The Knee 26 (2019) 207–212

Contents lists available at ScienceDirect

The Knee

Older age and female gender are independent predictors of early conversion to total knee arthroplasty after high tibial osteotomy

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ARTICLE INFO

Article history:
Received 20 June 2018
Received in revised form 17 October 2018
Accepted 7 November 2018

Keywords:
High tibial osteotomy
Osteoarthritis
Failure
Survival
Predictors

ABSTRACT

Background: The primary aim was to assess survival of opening wedge high tibial osteotomy (HTO) for medial compartment osteoarthritis. The secondary aim was to identify independent predictors of early conversion to total knee arthroplasty (TKA).
Methods: During the 18-year period (1994–2011) 111 opening wedge HTO were performed at the study centre. Mean age was 45 years (range 18–68) and the majority male (84%). Mean follow-up was 12 (range six to 21) years. Failure was defined as conversion to TKA. Kaplan–Meier, Cox regression and receiver operating curve (ROC) analyses were performed.
Results: Forty (36.0%) HTO failed at a mean of 6.3 years (range one to 15). By Kaplan–Meier analysis, the five-year survival rate was 84% (95% confidence interval (CI) 82.6–85.4), 10-year rate 65% (95% CI 63.5–66.5) and 15-year rate 55% (95% CI 53.3–56.7). Cox regression analysis identified older age (hazard ratio (HR) 1.07 for each additional year, 95% CI 1.03–1.11, p b 0.001) and female gender (HR 2.37, 95% CI 1.06–5.33, p = 0.04) as independent predictors of failure. ROC analysis identified a threshold age of 47 years above which the risk of failure increased significantly (area under curve 0.72, 95% CI 0.62–0.81, p b 0.001). Cox regression analysis, adjusting for covariates, identified a significantly greater (HR 2.49, 95% CI 1.26–4.91, p = 0.01) risk of failure in patients aged 47 years old or more.
Conclusion: The risk of early conversion to TKA is significantly increased in females and those older than 47. These risk factors should be considered pre-operatively when planning intervention for isolated medial compartment osteoarthritis.

1. Introduction

High tibial osteotomy (HTO) for the treatment of knee osteoarthritis was introduced by Jackson and Waugh in 1961 [1] and refined by Coventry in 1965 [2]. The procedure has been recommended particularly for younger active patients with symptomatic medial compartment osteoarthritis. The rationale of HTO is to restore or to slightly overcorrect the tibio-femoral angle and thereby redistribute the load through the knee from the medial to the lateral tibio-femoral joint [1,2]. In this way, symptoms of osteoarthritis may be relieved with relative preservation of bone stock and to avoid or at least delay the need for total knee arthroplasty (TKA). This is particularly helpful in younger patients, where the long-term aim is to delay primary arthroplasty and therefore reduce the risk of subsequent revision surgery.

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https://doi.org/10.1016/j.knee.2018.11.008
0968-0160/

A small number of previous studies have estimated HTO survival rates. For example a Finnish registry study reported a five-year survival rate of 89% (95% confidence intervals (CI) 88–90) and a 10-year rate of 73% (95% CI 72–75) [3], while an American study described a 15-year survival rate of 56% [4]. However, survival rates may vary substantially between different countries and patient cohorts, and accurate data are heavily dependent on follow-up. Only a small number of previous studies have analysed potential predictors of HTO survival [4–7].

The primary aim of this study was to assess the medium to long-term survival of the opening wedge HTO for medial compartment osteoarthritis. The secondary aim was to identify independent predictors of early (before 12 years) conversion to TKA.

2. Methods

A consecutive series of opening wedge HTO operations performed at the study centre (which serves a population of approximately 780,000 people) between the 1st January 1994 and 31st December 2011 were retrospectively identified from a prospectively compiled patient database. The indication for undertaking the procedure was isolated medial compartment osteoarthritis in a varus knee. Patients undergoing HTO for other indications, such as cartilage resurfacing, meniscal transplantation and ligament reconstruction, were excluded from the study.

Patient demographics and comorbidities were recorded retrospectively from their medical notes. The Scottish Index of Multiple Deprivation (SIMD) was used (at the level of patient postcode) to assess each patient's socio-economic status; this parameter takes into account employment, income, crime, housing, health, education and access to services [8]. Patients were allocated to an ordinal quintile, which ranged from SIMD quintile one (most deprived) to five (least deprived). Post-operative complications were recorded from electronic medical records. Patient mortality data were obtained from hospital records and the Scottish Office (Communities Analytical Services, Scottish Executive Justice and Communities) to enable survival analysis to be adjusted for those patients who had died during the study period.

2.1. Procedure

HTO was performed or directly supervised by a consultant surgeon. Under tourniquet, an eight to 10 cm incision was made parallel to the anterior border of the medial collateral ligament, adjacent to the anteromedial aspect of the proximal tibia. The medial collateral ligament was stripped from the tibia posteriorly to expose the proximal medial surface of the tibia. Under the guidance of fluoroscopy, a guide wire was advanced medially from one to two centimetres distal to the level of the joint up to the lateral cortex, and an osteotomy apparatus was mounted on the guide wire. A second Kirschner wire was then introduced at an appropriate angle up to the lateral cortex. Medial, anterior and posterior cortices were cut immediately under the guide wire up to one centimetre to the lateral cortex. The osteotomy was opened until the lower limb mechanical axis passed across the Fujisawa point [9]. The osteotomy was fixed with a plate (non-locking and when locking plates became more mainstream practice was changed) and the osteotomy site was grafted with an allogenic bone graft (femoral head). After the closure of the layers, the knee was placed into a hinged immobilizer. Prophylactic intravenous antibiotics were administered before application of the tourniquet. Patients were allowed to walk non-weight-bearing (using two crutches) for six weeks. Full weight-bearing was permitted six weeks after surgery, when strengthening exercises were initiated. Patients were clinically reviewed at six weeks after surgery, then one, five and 10 years later.

2.2. Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). Failure of HTO was defined as conversion to TKA. Univariate analysis of failure was performed as follows: (i) unpaired Student's t test was used to compare patient age (as a linear variable) between groups (i.e. failure and no failure) and (ii) chi-squared test was used to compare gender and SIMD (as categorical and ordinal variables, respectively) between groups (i.e. failure and no failure). Kaplan–Meier analysis and a life table were used to examine HTO survival as a function of time. Patients reaching the end of their follow-up period and/or dying were censored. HTO failure was recorded as the primary endpoint. When a patient was censored, the total number of patients at risk fell by one. When an HTO failed, the failure proportion of those at risk was calculated as a simple proportion and added to the cumulative failure proportion (hazard proportion). A Cox proportional hazards model was used to examine the independent effects of the respective variables on survival over time. Receiver operating characteristic (ROC) analysis was used to identify a threshold (cut-off point) for age at which HTO failure was more likely. The area under the curve (AUC) ranges from 0.5 (a test with no accuracy) to 1.0 (a test with perfect accuracy). The threshold is equivalent to the point (age) at which the sensitivity and specificity are maximal in predicting failure. A p-value <0.05 was defined as showing a significant difference between comparison groups. A post hoc power calculation was performed for the regression model using the minimum odds ratio of 2.4 and the sample size of 111 patients offered an alpha of 0.04 and a power of 97% using a one-way analysis.

Ethical approval was not required due to the retrospective nature of the study assessing routinely collected data.

Table 1
Life table for cumulative survival of medial open wedge HTO for OA.

Years since operation	Number at start	Failure	Withdrawn	Number at risk	Annual failure rate (%)	Cumulative survival	95% CI	
							Lower	Upper
0 to 1	111	0	0	111	0	100.0	98.6	100
1 to 2	111	6	2	110	5	95.0	93.6	96.4
2 to 3	103	6	0	103	6	89.0	87.7	90.4
3 to 4	97	3	0	97	3	86.0	84.6	87.4
4 to 5	94	3	0	94	3	84.0	82.6	85.4
5 to 6	91	1	2	90	1	83.0	81.4	84.6
6 to 7	88	3	7	84.5	4	80.0	78.4	81.7
7 to 8	78	3	8	74	4	76.0	74.4	77.6
8 to 9	67	3	13	60.5	5	73.0	71.4	74.6
9 to 10	51	5	5	48.5	10	65.0	63.5	66.5
10 to 11	41	3	5	38.5	8	60.0	58.6	61.4
11 to 12	33	1	2	32	3	58.0	56.5	59.5
12 to 13	30	0	3	28.5	0	58.0	56.4	59.6
13 to 14	27	0	4	25	0	58.0	56.3	59.7
14 to 15	23	1	4	21	5	55.0	53.3	56.7
15 to 16	18	2	6	15	13	48.0	46.5	49.5

3. Results

During the 18-year period (1994–2011), 111 opening wedge HTO operations were performed on 111 patients for medial compartment osteoarthritis at the study centre. The study cohort comprised 93 (83.8%) men and 18 (16.2%) women. Patient mean age was 45 years (range 18–68). Mean follow-up of the study cohort was 12 years (range six to 21). During this time 13 patients died.

3.1. HTO survival

Forty (36.0%) patients were converted to TKA at a mean follow-up of 6.3 years (range one to 15). Table 1 illustrates the life table for survival after HTO. Kaplan–Meier analysis (Figure 1) revealed a five-year survival rate of 84% (95% CI 82.6–85.4), a 10-year rate of 65% (95% CI 63.5–66.5) and a 15-year rate of 55% (95% CI 53.3–56.7). The Kaplan–Meier curve demonstrated a steady failure rate, with no sharp decline (Figure 1).

3.2. Predictors of failure

Univariate analysis (Table 2) demonstrated older age to be a significant risk factor for HTO failure ($p < 0.001$). Gender ($p = 0.18$) and SIMD ($p = 0.25$) were not significant factors in univariate analysis. However, Cox regression analysis (Table 3, Figure 2), adjusting for covariates, identified both older age ($p < 0.001$) and female gender ($p = 0.04$) as independent predictors of failure.

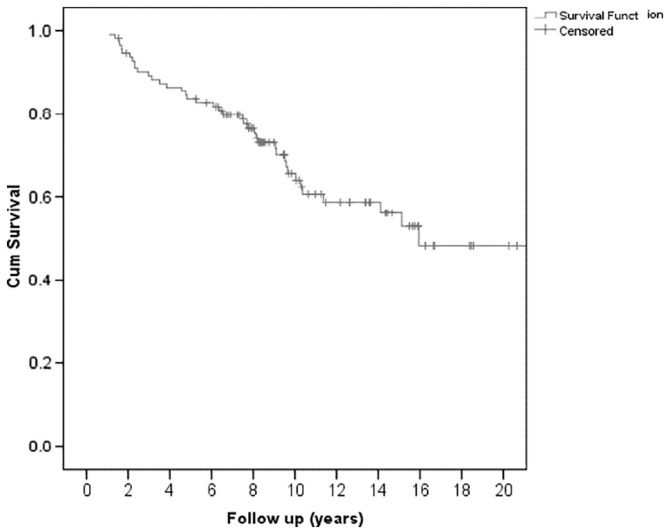

Figure 1. Kaplan–Meier survival curve for the study cohort (n = 111) after HTO, with conversion to TKA being defined as failure. | = censored patients.

Table 2
Patient demographics the cohort (n = 111) and predictors of revision (conversion to TKA) after HTO on univariate analysis.

Predictor	Cohort (n = 111)	Revised (n = 40)	Not revised (n = 71)	Diff/OR (95% CI)	p-Value
Age (years: mean, SD)	45 (10.1)	50.1 (6.8)	42.3 (10.9)	Diff. 7.8 (4.0 to 11.6)	<0.001[a]
Gender (n, %)					
Male	93 (83.8)	31 (77.5)	62 (87.3)	OR 0.5 (0.2 to 1.4)	0.18[b]
Female	18 (16.2)	9 (22.5)	9 (12.7)		
SIMD (quintiles %)					
Q1 most deprived	8 (7.2)	4 (10.0)	4 (5.6)	–	0.25[b]
Q2	23 (20.7)	13 (32.5)	10 (14.1)		
Q3	28 (25.2)	8 (20.0)	20 (28.2)		
Q4	27 (24.3)	9 (22.5)	18 (25.4)		
Q5 least deprived	20 (18.0)	6 (15.0)	14 (19.7)		

Diff = difference, R = odds ratio.
[a] Student's t-test.
[b] Chi square test.

Table 3
Cox regression analysis to identify independent predictors of failure (conversion to TKA) after HTO.

Predictor	Hazard ratio	95% CI	p-Value
Age (for each year)	1.07	1.03 to 1.11	<0.001
Gender			
Male	Reference		
Female	2.37	1.06 to 5.33	0.04
SIMD			
Q1 most deprived	Reference		
Q2	1.18	0.37 to 3.73	0.78
Q3	0.87	0.26 to 2.90	0.82
Q4	0.97	0.30 to 3.17	0.96
Q5 least deprived	0.68	0.19 to 2.45	0.56

For age, each additional year was associated with a seven percent (95% CI three to 11%) increased risk of failure. Women were more than twice as likely than men (hazard ratio 2.4, 95% CI 1.1–5.3) to undergo conversion to TKA. ROC analysis identified a cut point of ≥47 years was predictive of failure, with a sensitivity and specificity of 60% (Figure 3) and AUC using age to predict failure was 0.72 (95% CI 0.62–0.81, p < 0.001). Patients aged 47 years old or more were associated with a significantly greater risk of failure (Cox regression analysis, hazard ratio 2.49, 95% CI 1.26 to 4.91, p = 0.01) when adjusting for covariates (Figure 4).

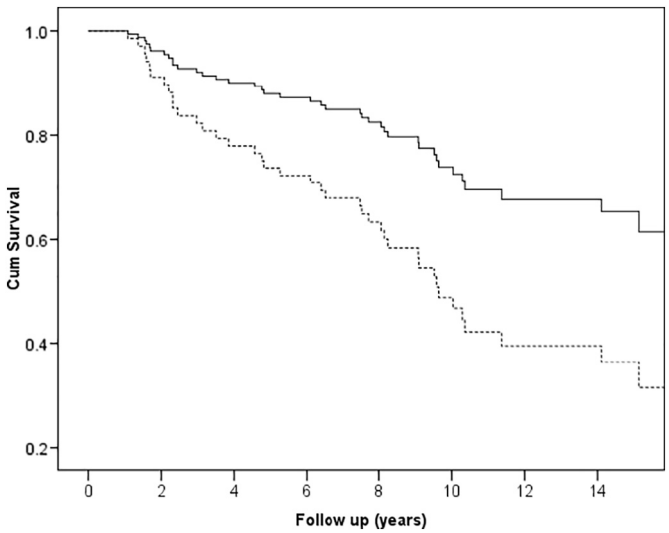

Figure 2. Kaplan–Meier survival curve comparing male (solid line) with female (dashed line) patients after HTO, with conversion to TKA being defined as failure.

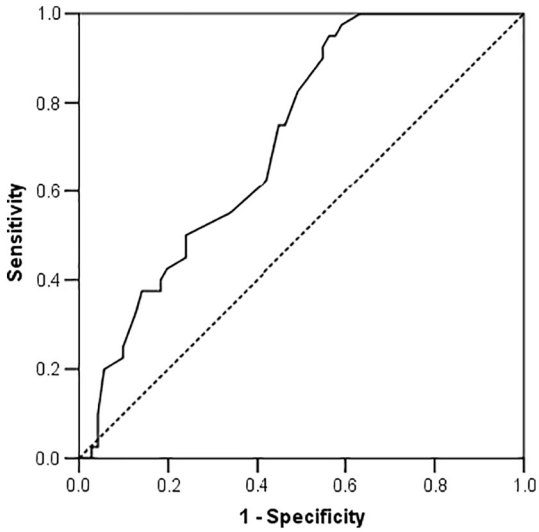

Figure 3. A ROC curve assessing risk of failure according to age, which determined a threshold value of 67 with a sensitivity and specificity of 71.5%.

4. Discussion

This study has demonstrated a five-year survival rate of 84%, a 10-year rate of 65% and a 15-year rate of 55% for opening wedge HTO for the treatment of medial compartment osteoarthritis of the knee. There were two independent predictors of failure; older age and gender. Older patients were significantly more likely to require early conversion to TKA with a threshold identified at an age of 47 years, above which the failure risk was significantly increased. The significant difference between survival rates above and below this threshold was apparent within 12 years of surgery (from Kaplan–Meier analysis, Figure 4), but survival rates continued to diverge during the course of the follow-up period. In addition, women were significantly more likely to require conversion to TKA than men, which became apparent only after adjustment for age.

It was interesting to note that socio-economic deprivation did not significantly influence HTO failure in the dataset, even after controlling for age and gender, though hazard ratios for HTO failure were numerically higher in patients with higher levels of socio-economic deprivation (Table 3). However, the data suggests that the influence of socio-economic deprivation, if real, is smaller than that of age and gender. Interestingly Clement et al. [10] showed similar findings in TKA patient population with no significant difference in TKA patient reported outcomes with social deprivation after adjusting for confounding variables.

Previous studies have reported incredibly varied survival rates ranging from 51% by Naudie et al. [11] to 93.2% by Koshino et al. [12] at 10 years. Age was demonstrated as an independent predictor of survival of HTO in the current study which is supported by a recent registry study from Canada [13]. The significant effect of gender found in the current study is also supported by

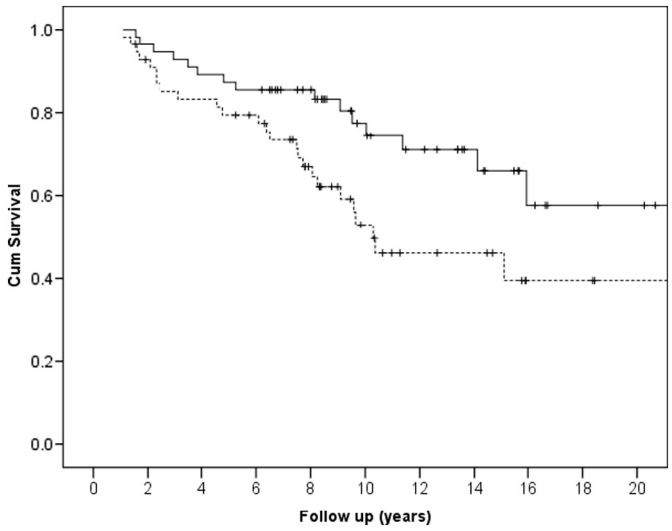

Figure 4. Kaplan–Meier survival curve comparing patients <47 years old (solid line) with those ≥47 years old (dashed line) after HTO, with conversion to TKA being defined as failure. | = censored patients.

registry data from Finland [3]. Several cohort studies have also reported that age and sex are significant [4,5]. This demonstrates importance of taking into account patient characteristics when comparing HTO survival between hospitals/countries/studies, especially age and sex.

The strengths of this study include the prospective nature of data collection from a relatively large cohort of patients; this provided sufficient study power to detect differential failure rates according to both age and gender. In addition, the Kaplan–Meier methodology enabled meaningful calculation of failure rates despite differential follow-up times, while the Cox regression methodology permitted analysis of the effects of several parameters on failure. However, the study is limited by the retrospective nature of its planning. One limitation is that body mass index (BMI) data were not available for all patients and could not be used. This parameter would have provided a useful additional covariate for inclusion in Cox regression analysis, given that a previous study reported BMI as another independent predictor of failure [14]. In addition, the grade of osteoarthritis was not recorded pre-operatively and therefore could not be included in the analysis as radiographs for the vast majority of these patients were not available due to them bring destroyed at the introduction of the centre's digital imaging system and them not being transferred across.

The literature is undecided in regard to outcomes of conversion to TKA following HTO compared to primary TKA in the native knee. Several studies have shown worse outcomes [15,16] whereas some have shown no difference [16]. However, it is generally accepted the TKA is more technically demanding after previous HTO [17]. A systematic review concluded patients receiving TKA after failed HTO showing similar outcomes of TKA in native joints [18].

5. Conclusion

The risk of early conversion to TKA after an opening wedge HTO is significantly increased in female patients and those older than 47 years old. These risk factors should be considered pre-operatively and discussed with patients when planning surgical intervention for isolated medial compartment osteoarthritis.

Conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
There are no declarations of interest to declare for any authors.

Ethical statement

This study was discussed prior to initiation with the local ethics committee and the decision was that as it was an observational study with no alteration of existing practice that it was exempt from requiring a formal research ethics committee application and the study was approved to proceed.

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