	< 4 (< 1)	10 (< 1)
Missing (including unlinked data)	470 (16)	139 (15)	609 (16)
ASA grade, n (%)[16]			
I	110 (4)	51 (5)	161 (4)
II	1663 (57)	514 (54)	2,177 (56)
III	1,143 (39)	355 (38)	1,498 (39)
IV	28 (1)	27 (3)	55 (1)
IMD quintiles, n (%)			
1 (most deprived areas)	551 (19)	144 (15)	695 (18)
2	538 (18)	171 (18)	709 (18)
3	600 (20)	201 (21)	801 (21)
4	622 (21)	233 (25)	855 (22)
5 (least deprived areas)	609 (21)	185 (20)	794 (20)
Missing	24 (< 1)	13 (1)	37 (1)
Indication for surgery, n (%)			
Acute trauma	0 (0)	947 (100)	947 (24)
The squelae of trauma	527 (18)	0 (0)	527 (14)
Inflammatory arthritis	1378 (47)	0 (0)	1,378 (35)
Osteoarthritis	928 (32)	0 (0)	928 (24)
Other	111 (4)	0 (0)	111 (3)
Median CCI (IQR)†	1 (1 to 3)	1 (0 to 3)	1 (1 to 3)
Median CCI-SHMI (IQR)‡	4 (4 to 2)	4 (0 to 14)	4 (4 to 12)

*n = 879.
†Score range 0 to 30; n = 3,133.
‡Score range 0 to 130; n = 3,133.
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; IMD, Index of Multiple Deprivation; SHMI, Summary Hospital Level Mortality Indicator.

The crude annual incidences of TEAs per 100,000 persons were calculated using estimations of the mid-year populations published by the ONS by age group, sex, Index of Multiple Deprivation (IMD) quintiles and ethnicity. The IMD quintiles were created using the 2015 version of the English IMD.[10] Ethnicity was categorized into six categories based on the ONS ethnic group classification 6a.[11] Standardized rates were calculated using direct standardization, with the estimations of the mid-year populations from the ONS as the standard population. We excluded 2012 from the analysis of annual trends due to the fact that the collection of NJR data began on 1 April of that year.

The waiting time for elective surgery was calculated using the date on which it was decided that the patient should be admitted for surgery (variable "ELECDATE" from the HES-APC data)[12] and the date of surgery (from the NJR data). Comorbidities were identified using the International Classification of Diseases-10 codes in the HES-APC data,[13] considering all comorbidities listed prior to and at the time of admission for TEA. The Charlson Comorbidity Index (CCI)[14] was calculated for each patient using the original weights and updated weights which are used to establish the Summary Hospital-level Mortality Indicator (CCI-SHMI) by calibrating the weights based on data in England. The methods published by the Health and Social Care Information Centre were used to calculate the CCI-SHMI.[15]

Patients with serious adverse events (SAEs) were those who developed a SAE during the same hospital admission or were readmitted with pulmonary embolism, myocardial infarction, lower respiratory tract infection, acute renal injury, urinary tract infection, or a cerebrovascular accident, within 30 or 90 days of the TEA. Data about all-cause death were obtained from the Civil Registration of Deaths Dataset and included as part of the 30- and 90-day SAEs. The analysis excluded TEAs from 2022 as HES-APC data only go up to 31 March 2022. Stata v. 18 (StataCorp, USA) was used for the analysis. Significance was set at $p < 0.05$.

Results

The NJR elbow dataset contained 11,946 procedures, of which 4,399 were primary TEAs performed in England during the study period. Supplementary Figures a and b show flow diagrams of the preparation of the data. For the 508 TEAs which did not meet the inclusion criteria, there were 169 procedures with no consent (33%), eight in which modular implants were used rather than a standard primary TEA (2%), seven were non-traced procedures (1%), and four (1%) were undertaken in patients who were outside the age limit. Additionally, 320 (63%) unconfirmed TEAs in which the implants did not match those which were submitted to NJR were excluded from the primary analysis. Comparisons of confirmed and unconfirmed procedures are shown in Supplementary Table i.

With 3,891 confirmed TEAs, the annual incidence between 2014 and 2019 ranged between 0.67 and 0.82 per 100,000 persons (Figure 1a). In 2020, the incidence dropped to 0.40 per 100,000 persons, with a gradual subsequent increase. This decrease in incidence was mainly seen in elective TEA. The incidence in older age groups and females was also higher. Females had a higher rate of TEA than males in all age groups (Figures 1b and 1c) and were between 2.5 and three times more likely to undergo TEA than males (Figure 1d). The crude incidence including confirmed and unconfirmed TEAs is shown in Supplementary Figure c.

The incidence of TEA varied across different socioeconomic groups throughout the study period. According to the crude incidence, patients in the least deprived areas had the highest incidence of TEA (Supplementary Table ii). However, after adjusting for age and sex, the more deprived areas had a higher incidence. Patients in the most deprived areas (first and second

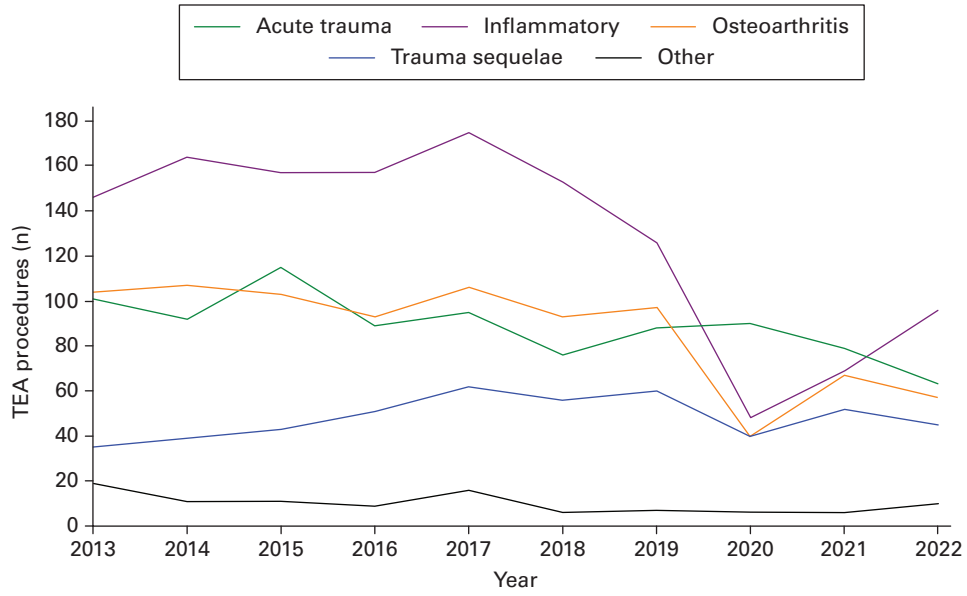

Fig. 4

The incidence of total elbow arthroplasties (TEA) annually by the indication for surgery.

IMD quintiles) had a median annual incidence of 1.10 (range 0.37 to 1.3) and 0.89 (range 0.61 to 1.35) per 100,000 persons, respectively, whereas those in the least deprived areas (fourth and fifth IMD quintiles) had a median incidence of 0.90 (range 0.44 to 1.08) and 0.80 (range 0.48 to 1.00) per 100,000 persons, respectively (Figure 2).

A total of 3,313 TEAs (85%) had successful data linkage between NJR and HES-APC. Supplementary Figure d and Table iii include the reasons for non-linked data and a descriptive analysis comparing linked and non-linked data. Of the 3,313 linked TEAs, ethnicity data were available for 3,282. Crude analysis revealed that white patients had a higher incidence of TEA compared with other ethnic groups. When all non-white ethnic groups were combined, white patients were 2.5 to 4.9 times more likely to have TEA prior to 2021 (Figure 3). In 2021, this ratio increased noticeably to 6.5. The low numbers of TEAs for some ethnic groups led to volatility in annual age and sex standardized rates (Supplementary Figure e and Table iv).

The characteristics of patients undergoing TEA are summarized in Table I. Those with acute trauma had a higher mean age of 77 years (SD 9.0), compared with 67 years (SD 12.0) for elective cases. Almost all TEAs (99.8%) were unilateral; four patients had simultaneous bilateral procedures.

Typically, there were 2.5 to 4.1 times more elective TEAs compared with acute TEAs, except in 2020 when there were only 1.5 times as many elective TEAs (Figure 1a). Inflammatory arthritis was consistently the most common indication for elective TEA, accounting for 47% of TEAs, followed by OA (32%) and the sequelae of trauma (18%). Figure 4 shows that inflammatory arthritis accounted for more TEAs each year, except in 2020 and 2021.

Patients in both elective and acute trauma groups had a median CCI of one and CCI-SHMI of four at the time of surgery, respectively. Those who underwent TEA for acute trauma had a higher or equal incidence of most comorbidities compared with those who underwent an elective TEA (Supplementary Table v).

The components of most TEAs (n = 3,861; 95%) were linked (i.e. the humeral and ulnar components were connected with a rod or a cap) and cemented (n = 3,891; 99%). Unlinked implants were predominantly used in elective procedures (94% n = 184). The Coonrad-Morrey TEA was used in 48% (n = 1,861), followed by the Discovery TEA (26%, n = 995) and the Latitude EV TEA (13%, n = 504). Since 2014, the use of Latitude EV TEAs has increased, becoming the most used in elective procedures in 2022. Despite a decline in the use of the Coonrad-Morrey TEA, it remained the most widely used implant in patients with acute trauma in 2022 (Supplementary Figure f). The number of Discovery TEAs has gradually decreased since 2017.

Most TEAs (95%) were performed by a consultant surgeon, and most (96%) were funded by the NHS (Supplementary Tables vi and vii). Throughout England, hospitals and surgeons typically performed a median of two (IQR 1 to 3) TEAs per year except for 2020 when the median TEAs per hospital was only one (IQR 1 to 3). There was little regional variation in the median number of TEAs performed by a surgeon and a hospital, with an overall median of two (IQR 1 to 3) TEAs per year in all authorities other than London, which had a median of one TEA (IQR 1 to 2) performed by surgeons (Supplementary Table vii). The median number of TEAs performed each year in each region varied between 57 (range 24 to 82) in the North West of England and 19 (range 12 to 34) in the South-Central region. Based on the GIRFT recommendations, this is likely to represent the future number of procedures in a single regional centre providing all TEA services (Table II). This would be equivalent

Table II. Summary of the number of total elbow arthroplasties per hospital per region.

Health authority	Median total annual TEAs, median (range)		
	Total	Per hospital	Maximum performed by a hospital within region*
East Midlands	35 (12 to 46)	3 (1 to 17)	11 (6 to 17)
East of England	32 (20 to 52)	2 (1 to 13)	8 (4 to 13)
London	35 (21 to 40)	2 (1 to 14)	9 (6 to 14)
North East	28 (15 to 46)	2 (1 to 10)	6 (4 to 10)
North West	57 (24 to 82)	2 (1 to 24)	16 (6 to 24)
South-Central	19 (12 to 34)	2 (1 to 12)	8 (3 to 12)
South East Coast	32 (23 to 45)	2 (1 to 11)	7 (4 to 11)
South West	47 (9 to 61)	2 (1 to 14)	8 (3 to 14)
West Midlands	41 (23 to 62)	2 (1 to 21)	12 (8 to 21)
Yorkshire and the Humber	45 (27 to 55)	2 (1 to 17)	12 (5 to 17)

*In some regions one hospital consistently performs the highest number of TEAs annually, while in other regions this can vary.
TEA, total elbow arthroplasty.

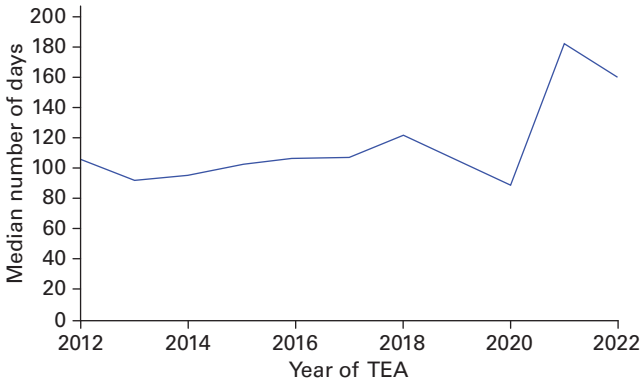

Fig. 5

The wait for elective total elbow arthroplasties (TEA) per year.

to a three- to six-fold increase compared with the median of the highest number of TEAs performed by any hospital in a region.

In 2022, 76 of 95 (80%) surgeons performed < four TEAs; 37 (39%) performed only one TEA, 25 (26%) performed two TEAs, and 14 (15%) performed three TEAs. The percentage of surgeons performing < four TEAs remained consistent, ranging between 76% and 82%, except for in 2020 when 87% of surgeons performed < four TEAs. Hospitals showed a similar trend, with < four TEAs being performed in between 68% and 80%.

The median waiting times for elective TEA in the years between 2012 and 2020 ranged between 89 (IQR 41 to 221) and 122 days (IQR 74 to 189) before increasing markedly to 183 days (IQR 66 to 350) in 2021 and 160 (IQR 29 to 376) in 2022 (Figure 5). There was minimal variation in the median waiting time for elective TEA between different IMD groups (Supplementary Table viii).

Patients who underwent TEA for acute trauma tended to have longer hospital stays, with a median of four days (IQR 2 to 10), compared with those who underwent elective TEA with a median of two days (IQR 1 to 4). However, the median length of stay for those undergoing TEA for acute trauma reduced from eight days (IQR 4 to 15) in 2012 to four (IQR 1 to 9) in 2022. For those who underwent elective TEA, the median length of stay was three days between 2012 and 2014, and has been two days since 2014. For more information, see Supplementary Figures g to i.

The linked NJR and HES-APC data for 3,313 TEAs showed that 62 patients (2%) had at least one SAE within 30 days of TEA. The proportion of patients who had at least one SAE, excluding death, was marginally higher in the those with acute trauma (30-day SAEs, 3%; 90-day SAEs 6%) compared with those who underwent elective TEA (30-day SAEs, 2%; 90-day SAEs, 5%) (Figure 6). Mortality was also higher in the acute trauma group, with eight deaths (1%) within 30 days of TEA and 17 deaths (2%) within 90 days, compared with only one (< 1%) within 30 days and seven (< 1%) within 90 days in the elective TEA group.

The most common SAEs were acute renal injury, lower respiratory tract infection, and urinary tract infection (30-day rate, 1%; 90-day rate, 2% each). Patients in the most deprived areas (IMD quintile 1) had the highest proportion of SAEs and death when they underwent TAE for acute trauma, with a rate of death of 11% within 90 days of surgery. Supplementary Figures j to l summarize the annual rates of 30- and 90-day SAEs, and SAEs by IMD groups.

Discussion

This study provides a detailed analysis of the services offering TEA in England. Linking the NJR data to HES-APC, ONS, and the Civil Registration of Deaths Dataset allowed an in-depth analysis of the incidence of TEA, the characteristics of the patients and the services, and the outcomes which are not reported by the annual report of the NJR.

Between 2012 and 2019, the incidence of TEA in England was consistent. However, in 2020, elective TEAs dropped by almost 50%, accompanied by a significant increase in waiting times, which nearly doubled. This was likely to have been due to the impact of COVID-19 on health services.[17] While the incidence has begun to recover, it has yet to return to its pre-2020 levels. This could be explained by the after-effects of COVID-19 and recent industrial actions.[17–20]

We found that the incidence of TEA in England is higher in older age groups and females, which is consistent with global findings.[21–25] This is likely to be because females are more susceptible to inflammatory arthritis, which is the most common

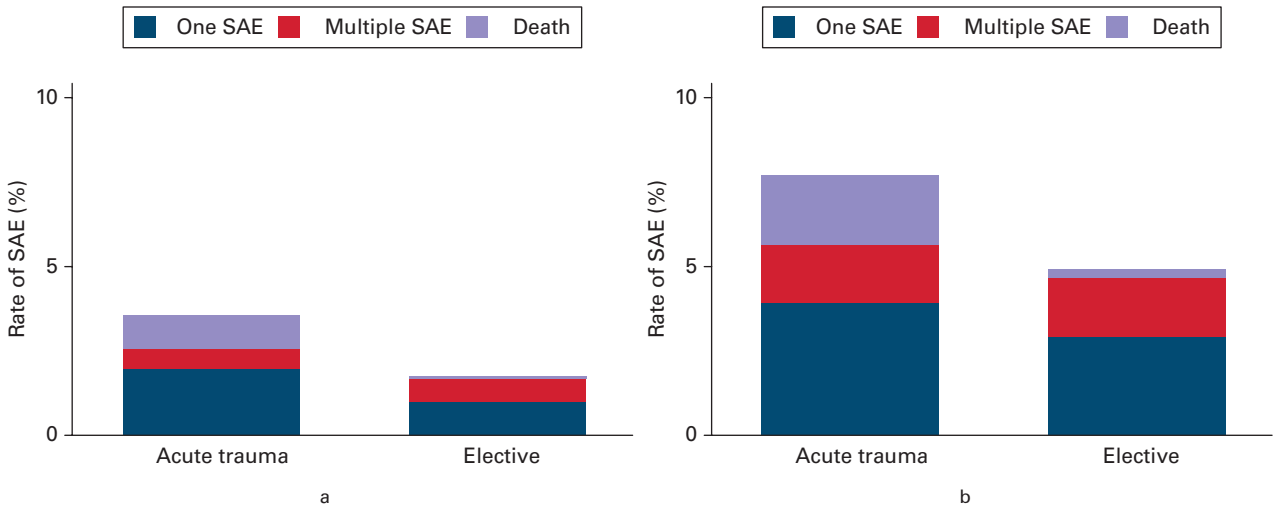

Fig. 6

The rate of serious adverse events (SAEs) and death within 30 and 90 days after primary total elbow arthroplasty.

indication for TEA.[26] Most conditions of the elbow also worsen with the passage of time, making older patients more likely to require TEA. The selection of patients for TEA may also play a role in the differing incidences, as some studies have shown that the rate of failure after TEA is higher in younger patients and males, and surgeons may be less likely to offer these patients TEA.[27,28] We found that the incidence of TEA varied according to the socioeconomic status of the patients. Similar findings have been reported for arthroplasty of the shoulder in England.[29] We also found that white patients were more likely to undergo TEA, and similar findings have been reported for hip and knee arthroplasty. The reasons for this are likely to be multifactorial and may include inequitable access to healthcare, although this needs further study.[30]

In England, most surgeons and hospitals perform a median of two TEAs annually, which has stayed the same since 2012. Centralizing primary TEA services to one centre per region, as recommended by GIRFT, could increase the number of TEAs being undertaken in those centres by three to six times. This may require more than one centre in some regions, or the expansion of facilities in a single centre. The ability of selected centres to accommodate the increase in the number of TEAs which are undertaken is still to be determined. The precise number of TEAs per surgeon cannot be predicted accurately at this time, and factors such as using two consultants in complex cases and hospital capacity may influence the number of TEAs performed.

The rates of SAEs following TEA are similar to those reported for arthroplasty of the shoulder. However, the rates of SAEs after TEA have been constant over time, unlike the yearly increase reported after arthroplasty of the shoulder.[29] Patients undergoing TEA for acute trauma are older and have a higher rate of comorbidities, which may explain the longer postoperative length of stay and higher rates of SAEs and mortality. Centres will need to accommodate patients with acute trauma who have more comorbidities, especially those from deprived areas, who are likely to remain in hospital twice as long as those who undergo elective TEA.

A strength of this study is the use of NJR data, which is accurate and comprehensive, capturing most TEAs in England. Most unconfirmed TEAs are likely to be distal humeral hemiarthroplasties or radial head arthroplasties, based on the date of surgery (before 2018, when distal humeral hemiarthroplasties were first collected in the NJR), the indication for surgery (acute trauma), and the components. A limitation of this study is that only 85% of the NJR data were linked to HES-APC data, resulting in an underestimation of the incidence of TEA for all ethnic groups. Also, HES-APC data only represent NHS patients and do not include those undertaken in the independent sector. The non-linked and missing data in the analysis have probably occurred at random. Thus, the ratio between different ethnic groups, the length of stay postoperatively and the rates of SAE for services in the NHS are likely to be accurate. The use of HES-APC data only captures SAEs which led to a hospital admission, missing complications occurring in the community. However, SAEs leading to admission can be considered to be more serious, and patients and service providers are likely to be interested in this information. Lastly, the waiting time for elective TEA was calculated using an unvalidated approach. The findings, however, indicate the impact of the COVID-19 pandemic on the provision of TEA.

In summary, TEA has an annual incidence in England of 0.70 per 100,000 persons. It is more commonly undertaken in older patients, females and those of white ethnicity. The incidence of elective TEA and waiting times, which were adversely affected by the COVID-19 pandemic, have not yet recovered. Patients in deprived areas who underwent TEA for acute trauma had higher rates of SAEs and mortality. The number of TEAs performed by surgeons and hospitals remains very low. If the GIRFT recommendations were followed by centralizing services to one centre per region, the impact would be up to a six-fold increase in the number of TEAs being undertaken per centre.

Take home message

- The incidence of total elbow arthropalsty (TEA) decreased by half during the COVID-19 pandemic and the waiting times for elective TEA nearly doubled. Services providing TEA have not yet returned to pre-pandemic levels.
- Overall, patients living in the most deprived areas experienced higher rates of serious adverse events and death.
- The number of TEAs performed by individual surgeons and hospitals is very low and has not changed during the study period; if the Getting It Right First Time recommendations were followed by centralizing services to one centre per region, the impact would be up to a six-fold increase in the number of TEAs being undertaken per centre hospital.

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Supplementary material

Supplementary flowcharts, figures, and tables

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