A population-based study of prevalence and hospital charges in total hip and knee replacement

Wei-Che Tien · Hao-Yun Kao · Yuan-Kun Tu ·
Herng-Chia Chiu · King-Teh Lee · Hon-Yi Shi

Received: 18 April 2008 / Accepted: 19 May 2008 / Published online: 9 July 2008
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Abstract The purpose of this study was to explore the increasing prevalence of factors affecting hospital charges for primary total hip replacement/total knee replacement (THR/TKR). This study analysed 37,918 THR and 76,727 TKR procedures performed in Taiwan from 1996 to 2004. Odds ratio (OR) and effect size (ES) were calculated to assess the relative change rate. Multiple regression models were employed to predict hospital charges. The following factors were associated with increased hospital charges: age younger than 65 years old; increased disease severity (Charlson comorbidity index [CCI]=1 or ≥ 2); absence of primary diagnoses of osteoarthritis (OA), rheumatoid arthritis (RA), avascular necrosis (AVN); treatment at a hospital or by a surgeon performing a high volume of operations; and longer average length of stay (ALOS). The Bureau of National Health Insurance (BNHI) should ensure that surgeons take precautionary measures to minimise complications and maximise quality of life after surgery. Use of joint prostheses from different manufacturers can reduce costs without compromising patient satisfaction.

Résumé Le propos de cette étude est d'explorer les facteurs influençant la durée moyenne de séjour des prothèses totales de hanche et des prothèses totales du genou. Cette étude a analysé 37 918 prothèses totales de hanches et 76 727 prothèses totales du genou, réalisées à Taiwan de 1996 à 2004. Les facteurs suivants étaient associés à une augmentation de la durée de séjour: un âge inférieur à 65 ans. L'indice de sévérité des lésions CCI=1 ou ≥ 2 , l'absence de diagnostic primaire (coxarthrose, arthrite rhumatoïde, nécrose) le traitement dans un hôpital ou par un praticien réalisant de gros volumes opératoires, la longueur de l'ALOS. Le Bureau Central d'Assurance BNHI demande que les praticiens prennent les mesures nécessaires pour diminuer le nombre de complications et augmenter la qualité de vie après l'intervention. L'utilisation de prothèses de différents fabricants permet de réduire les coûts sans compromettre la satisfaction des patients.

Introduction

The purpose of this study was to explore the increasing prevalence of factors affecting hospital charges of primary total hip replacement/total knee replacement (THR/TKR). This study analysed 37,918 THR and 76,727 TKR procedures performed in Taiwan from 1996 to 2004. Odds ratio (OR) and effect size (ES) were calculated to assess the relative change rate. Multiple regression models were employed to predict hospital charges. The following factors were associated with increased hospital charges: age younger than 65 years old; increased disease severity (Charlson comorbidity index [CCI]=1 or ≥ 2); absence of primary diagnoses of osteoarthritis (OA), rheumatoid arthritis (RA), avascular necrosis (AVN); treatment at a hospital or by a surgeon performing a high volume of

W.-C. Tien · H.-C. Chiu · K.-T. Lee · H.-Y. Shi (✉)
Graduate Institute of Healthcare Administration,
Kaohsiung Medical University,
No. 100, Shih-Chuan 1st Road,
Kaohsiung 807, Taiwan
e-mail: hshi@kmu.edu.tw

H.-Y. Kao
Department of Information Management,
National Sun Yat-Sen University,
Kaohsiung, Taiwan

Y.-K. Tu
Department of Orthopaedics, E-Da Hospital,
Kaohsiung, Taiwan

operations; and longer ALOS. The Bureau of National Health Insurance (BNHI) should ensure that surgeons take precautionary measures to minimise complications and maximise quality of life after surgery. Use of joint prostheses from different manufacturers can reduce costs without compromising patient satisfaction.

The effectiveness of total hip replacement/total knee replacement (THR/TKR) surgery in relieving pain and improving physical function has been well documented [1, 2]. In addition to improved surgical techniques, the excellent performance of new implant materials and designs has substantially increased the demand for THR/TKR. The growing population of elderly patients is yet another factor. In November 1997, the Bureau of National Health Insurance (BNHI) in Taiwan implemented a case payment system for THR/TKR in order to control the use of medical resources. Since the system provides insurance coverage for expensive and frequently used medical items, the financial burden of THR/TKR should not be overlooked.

Although the volume of THR/TKR procedures is increasing annually, the prevalence and hospital charges for these procedures have not been documented in a Taiwan study. The BNHI reported 12,088 primary TKR procedures performed in 2004, a 5.8% increase from the 11,425 procedures in 2003; during the same period, 6,519 primary THR procedures were performed which was a 2.1% rate of increase [3]. Thus, this study explored the increasing prevalence of factors affecting hospital charges for THR/TKR.

Materials and methods

The source of data analysed was the administrative claims data from the BNHI. Because the BNHI is the sole purchaser in Taiwan, the BNHI dataset was presumed to be the most comprehensive and reliable data source for the study. This study analysed data for all patients who received primary THR/TKR procedures (ICD-9-CM procedure codes of 81.51/81.54) during 1996–2004. All THR/TKR procedures performed for treatment of chronic or complicated diseases and traffic accidents were excluded from analysis. The study analysed 39,569 THR and 76,727 TKR procedures.

This study analysed four dimensions of THR/TKR procedures performed in Taiwan: (1) patient demographic characteristics, (2) patient clinical characteristics, (3) hospital/physician surgical volume, and (4) medical resource usage. Demographic characteristics studied included age and gender. Age categories were 44 years old and younger, 45–64 years old, and 65 years old and older. Clinical characteristics analysed were disease severity and primary diagnoses. Disease severity was classified by Charlson comorbidity index (CCI) scores of 0, 1, or ≥ 2 [4]. Primary

diagnoses were categorised as osteoarthritis (OA), rheumatoid arthritis (RA), avascular necrosis (AVN), and other. The ICD-9-CM codes for primary diagnoses of OA, RA, and AVN were 715.00–715.98; 714 and 714.0; and 733.40, 733.42, and 733.49, respectively. Surgical volume of hospital and surgeon were classified as low (≤ 25 th percentile), medium (26th–74th percentiles), and high (≥ 75 th percentile). Medical resource usage was measured by average length of stay (ALOS).

The study period was divided into three approximately equal time intervals (period 1: 1996–1998; period 2: 1999–2001; and period 3: 2002–2004). Odds ratio (OR) and effect size (ES) were determined to assess the relative change for each factor when using period 1 as the reference group in comparison with period 3. Effect size was calculated as the difference between the mean preoperative score and postoperative score, divided by the standard deviation of the preoperative score [5]. Effect size is a method of standardising the extent of change between different factors. An ES of 1.0 is equivalent to a change of one standard deviation in the sample. Effect sizes of 0.2, 0.5, and 0.8 are typically regarded as indicating small, medium, and large changes, respectively. Multiple regression models were used to predict hospital charges, including the patient demographic and clinical characteristics, hospital/surgeon surgical volume, and medical resource usage. Hospital charges of different levels of hospitals were adjusted for differences in reimbursement from the BNHI, which provides the largest reimbursement to medical centres and the smallest to district hospitals. Statistical analyses were conducted using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). To reflect the real dollar value, all dollar values at the end of each year were also adjusted to 2004 Taiwan currency values. All hospital charges were then converted from Taiwan dollars to U.S. dollars using an exchange rate of 31.5:1, based on the average exchange rate during 1996–2004. All tests were two-sided, and *p* values less than 0.05 were considered statistically significant.

Results

The prevalence rate of THR/TKR was 16.69/22.86 per 100,000 persons in 1996 and gradually increased to 22.65/54.95 in 2004, which represented increases at rates of 35.71% and 140.38% separately (Fig. 1). In 1996, the prevalence rate of TKR was 1.72 times that of THR. In 2004, it strikingly increased to 2.43.

Table 1 shows the increasing volume of THR/TKR procedures and the changes in patient demographic and clinical characteristics. Approximately 40% of all THR patients treated from periods 1 to 3 were female, and the

Fig. 1 Rate of change in the prevalence of total hip replacement (THR) and total knee replacement (TKR) from 1996 to 2004

number of female patients significantly increased between periods 1 and 3 (OR=1.07, 95% CI=1.02, 1.12). Conversely, the number of male patients significantly decreased (OR=0.95, 95% CI=0.92, 0.99). Approximately 65% of all THR patients were under 64 years of age. The number of THR patients younger than 44 years old significantly decreased between periods 1 and 3 (OR=0.87, 95% CI = 0.82, 0.91), but the number of THR patients older than 65 years of age significantly increased (OR=1.17, 95% CI= 1.11, 1.23). In terms of clinical characteristics, the data revealed a statistically significant increase in the number of patients with CCI scores of 1 and more between periods 1

and 3 (OR=1.24, 95% CI=1.14, 1.35, and OR=1.31, 95% CI=1.13, 1.51, respectively). The principal diagnoses during periods 1–3 were OA and AVN, which ranged from 39.52–42.52% and from 43.04–47.38%, respectively.

Analysis of demographic characteristics revealed that 70% of all TKR patients were female; the percentage of females increased 1.57% between period 1 and period 3, whereas the percentage of males decreased (−4.25%). Approximately 70% of TKR patients were older than 65 years. The number of patients younger than 44 years old and the number of patients 45–64 years old significantly declined between periods 1 and 3 (OR=0.61, 95% CI= 0.52, 0.72 and OR=0.82, 95% CI =0.79, 0.85, respectively), but the number of patients older than 65 years significantly increased (OR=1.09, 95% CI=1.06, 1.12). In clinical terms, the number of patients who had CCI scores of 1 and more significantly increased between periods 1 and 3 (OR=1.25, 95% CI =1.18, 1.32, and OR=1.14, 95% CI=1.02, 1.28, respectively), and the number of patients with CCI scores of 0 also significantly increased (OR= 0.96, 95% CI=0.94, 0.99). The principal diagnosis in the TKR patients was OA, which ranged from 91.37% to 94.54%.

Table 2 presents the changing trend in medical resources allocated to THR/TKR. Average length of stay (ALOS) and hospital charges of THR/TKR significantly declined ($p < 0.05$). In THR, ALOS declined from 11.82 days to 8.96 days (−24.24%), and total hospital charges decreased from \$4,523.47 to \$3,960.06 (−12.46%). In TKR, ALOS

Table 1 Comparison of changes in surgical volume for 39,569 THR/TKR procedures by patient demographic and clinical characteristics^a

		Total hip replacement (THR)					Total knee replacement (TKR)				
		Period 1	Period 2	Period 3	Change	Odds ratio	Period 1	Period 2	Period 3	Change	Odds ratio
		(N=11217)	(N=13923)	(N=14578)	(%) ^b	(95% CI)	(N=18458)	(N=25391)	(N=32878)	(%) ^b	(95% CI)
Demographic characteristics											
Gender	Female	38.86	38.41	41.65	7.18	1.07 (1.02,1.12)	73.07	73.75	74.22	1.57	1.02 (0.99–1.04)
	Male	61.14	61.59	58.35	−4.56	0.95 (0.92,0.99)	26.93	26.25	25.78	−4.25	0.96 (0.92–1.00)
Age	≤44	28.33	28.68	24.53	−13.41	0.87 (0.82,0.91)	1.65	1.21	1.02	−38.61	0.61 (0.52–0.72)
	45–64	40.93	39.23	39.60	−3.25	0.97 (0.92,1.01)	30.53	26.47	25.06	−17.90	0.82 (0.79–0.85)
	≥65	30.75	32.10	35.87	16.67	1.17 (1.11,1.23)	67.82	72.31	73.92	9.00	1.09 (1.06–1.12)
Clinical characteristics											
CCI	0	88.95	88.12	86.12	−3.18	0.97 (0.93,1.00)	86.10	85.51	82.89	−3.73	0.96 (0.94–0.99)
	1	8.27	8.90	10.25	23.93	1.24 (1.14,1.35)	11.30	11.77	14.14	25.11	1.25 (1.18–1.32)
	≥2	2.78	2.98	3.63	30.72	1.31 (1.13,1.51)	2.60	2.73	2.97	14.43	1.14 (1.02–1.28)
Primary diagnosis	OA	40.02	39.52	42.52	6.25	1.06 (1.02,1.11)	91.37	93.79	94.54	3.47	1.03 (1.01–1.06)
	RA	1.39	1.29	1.29	−7.18	0.93 (0.75,1.15)	3.01	2.84	2.28	−24.38	0.76 (0.68–0.85)
	AVN	43.04	47.38	45.11	4.82	1.05 (1.00,1.10)	0.20	0.05	0.04	−78.60	0.21 (0.12–0.40)
	Other	15.55	11.81	11.07	−28.79	0.71 (0.66,0.77)	5.42	3.32	3.14	−42.07	0.58 (0.53–0.63)

CCI Charlson comorbidity index, OA osteoarthritis, RA rheumatoid arthritis, AVN avascular necrosis

^a Values are percentages

^b Change (%): (period 3 – period 1)/(period 1) × 100 (%)

Table 2 Medical resource usage of total hip and total knee replacement^a

	Period 1	Period 2	Period 3	Change ^b (%)	<i>P</i> value ^c	Effect size (ES)
THR						
ALOS	11.82	9.47	8.96	−24.24	<0.01	−1.04
Charges	142,489.37	129,358.15	124,742.18	−12.46	<0.01	−0.75
TKR						
ALOS	12.83	9.96	9.07	−29.31	<0.01	−1.71
Charges	159,489.73	143,843.13	136,410.76	−14.47	<0.01	−0.94

THR total hip replacement, TKR total knee replacement, ALOS average length of stay

^a Values are means

^b Change (%): (period 3 − period 1)/(period 1) × 100 (%)

^c Independent *t* test was used to evaluate the mean difference between period 1 and period 3

decreased from 12.83 days to 9.07 days (−29.31%), and hospital charges decreased from \$5,063.17 to \$4,330.50 (−14.47%). Additionally, the decline in ES of ALOS and hospital charges was larger in TKR patients than in THR patients between periods 1 and 3.

Tables 3 shows the multiple regression models used to evaluate the predictors for hospital charges. The statistically significant predictors for hospital charges among THR patients were gender, age, severity of disease, primary diagnoses, surgical volumes of surgeon and hospital, and ALOS. This model indicated that male gender, CCI scores of 1 or higher, RA, large surgical volumes of treating surgeon and/or hospital, and longer ALOS were associated with higher

hospital charges for THR, while older age was associated with lower hospital charges. Additionally, the statistically significant predictors for increased total hospital charges among TKR patients were age, disease severity, primary diagnoses, surgical volumes of surgeon and hospital, and ALOS (*p* < 0.05). This model indicated that CCI scores of 1 or more, other diagnoses, larger surgical volume of surgeon and hospital, and longer ALOS were associated with higher hospital charges for TKR, while older age was associated with lower hospital charges. All other covariates did not statistically affect hospital charges.

According to the standardised coefficients, ALOS had the largest coefficient with hospital charges while the lowest was a

Table 3 Multiple regression model of the relationship between total hospital charges and effective predictors for THR/TKR^{*}

Variable	Factor	Total hip replacement (THR)			Total knee replacement (TKR)		
		Unstandardized coefficients	Standardised coefficients	<i>P</i> value	Unstandardised coefficients	Standardised coefficients	<i>P</i> value
(Constant)		2255.51		<0.01	4247.66		< 0.01
Demographic characteristics							
Gender	Male	71.95	0.02	<0.01	−	−	−
Age	45–64	−106.26	−0.03	<0.01	−2181.75	−0.50	< 0.01
	≥65	−161.54	−0.05	<0.01	−2196.83	−0.51	< 0.01
Clinical characteristics							
CCI	1	46.21	0.01	0.04	45.45	0.01	< 0.01
	≥2	370.89	0.04	<0.01	208.15	0.02	< 0.01
Primary diagnoses	OA						
	RA	152.85	0.01	<0.01	−	−	−
	AVN	−25.32	−0.01	0.09	−357.94	−0.01	0.07
	Others	112.80	0.02	<0.01	652.05	0.06	< 0.01
Surgical volume							
Physician	High	196.27	0.04	<0.01	223.60	0.04	< 0.01
Hospital	High	261.10	0.05	<0.01	410.12	0.07	< 0.01
Medical resource utilization							
ALOS		156.21	0.61	<0.01	185.24	0.53	< 0.01
		<i>R</i> ² =0.38, adjusted <i>R</i> ² =0.38			<i>R</i> ² =0.32, adjusted <i>R</i> ² =0.32		

CCI Charlson comorbidity index, OA osteoarthritis, RA rheumatoid arthritis, AVN avascular necrosis, ALOS average length of stay

^{*} Variables entered were gender, age, disease severity, primary diagnosis, surgical volume of physician and hospital and average length of stay. Reference characteristics: gender (female), age (≤44), CCI (0), primary diagnosis (OA), physician (low), hospital (low)

CCI score of 1. Finally, the influence of age on hospital charges in TKR patients cannot be ignored because its standardised coefficient was approximately 0.5 (Table 3).

Discussion

This population-based study was the first to analyse patient demographics and clinical characteristics, hospital/surgeon surgical volume, and medical resource usage to examine changing trends in the prevalence of THR/TKR surgery and to identify factors predictive of hospital charges of THR/TKR surgery. This study demonstrated that the prevalence of these procedures has increased annually. Likely causes are the growing population of elderly patients and improving surgical techniques, implant materials, and designs [6, 7]. This study confirmed the findings of previous studies [8, 9] that female gender, advanced age (≥ 65 years old) and CCI scores of 1 or higher were associated with increased likelihood of undergoing THR/TKR.

In Taiwan, the principal diagnoses in THR patients are OA (approximately 40%) and AVN (approximately 45%), and approximately 94% of TKR patients are diagnosed with OA. However, a U.S. study by Bozic et al. [10] noted that 86% of THR and 90% of TKR patients had OA. A possible explanation for these findings is that THR patients in Taiwan are more likely to use antibiotics, tobacco, and alcohol than those in the United States; however, further research is needed.

Analysis of trends in medical resource usage revealed that ALOS and hospital charges dramatically decreased between period 1 and period 3; this decrease may have been due to improvements in surgical technique, implant material, design, and changes in the medical payment system. Previous studies [11] reveal that minimally invasive surgery can simultaneously reduce complications as well as duration of recovery. The case payment system in Taiwan had not been implemented until period 3 of this study whereas fee-for-service had been implemented in period 1. Many previous studies [12, 13] indicate that case payment dramatically reduces ALOS and hospital charges simultaneously.

In multiple regression analyses, gender was a risk factor in THR, and, on average, males had higher total hospital charges than females, which may have been due to increased disease severity in males than in females before surgery. This study showed that primary diagnoses of other diseases in younger THR patients were mainly ankylosing spondylitis (4.4%), traumatic arthropathy (2.4%), congenital hip deformity (1.5%), congenital hip dislocation (1.6%), and pyogenic arthritis (1.5%). In younger TKR patients, other primary diagnoses were malignant neoplasm of long bones of lower limb (5.5%), traumatic arthropathy (1.1%), congenital factor VIII disorder (1.0%), gouty arthropathy

(0.6%), and chronic osteomyelitis (0.5%). Patients aged younger than 44 had a higher proportion of primary diagnoses than any other age group. A possible cause is the higher hospital charges in this group.

Moreover, higher CCI scores were associated with higher hospital charges. This finding is also consistent with previous studies [14, 15]. Primary diagnosis of other medical conditions was a factor in hospital charges. On further analysis, primary diagnoses of other factors in THR mainly involved mechanical complications of the internal orthopaedic device, implant, or graft (11.5%), fracture (9.3%), congenital hip deformity (7.4%), ankylosing spondylitis (6.6%), and traumatic arthropathy (6.3%). In TKR, other conditions were traumatic arthropathy (11.2%), gouty arthropathy (7.5%), malignant neoplasm of long bones of lower limb (7.0%), mechanical complications of the internal orthopaedic device, implant, or graft (5.3%), and chronic osteomyelitis (4.7%). A previous study [16] demonstrated that patients with primary diagnoses of other factors tend to have a longer ALOS as well as higher hospital charges.

As hospital charges increase, patients requiring THR/TKR tend to seek treatment from surgeons and hospitals with high surgical volume. Previous studies [16, 17] found that many clinical parameters are strongly associated with hospital charges. However, many clinical parameters could not be analysed in this study due to the limited availability of claims data.

The surgical volume of TKR/THR is currently increasing, and the rate of medical resource usage is rising. This study revealed that the following factors were associated with considerably increased hospital charges: young age; increased disease severity; absence of primary diagnoses of OA, RA, and AVN; higher surgical volume of surgeon or hospital; and a longer ALOS. These factors must be carefully managed to minimise medical resource usage. Additionally, the BNHI must develop a programme for minimising complications and improving quality of life after these procedures. Joint prostheses from different manufacturers must be carefully regulated to maximise patient safety and to ensure efficient use of medical resources.

Acknowledgments This work was supported by a grant (NSC 96–2314-B-037–050-MY3) from the National Science Council in Taiwan.

References

1. Rasanen P, Paavolainen P, Sintonen H et al (2007) Effectiveness of hip or knee replacement surgery in terms of quality-adjusted life years and costs. *Acta Orthop* 78:108–115
2. Jones CA, Beaupre LA, Johnston DW, Suarez-Almazor ME (2007) Total joint arthroplasties: current concepts of patient outcomes after surgery. *Rheum Dis Clin North Am* 33:71–86

3. Bureau of National Health Insurance (2006) National health insurance annual statistical report 2004. BNHI, Taipei
4. Wu S-C, Chien L-N, Ng Y-Y (2004) Using the comorbidity index to evaluate the medical utilization and outcomes of total hip replacement through analyzing national insurance claimed data. *Taiwan J Public Health* 23:121–129
5. Kazis LE, Anderson JJ, Meenan RF (1989) Effect sizes for interpreting changes in health status. *Med Care* 27:178–189
6. Shi HY, Chiu HC, Chang JK et al (2008) Evaluation and prediction of health-related quality of life for total hip replacement among Chinese in Taiwan. *Int Orthop* 32:27–32
7. Mahomed NN, Barrett JA, Katz JN et al (2003) Rates and outcomes of primary and revision total hip replacement in the United States Medicare population. *J Bone Joint Surg Am* 85:27–32
8. Jain NB, Higgins LD, Ozumba D et al (2005) Trends in epidemiology of knee arthroplasty in the United States, 1990–2000. *Arthritis Rheum* 52:3928–3933
9. Kurtz S, Mowat F, Ong K et al (2005) Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. *J Bone Joint Surg Am* 87:1487–1497
10. Bozic KJ, Katz P, Cisternas M et al (2005) Hospital resource utilization for primary and revision total hip arthroplasty. *J Bone Joint Surg Am* 87:570–576
11. Barry MC, Mackle T, Joyce L et al (2003) Endoluminal graft stenting of peripheral aneurysms: questionable results compared with conventional surgery. *Surgeon* 1:42–44
12. Healy WL, Iorio R (2007) Implant selection and cost for total joint arthroplasty: conflict between surgeons and hospitals. *Clin Orthop Relat Res* 457:57–63
13. Mitsuyasu S, Hagihara A, Horiguchi H et al (2006) Relationship between total arthroplasty case volume and patient outcome in an acute care payment system in Japan. *J Arthroplasty* 21:656–663
14. Peng MM, Kurtz S, Johannes RS (2006) Adverse outcomes from hospital-acquired infection in Pennsylvania cannot be attributed to increased risk on admission. *Am J Med Qual* 21:17S–28S
15. Ferrucci L, Guralnik JM, Pahor M et al (1997) Hospital diagnoses, Medicare charges, and nursing home admissions in the year when older persons become severely disabled. *JAMA* 277:728–734
16. Ilfeld BM, Mariano ER, Williams BA et al (2007) Hospitalization costs of total knee arthroplasty with a continuous femoral nerve block provided only in the hospital versus on an ambulatory basis: a retrospective, case-control, cost-minimization analysis. *Reg Anesth Pain Med* 32:46–54
17. Gonano C, Leitgeb U, Sitzwohl C et al (2006) Spinal versus general anesthesia for orthopedic surgery: anesthesia drug and supply costs. *Anesth Analg* 102:524–529