■ ARTHROPLASTY

The epidemiology of revision total knee and hip arthroplasty in England and Wales

A COMPARATIVE ANALYSIS WITH PROJECTIONS FOR THE UNITED STATES. A STUDY USING THE NATIONAL JOINT REGISTRY DATASET

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Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are recognised and proven interventions for patients with advanced arthritis. Studies to date have demonstrated a steady increase in the requirement for primary and revision procedures. Projected estimates made for the United States show that by 2030 the demand for primary TKA will grow by 673% and for revision TKA by 601% from the level in 2005. For THA the projected estimates are 174% and 137% for primary and revision surgery, respectively. The purpose of this study was to see if those predictions were similar for England and Wales using data from the National Joint Registry and the Office of National Statistics.

Analysis of data for England and Wales suggest that by 2030, the volume of primary and revision TKAs will have increased by 117 % and 332%, respectively between 2012 and 2030. The data for the United States translates to a 306% cumulative rate of increase between 2012 and 2030 for revision surgery, which is similar to our predictions for England and Wales.

The predictions from the United States for primary TKA were similar to our upper limit projections. For THA, we predicted an increase of 134% and 31% for primary and revision hip surgery, respectively.

Our model has limitations, however, it highlights the economic burden of arthroplasty in the future in England and Wales as a real and unaddressed problem. This will have significant implications for the provision of health care and the management of orthopaedic services in the future.

Cite this article: *Bone Joint J* 2015;97-B:1076–1081.

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are well-recognised and proven procedures for patients with advanced arthritis, being both clinically and cost effective.[1] Evaluated in terms of quality adjusted life years (QALY),[2] TKA and THA are economically favourable procedures in improving health, with a cost of £2101 and £1372 per QALY gained respectively, which are well below the £20 000 that NHS decision makers are willing to pay for a QALY.[3]

A steady increase in the number of primary and revision TKAs being undertaken in the United States between 1990 and 2000 has been reported.[4] The increase in revision surgery has been attributed to a number of factors, including the increase in primary procedures being undertaken, increased life expectancy, an increased prevalence of obesity and extending the surgical indications to younger patients.[5,6] It has been estimated that by 2030, the demand for primary TKA will increase by 673% and for revision TKA by 601% compared with the number undertaken in 2005.[7] Projections for THA are more conservative, with demand for primary procedures increasing by 174%, and for revision THA by 137%.[7] From the New Zealand Joint Registry, Hooper et al[8] have shown that the demand for TKA and THA will increase by 183% and 84%, respectively, from the levels in 2001. For a Swedish citizen aged ≥ 40 years, the incidence of THA in 2010 was 332 per 100 000 people, and it is predicted to increase to 784 per 100 000 by 2030.[9] Culliford et al[10] found that the rate of primary TKA trebled and the rate of primary THA had doubled between 1991 and 2006 in the United Kingdom. Hospital costs for revision TKA in the Medicare US population have been predicted to be in excess of $2 billion by 2030.[11] By the end of 2015, hospital charges for all revision TKAs in the United States are predicted to reach $4.1 billion, while charges for revision THA have been projected to cost $3.8 billion.[12]

The population of England and Wales continues to increase from 56 million, as determined by the mid 2011 census. Estimates from

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doi:10.1302/0301-620X.97B8.35170 $2.00

Bone Joint J
2015;97-B:1076–1081.
Received 22 September 2014; Accepted after revision 8 April 2015

the Office of National Statistics (ONS) predict a rise to 64 million by 2030.[13] This increase, particularly in the older population, will have an impact on the number of TKAs and THAs which are undertaken. In 2012, a total of 84 653 entries were submitted to the 9th National Joint Registry (NJR) report for England, Wales and Northern Ireland, 79 516 being primary and 5137 being revision TKAs.[14] Furthermore, 86% of revision TKAs were performed under the umbrella of the National Health Service (NHS).[14] For THA, a total of 80 314 entries were made, 71 672 being primary procedures and 8641 being revisions. The expenditure associated with revision TKA and THA carried out under the NHS in 2000 exceeded £60 million.[15] Compared with primary procedures, the cost of revision surgery and the consumption of hospital resources is substantially greater. Revision operations take longer, require more expensive prostheses, and the patients stay in hospital longer with higher associated complication rates and morbidity. All these factors lead to higher costs and an increased burden on resources. Furthermore, the indication for revision surgery has a direct effect on cost, with infected cases being significantly more expensive than aseptic revisions.[16] In the United States, the proportion of revision TKAs being undertaken for infection has been projected to increase from 16.8% in 2005 to 65.5% in 2030. The incidence of deep infection in primary and revision operations has also been projected to increase at a similar rate for TKA and THA.[17] These forecasts present a bleak epidemiological and economic outlook for revision arthroplasty. With the implication of financial austerity measures and rationing, the quantification of the future burden is both important and necessary.

The purpose of the study was to quantify the revision TKA and THA burden in England and Wales with the passage of time, aiming to determine whether the projected estimates for the United States are applicable to trends observed in NJR data for part of the United Kingdom population.

Materials and Methods

Data sources. The NJR has collected data on all primary and revision TKAs and THAs undertaken by public and private providers in England and Wales since 2003. Data were available for nine consecutive years from the first report, which was published in 2004. Demographic data (age and gender) for these patients was recorded. We only used data from 2005 onwards, in order to avoid the problem of invalidly attributing increasing annual volumes to low coverage in the NJR's first two years. Owing to the proportion of primary and revision operations with missing age or gender information in 2005, 2006 and 2007 (28%, 16%, 6%, respectively for knees and 25%, 17%, 6%, for hips, compared with > 3% for both in subsequent years), these years were not considered in the analysis. Estimated coverage based on the proportion of registered implant tax returns suggests that from 2008, the registry has collected > 90% of all procedures performed in England and Wales. Starting in 2012, the NJR also recorded procedures from Northern Ireland, but these data were excluded. Our sample covers the period until 2012. We obtained the data from the NJR in January 2014, however, we were unable to incorporate 2013 data as this had not been fully processed at the time.

Variables. We used information from the NJR on the type of procedure to identify primary (primary, primary complex) and revision (revision single stage and revision two-stage) procedures, and information on the calendar year of operation, gender and age. Age was categorised into five groups (< 44 years, 45 to 64, 65 to 74, 75 to 84, > 85 years). We obtained data from the ONS on the total population in each year for the ten gender–age groups. We also obtained the size of the projected population for the years from 2013 to 2030 for these groups.

Statistical analysis. Two sets of analyses were performed, one for TKAs and one for THAs. In each case we ran four separate Poisson regressions on the annual number of procedures, one regression per gender-operation (primary *vs* revision) combination. In each regression we included a covariate for the difference between the year of operation minus the reference year (2008), and its squared value as a second covariate; four covariate indicators for the individual age groups (one per group except for between 65 and 74 years, which acted as the reference group); and an offset variable for the size of the population (i.e. the natural logarithm of the size of the population with its coefficient fixed at one), to adjust for the effect of variations in the size of the population on the number of operations in a given year. Covariates whose estimated coefficients had p-values > 0.1 were excluded from the subsequent, final iteration of the respective regression model.

The estimated effects of the year, age and size of population covariates were used to project the volume of operations in subsequent years based on the size of the population projected by the ONS by age and gender for the period between 2013 and 2030. We distinguish the effect of a one-year period on the volume of operations, independent of the size of population and age structure, and refer to it as the annual rate of change in the incidence. The projected quantities by year from the Poisson regression for men were added to projections from the Poisson regression for women to obtain the total number of projected operations for each type of operation.

Results

Our best estimates suggest that the future growth in the total number of primary TKAs will be dominated by operations undertaken on women. By the end of the observation period, the volume of primary TKAs was growing at an annual rate of 1.6% in men, while in women the rate of these operations was increasing at an annual rate of 3.2% (Table I). We assumed primary operations would increase at these annual rates throughout the period between 2012 and 2030,

Table I. Number of hip and knee arthroplasties in England and Wales between 2008 and 2012

Procedure		2008	2009	2010	2011	2012
Primary knee arthroplasties	n	77 766	79 128	81 500	84 693	88 038
	Annual change (%)		*1.8*	*3.0*	*3.9*	*3.9*
	Mean annual change (%) 2008 to 2012			*3.2*		
Revision knee arthroplasties	n	4067	4414	4915	5003	5668
	Annual change (%)		*8.5*	*11.4*	*1.8*	*13.3*
	Mean annual change (%) 2008 to 2012			*8.7*		
Primary hip arthroplasties	n	71 077	71 472	73 581	76 355	79 949
	Annual change (%)		*0.6*	*3.0*	*3.8*	*4.7*
	Mean annual change (%) 2008 to 2012			*3.0*		
Revision hip arthroplasties	n	7038	7332	8030	8918	10008
	Annual change (%)		*4.2*	*9.5*	*11.1*	*12.2*
	Mean annual change (%) 2008 to 2012			*9.2*		

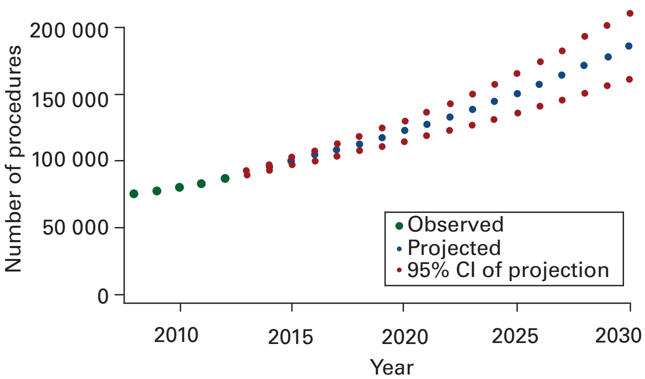

Fig. 1

Graph showing the actual and projected total number of primary total knee arthroplasties with 95% confidence intervals (CI) in England and Wales.

although the annual rate of increase of the total number of primary TKAs in women had been rising over the five-year observation period. Alternatively, we presented a scenario whereby the rising trend in women during the whole observation period continued during the projected phase. We applied the same logic to the projected trends of revision TKAs, and to the projected trends for primary and revision THAs for comparison.

Primary TKAs in the 18 years after 2012 are projected to be similar in number to THAs based on the trends of the last few years of available data, as shown in Figure 1 and the estimates for both TKA and THAs in Figure 2a. This would imply a rate of increase between 2012 and 2030 of 117% (95% confidence interval (CI) 83 to 40). We present the alternative, extreme projection scenario where the rate of primary TKA in women grows at an ever increasing rate (Fig. 2b). In this case the projected rate of increase in primary TKA and THAs during this period would be 546% and 908%, respectively (Table II).

The number of revision operations is expected to increase relative to the number of primary operations at constant proportional increase in incidence rates for TKAs (Figs 3 and 4a) and THAs (Fig. 4a). Comparing Figures 4a and 4b shows that the effect of demographic trends alone accounts for a larger share of the total projected increase in revision knee operations than for hip revisions. If the incidence of revision operations continues to increase at the observed annual rate of 7.3 (relative risk (RR): 1.073; 95% CI 1.056 to 1.090) in men and 6.4% in women (RR 1.064; 95% CI 1.050 to 1.079), they will constitute an increasing share of knee operations, assuming a constant rate of increase in the incidence of primary operations in women. In this scenario, the number of revision TKA operations would increase by 332% (95% CI 242 to 422) between 2012 and 2030 (Table II). The number of revision THAs is projected to grow at a higher rate, but unlikely to sustain the high accelerating rates observed in the period from 2008 to 2012. Our projections are, therefore, based on a constant annual rate of growth in incidence, at the estimated pace of the last observed year.

Discussion

Analysis of NJR and ONS data for England and Wales suggests that by 2030, the number of primary and revision TKAs will have increased by 117% and 332%, respectively. These numbers reflect a constant annual rate of increase in the incidence of these operations at the average rate observed between 2008 and 2012. If the increasing incidence of primary TKAs observed among women during this period is used instead for projection, the number of primary TKAs would increase by 546% during these 18 years.

The cumulative projected rate of increase in the number of TKAs in the United Kingdom is similar to predictions made by Kurtz et al[7] for the United States. The 601% rate of increase for revision TKAs between 2005 and 2030 in the United States translates to an average 8% annual rate of increase; that is, a cumulative rate of increase of 306% in the United States between 2012 and 2030. For the same period, we obtained a 332% cumulative prediction of increase for England and Wales. Similarly, the rate of increase in primary TKAs for the same period of 336% in the United States is in line with our upper limit projections for England and Wales, which are based on the assumption that the increasing incidence observed in the past few years will persist over the entire projected period.

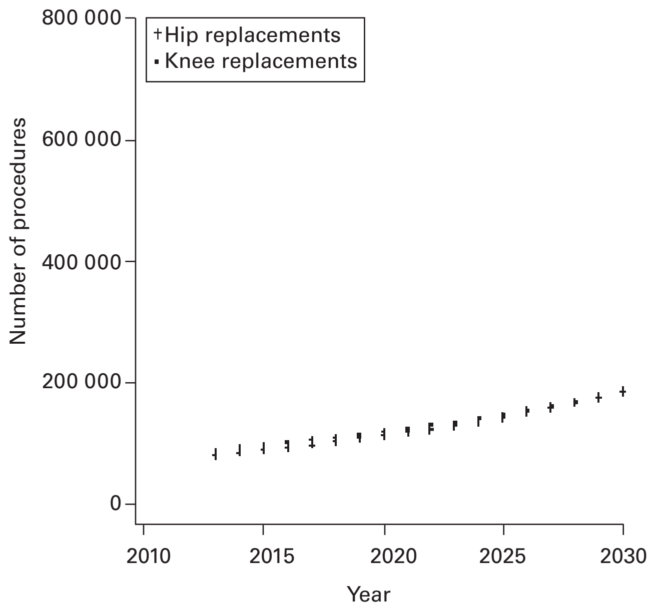

Fig. 2a

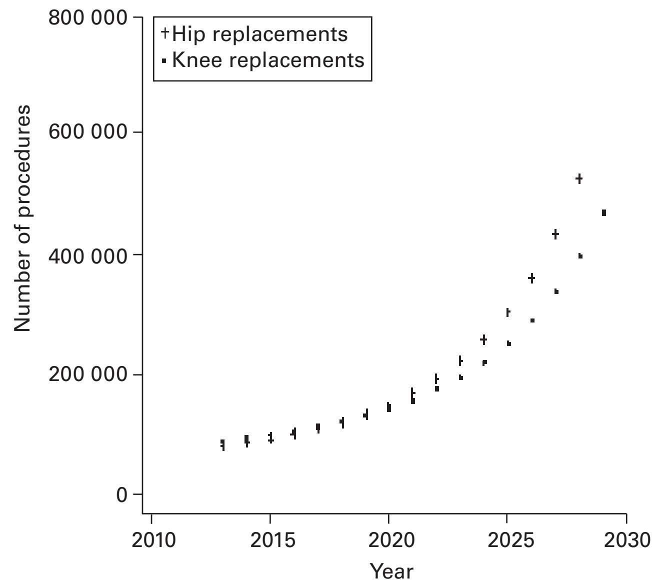

Fig. 2b

Graphs showing the projected total number of primary total hip and knee arthroplasties in England and Wales between 2012 and 2030, when the incidence rate is subject to a) constant and b) accelerating proportional increase.

Table II. Projected growth of total hip and knee arthroplasties (THA, TKA) with 95% confidence intervals (CI) between 2012 and 2030

Procedure		**Year**	**Number (95% CI)**	**Predicted growth % (95% CI)**
Primary TKA	Actual	2012	88 038	-
	Projected – constant proportional growth in incidence	2030	186 302 (160 967 to 211 638)	*117* (83 to 140)
	Projected – accelerating proportional growth in incidence	2030	568 961 (259 507 to 878 415)	*546* (195 to 898)
Revision TKA	Actual	2012	5668	-
	Projected – constant proportional growth in incidence	2030	24 496 (19 403 to 29 589)	*332* (242 to 422)
	Projected – constant incidence	2030	7224 (7066 to 7382)	*27* (25 to 30)
Primary THA	Actual	2012	79 949	-
	Projected – constant proportional growth in incidence	2030	186 893 (143 724 to 230 061)	*134* (80 to 188)
	Projected – accelerating proportional growth in incidence	2030	805 835 (173 117 to 1 438 554)	*908* (116 to 1699)
Revision THA	Actual	2012	10048	-
	Projected – constant proportional growth in incidence	2030	137 056 (69 842 to 204 270)	*1264* (595 to 1933)
	Projected – constant incidence	2030	13154 (12 848 to 13 461)	*31* (28 to 34)

Our analysis has some limitations. The projections were based on demographic trends and the observed relative use of operations in men and women of different ages. We did not account for differences by ethnicity, on which we had no information, or the effects of risk factors such as obesity, on which incomplete data were available to the NJR (with missing information for approximately one in three in 2012). These factors are likely to affect the future use of these operations. However, we expect that the effect of ethnicity would be less than that of age and gender. Furthermore, our estimated increasing temporal trend in operations, given a fixed size, age and gender mix of the population, is partly likely to reflect the higher predicted prevalence of obesity, as well as the emergence of joint arthroplasty as standard practice.[18] The incidence of obesity is postulated to increase the rate of primary operations as obese patients develop arthritis at an earlier stage.[19] This will also affect the rates of revision operations as primary arthroplasty will be potentially performed in younger patients who may require revision earlier. Surgeons may become more proficient at performing arthroplasty surgery in obese patients such that the threshold to operate might fall, further increasing the incidence of primary operations.

Our study does not account for cultural attitudes towards arthroplasty surgery and improving technology. There have been advances in technology, such as the improved wear characteristics of polyethylene.[20] In the future, the indications for arthroplasty may include younger patients and this fact combined with improved functional outcomes and better patient selection may again affect the demand for arthroplasty and revision surgery.

In our analysis, we accounted for the effect of sampling uncertainty in our projections, but did not account for the uncertainty of demographic projections from the ONS, which underpins the projected volumes of TKA and THA. Medical advances will mean that patients will have a longer

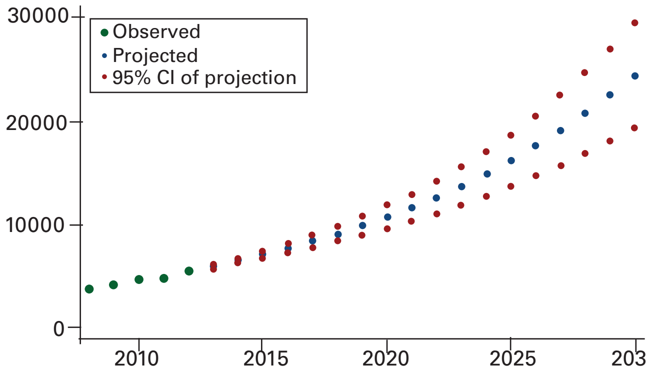

Fig. 3

Graph showing the projected total number of revision knee arthroplasties in England and Wales between 2013 and 2030.

life expectancy and higher levels of activity in old age. This could mean that the actual burden of primary and revision arthroplasty surgery will be far greater than we have predicted. We have only used data from the last five years from the NJR for England and Wales as prior data were incomplete. However, from this we have made an 18-year projection and acknowledge this potential limitation. This is, however, currently the best model that we have.

The demand for arthroplasty has increased over the last ten years and has been shown to be insensitive to economic downturns in the United States.[21] Predictions based on national health expenditure projections for primary THA in 2020 suggest a higher demand than had been anticipated previously, and this may cause concern for future health rationing among national funding bodies as well as providers.[7,21] This problem may become more severe in the near future because of the inadequate provision of infrastructure within healthcare to cope with increases in demand for arthroplasty surgery, resulting in patients having to wait longer for operations. This, together with the financial burden, may reduce access to arthroplasty and have a negative effect on figures projected for 2030.

Medical advances in the management of inflammatory arthritis have revolutionised the burden of disease in these patients. As a result, the surgical workload has been dramatically altered. Our projections do not take into account the possibility of similar advances in the medical management of osteoarthritis, which might reduce the demand for arthroplasty surgery. Our study specifically analyses the numbers of arthroplasties in England and Wales, which we predict to be in the range of 186 302 to 568 961 and 186 893 to 805 835 for primary TKA and THA, respectively, in 2030. These imply cumulative predictions of growth of the same order of magnitude as that reported for the United States.

Many changes will be required in the planning and delivery of health care as well as in the organisation of orthopaedic services if this increased demand for arthroplasty is to be accommodated.

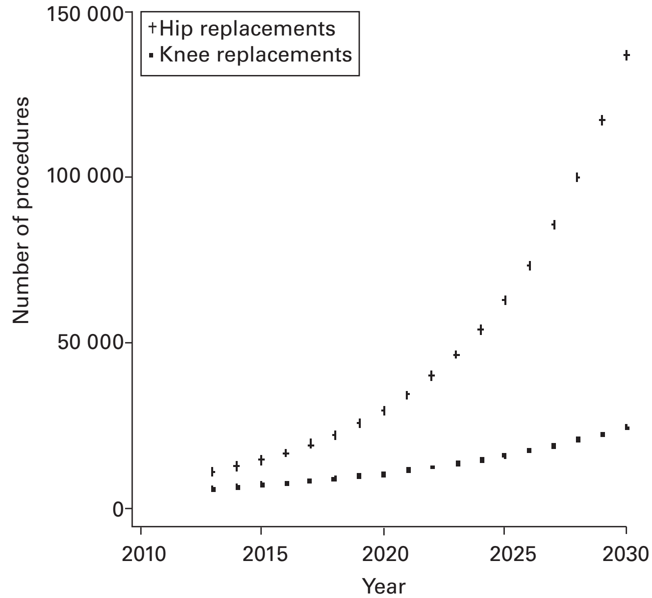

Fig. 4a

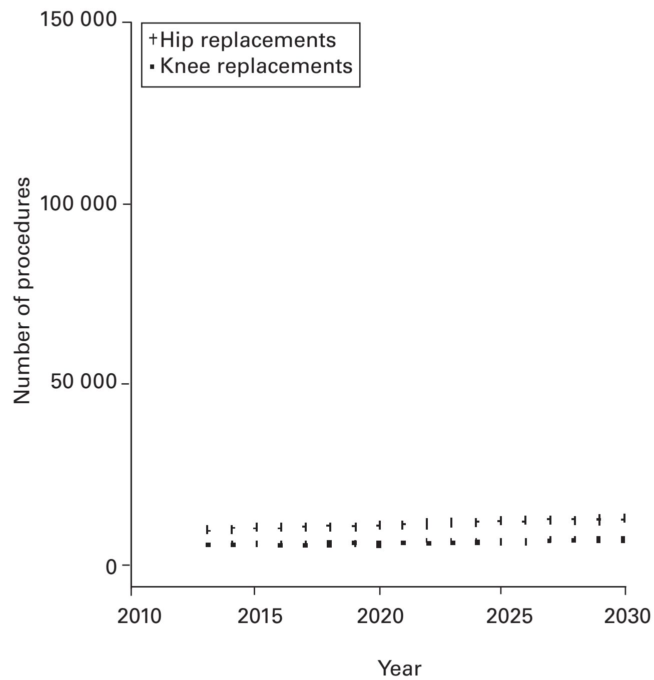

Fig. 4b

Graphs showing the projected total number of revision hip and knee arthroplasties at a) constant proportional increase in incidence rate and b) constant incidence rate in England and Wales between 2013 and 2030.

Supplementary material

Tables showing the estimated coefficients of the regression equations used to predict the use of hip and knee arthroplasties over the period between 2013 and 2030 are available with the online version of this article at www.bjj.boneandjoint.org.uk

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A. D. Toms: Initiated project, Given NJR approval, Writing the paper with all co-authors, Gave final approval pre-submission.

We thank the patients and staff of all the hospitals in England, Wales and Northern Ireland who have contributed data to the National Joint Registry. We are grateful to the Healthcare Quality Improvement Partnership (HQIP), the NJR Research Sub-Committee and staff at the NJR Centre for facilitating this work.

This work was commissioned by the National Joint Registry Research Sub-Committee.

The authors have conformed to the NJR's standard protocol for data access and publication. The views expressed represent those of the authors and do not necessarily reflect those of the National Joint Registry Steering Committee or the Health Quality Improvement Partnership (HQIP) who do not vouch for how the information is presented.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primary edited by G. Scott and first proof edited by J. Scott.

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