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Editorial office address: The Royal College of Orthopaedic Surgeons of Thailand
4 th Floor, Royal Golden Jubilee Building, 2 Soi Soonvijai, New Petchburi Road, Bangkapi,
Huay Khwang, Bangkok 10310
E-mail: secretariat@rcost.or.th
Telephone: +66 2 7165436-7
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Editorial

We are thrilled to present Volume 47, Number 2 (July-December) of the Journal of Southeast Asian Orthopedics (JseaOrtho), filled with an array of original articles showcasing the latest advancements in orthopedic research. This issue brings together a diverse collection of studies that explore various aspects of orthopedic care, ranging from fracture management to surgical innovations and rehabilitation strategies.

In one noteworthy original article investigate the impact of the timing of hip arthroplasty on the one-year survival rate in elderly patients with femoral neck fractures. Their findings shed light on the optimal window for performing this procedure, providing valuable insights for orthopedic surgeons in managing this common condition.

Additionally, one of the study examines the factors influencing postoperative functional outcomes in older patients with hip fractures at large hospital in Thailand. By identifying the determinants of successful recovery, their research offers guidance for healthcare professionals in optimizing the treatment and rehabilitation of this patient population.

Another contribution to this issue is the innovative technique known as RAPTOR (Radiography-Assisted Planning for Total Knee Arthroplasty). The authors present their novel approach to obtaining long leg standing radiography for total knee arthroplasty, revolutionizing the conventional radiographic process and potentially improving surgical outcomes.

Furthermore, the collection of articles in this volume explores various topics, including the outcomes of varus osteotomy in Legg-Calve-Perthes disease, the effectiveness of revision total knee arthroplasty with rotating-hinged knee prostheses, and the efficacy of different interventions for pain relief and functional recovery after arthroscopic ACL reconstruction.

We extend our gratitude to the authors and researchers who have contributed their valuable work to this issue, as well as to the dedicated reviewers who have ensured the scientific rigor and integrity of the published articles. Their contributions play a crucial role in advancing the field of orthopedics in the Southeast Asian region.

We invite all readers to delve into the thought-provoking research presented in this volume and engage in the scholarly discourse. Your active participation is instrumental in furthering our understanding of orthopedic conditions and promoting the delivery of optimal care.

Thank you for your continued support, and we hope you find this issue of the Journal of Southeast Asian Orthopedics both informative and inspiring.

Thanainit Chotanaphuti, MD, FRCOST
Editor in chief, Journal of Southeast Asian Orthopaedics
Past President, the RCOST

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Comparison of One-year Survival Rate of Hip Arthroplasty Performed within and After 72 Hours in Elderly Femoral Neck Fracture

Burin Suttaphakti, MD, Sirikarn Tananoo, MD, Witoon Thremthakanpon, MD, Wiboon Wanitcharoenporn, MD

Department of Orthopedics, Buddhachinaraj Hospital, Phitsanulok, Thailand

Purpose: Hip fracture is a common cause of mortality in the elderly. Our study compared the one-year mortality rate in elderly femoral neck fracture who received hip arthroplasty between an early (<72 hours after admission) and delayed group (≥ 72 hours after admission).

Methods: Eighty-one patients were included in the prospective cohort study. The type of operation (total hip arthroplasty or bipolar hemiarthroplasty/cemented or cementless arthroplasty) was chosen as indicated in standard treatment, depending on a patient's cognitive function, ambulatory status, and comorbidities.

Results: The sample was 81 patients (44 in the early and 37 in the delayed groups). The one-year mortality rate was 9.9% (4.5% in the early and 16.7% in the delayed group; P =0.079). The mean survival time was 11.47 months (11.97 months in the early and 10.88 months in the delayed group (P= 0.094, HR = 3.93)). Operations performed within 72 hours decreased the one-year mortality rate. Subgroup analysis showed that the early surgery group had a lower one-year mortality rate than the delayed group without preoperative medical conditions (P = 0.011, HR = 8.08).

Conclusions: There was no significant difference in the one-year mortality rate between the early and delayed surgery groups. Early surgery was associated with improved mean survival time and a significant reduction in one-year mortality in elderly patients with femoral neck fractures. Early surgery is recommended for these patients to reduce immobilization time, postoperative complications and improve survival.

Keywords: Hip Arthroplasty, Elderly, Femoral Neck Fracture, Mortality, Bipolar hemiarthroplasty

Hip fracture is a common and important cause of mortality and morbidity in the elderly worldwide. The one-year mortality rate after hip fracture of these patients is 20-30%. [1-2]

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Correspondence to: Burin Suttaphakti, MD
Department of Orthopedics, Buddhachinaraj Hospital, Phitsanulok, Thailand
E-mail: Sutthapaktiburin@gmail.com

The high mortality rate is probably due to major surgery in older adults with concurrent medical problems. Identifying which patients are at the greatest risk of developing complications and the time to operation is crucial[3].

The occurrence of hip fractures in Thailand is about 185.2 per 100,000 in a community survey[4]. Femoral neck fracture is one of the most common consequences of injuries[5].

The mortality rate after hip fracture is very high due to immobilization and loss of ability to perform daily activities. During the first year, the mortality rate is 18%. The median survival time is at 6 years[6].

The one-year mortality was eight times higher than the age-matched general population, and the 10-year mortality rate was up to 68%.[7]

Most patients require surgery to prevent the morbidities from bedridden statuses, such as pneumonia, urinary tract infection, pressure sore, or thromboembolic events, and to improve the quality of life to decrease the one-year mortality rate but the optimum timing of operation remains controversial[8].

Treatment type depends on the patient's condition (physical status before the injury, age, perception, and underlying diseases)[9]. Hip arthroplasty is the treatment of choice for displaced femoral neck fractures in older adults over 60[10,11]. Several studies have demonstrated that a delay in operation increases morbidity and mortality[1,2]. However, some studies show differences in results[10,12].

In Thailand, factors correlated with higher mortality were non-operative treatment, delayed surgical treatment, and absence of medical treatment for osteoporosis[13].

The demand for urgent surgery in many healthcare systems often exceeds the available resources. This study aimed to determine the optimum timing for surgery, to find out associated factors of mortality, and to compare the one-year mortality rate in elderly patients who received hip arthroplasty within and after 72 hours of admission time.

METHODS

This is a prospective cohort study. The study was approved by Ethic Committee (IRB No.034/62). Patients older than 60 with unilateral displaced femoral neck fractures were enrolled. Patients with MET (metabolic equivalents) <4, paraparesis or paraplegia, hemiparesis or hemiplegia, Parkinson's disease, pathologic fracture secondary to malignancy, history of previous surgery of the ipsilateral hip, and fracture duration less than 1 month were excluded.

Demographic, surgical, and anesthetic data were collected, and background variables associated with mortality were included.

The type of operation (total hip arthroplasty or bipolar hemiarthroplasty/cemented or cementless arthroplasty) was chosen as indicated in standard treatment, depending on a patient's cognitive function, ambulatory status, and comorbidities. Routine preoperative investigations include complete blood count, creatinine, blood urea nitrogen, electrolyte levels, electrocardiography, and chest radiograph.

All surgery was performed as soon as possible after the patient's preoperative status was ready and performed by a single hip and knee certificated surgeon. Early surgery was defined as surgery within 72 hours after hospitalization. Surgery performed after this time was considered to be delayed. All patients receive prophylactic antibiotics (Ceftriaxone and Fosfomycin), pain control with oral paracetamol, opioids (oral tramadol, parenteral morphine), and parecoxib adjusted with the patient's renal function and thromboembolic prophylaxis with low molecular weight heparin (enoxaparin) adjusted with patient's renal function at the first postoperative day if there were no contraindications.

The case analysis began at the time of hospitalization and ended one year later, or on the day the patient died. Mortality rate and timing from hospitalization to mortality, postoperative complications (pneumonia, urinary tract infection (UTI), pulmo-nary embolism, deep vein thrombosis, and surgical site infection), cause of death, and functional outcome at one year (Harris Hip Score) were collected.

Statistical analysis

Chi-square tests and the T-test were used to determine the basic data. Kaplan-Meier survival analysis was done to find the association between mortality and time to surgery. Hazard ratios were analyzed to compare the risk between the two groups, and multivariate analyses were adjusted for variable factors. The SPSS statistical program (version 12.0.1; SPSS, Chicago, Illinois) and

Microsoft Excel 2000 were used. The analysis was undertaken under the supervision of a statistician.

RESULTS

From February 2019 to February 2020, 81 patients were enrolled in the study (44 in the early group and 37 in the delayed group). Demographic data for the two groups are shown in Table 1; there were no significant differences between the groups.

The mean age was 74.82 years in the early and 76.95 in the delayed group. Of the 37 patients in the delayed group, 16 were due to medical morbidity that required treatment and preoperative evaluation (Table 2), and 21 were due to an unavailable operating room.

One-year mortality rate

Overall, the one-year mortality rate in this study was 9.9% (2 patients from the early group and 6 patients from the delayed group). This difference was insignificant (X2 = 3.076; p = .079), as shown in Table 3. The causes of death in the early group were acute kidney injury and home death. The causes of death in the delayed group were cerebrovascular disease, upper gastrointestinal bleeding, intracranial hemorrhage, respiratory failure due to pulmonary tuberculosis, sepsis, and home death.

Hip arthroplasty performed	Survival rate (%)	Survival time (month) Mean	(95% CI)	Hazard ratio	(95% CI)	p-value
Within 72 hours	95.5	11.97	(11.93-12.02)	Ref.		
More than 72 hours	83.8	10.88	(9.94-11.82)	3.93	(0.79-19.46)	0.094
Overall	90.1	11.47	(11.03-11.92)			

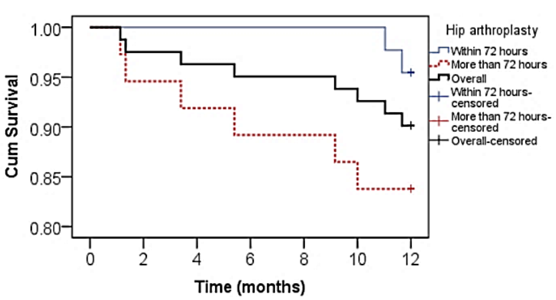

Fig.1 Survival Curve of elderly femoral neck fracture.

According to the survival analysis in Figure 1, the overall one-year survival rate was 90.1% (95.5% in the early group and 83.3% in the delayed group). The mean survival time is 11.47 months (95%CI: 11.03-11.92) which is longer in the early group. Moreover, there was a greater risk of mortality in the delayed group (hazard ratio: 3.93)

This result suggests that early arthroplasty decreases one-year mortality of elderly femoral neck fracture and improves mean survival time but not statistically significant at one year follow-up (P-value: 0.094).

Subgroup analysis between patients in delayed group without preoperative medical condition and patients in the early

The results show that the early group had a lower one-year mortality rate than patients without preoperative medical conditions in the delayed group. (P = 0.011, OR = 8.08, 95%CI = 1.27-90.44)

Factor associated with mortality

To compare the mortality that was adjusted with associated factors using Chi-square test (as shown in Table 4) demonstrated that there was the statistical of increasing of one-year mortality rate with the patient who had lower body mass index (BMI < 18.5).

Postoperative complications and mortality

Using the Chi-square test, there was a statistically significant increase in mortality rate among patients who developed a urinary tract infection postoperatively. (Table 5)

Furthermore, according to logistic regression analysis to evaluate a more accurate association of BMI, UTI, and mortality. This analysis reveals that individuals exposed to postoperative UTI were more likely to die 10.14 times than those without postoperative UTI. Moreover, BMI increased incrementally by 1 unit then the odds of mortality increased by 1.394 times. (Table 6-8)

Postoperative complications and time to surgery

There were no significant occurrences of pneumonia, urinary tract infection, pulmonary embolism, and surgical site infection between early and delayed groups, as shown in Table 9 by using the Chi-square test (there was no evidence of deep vein thrombosis in our study).

Functional outcome at one year (Harris Hip Score) and time to surgery

Seventy-two patients attended our outpatient department one year after admission. We assessed functional outcomes by Harris Hip Score (HHS). There was no significant difference in HHS between the early and delayed groups by using the Mann-Whitney Test since the data was not normal distribution as shown in Table 10 (U = 490.50, p = .098).

Table 1 Demographic data (n = 81).

Data	Total		Hip arthroplasty				P-value
			Within 72 hours		More than 72 hours		
	n	%	n	%	n	%	
Age (year)							
<80	54	66.7	31	70.5	23	62.2	0.430
80+	27	33.3	13	29.5	14	37.8	
Mean ± S.D. T	75.79 ± 8.10		74.82 ± 8.18		76.95 ± 7.97		0.242
Sex							
Male	16	19.8	7	15.9	9	24.3	0.343
Female	65	80.2	37	84.1	28	75.7	
BMI (kg/m²)							
<23.00	52	64.2	23	52.3	29	78.4	
23.00+	29	35.8	21	47.7	8	21.6	
Mean ± S.D. T	21.36 ± 3.46		21.98 ± 3.62		20.62 ± 3.15		0.079
Comorbidity							
Total	65	80.2	33	75.0	32	86.5	0.196
DM	23	28.4	11	25.0	12	32.4	0.460
HT	57	70.4	30	68.2	27	73.0	0.638
DLP	38	46.9	20	45.5	18	48.6	0.774
COPD F	3	3.7	-	-	3	8.1	0.091
Gout F	5	6.2	3	6.8	2	5.4	>0.999
CKD F	5	6.2	1	2.3	4	10.8	0.173
Type of Anesthesia							
GA	42	51.9	20	45.5	22	59.5	0.209
SA	39	48.1	24	54.5	15	40.5	
Type of treatment							
BHA	46	56.8	26	59.1	20	54.1	0.649
THA	35	43.2	18	40.9	17	45.9	
Smoking F							
Yes	3	3.7	2	4.5	1	2.7	>0.999
No	78	96.3	42	95.5	36	97.3	

*Statistically significant at p-value<0.05 determined by Chi-square test, F Fisher's exact test, and T T-test.

Table 2 Reasons for delayed group.

Reasons	n	%
Electrolyte imbalance/anemia	2	12.5
Uncontrolled blood pressure/dysrhythmia	1	6.25
Uncontrolled blood sugar	1	6.25
Fever	3	18.75
Pulmonary tuberculosis screening	1	6.25
Current oral anticoagulant	3	18.75
Other medical conditions	5	31.25
Total	**16**	**100**

Table 3 One-year survival rate between having surgery within and longer than 72 hours.

	< 72 hours (n=44)	> 72 hours (n=37)	Total	P-value
Death	2	6	8 (9.9%)	0.079
Survive	42	31	73 (90.1%)	

Table 4 Comparison of mortality rate with associated factors (categorical variables).

Factors	Death	Survive	X^2
Age			
<65	0 (0%)	7 (100%)	3.721 (p=0.239)
65-74	3 (10%)	27 (90%)	
75 – 84	2 (6.5%)	29 (93.5%)	
>85	3 (23.1%)	10 (76.9%)	
Gender			
Male	2 (12.5%)	14 (87.5%)	0.154 (p=0.154)
Female	6 (9.2%)	59 (90.8%)	
BMI**			
<18.5	5 (27.8%)	13 (72.2%)	8.713 (p=0.033)
18.5-22.9	2 (3.5%)	33 (94.3%)	
23.0-24.9	1 (6.3%)	15 (93.8%)	
25.0-29.9	0 (0%)	12 (100%)	
>30	0 (0%)	0 (0%)	
Smoking	0 (0%)	3 (100%)	0.341 (p=0.559)
Comorbidity			
DM	4 (17.4%)	19 (82.6%)	2.038 (p=1.530)
HT	4 (7.0%)	53 (93%)	1.767 (p=0.184)
Dyslipidemia	2 (5.3%)	36 (94.7%)	1.712 (p=0.191)
COPD	0 (0%)	3 (100%)	0.341 (p=0.559)
Gout	0 (0%)	5 (100%)	0.584 (p=0.445)
CKD	0 (0%)	5 (100%)	0.584 (p=0.445)
Intraoperative data			
ASA			
1	0 (0%)	1 (100%)	0.225 (p=0.973)
2	1 (10%)	9 (90%)	
3	7 (10.1%)	62 (89.9%)	
4	0 (0%)	1 (100%)	
Type of anesthesia			
GA	6 (14.3%)	36 (85.7%)	1.905 (p=0.167)
SA	2 (5.1%)	37 (94.9%)	
Operation			1.200 (p=0.273)
BHA	6 (13.0%)	40 (87.0%)	
THA	2 (5.7%)	33 (94.3%)	
Estimated blood loss			0.640 (p=0.424)
≤200 ml	4 (13.3%)	26 (86.7%)	
>200 ml	4 (7.8%)	47 (92.2%)	
Time to surgery (hours)			3.831 (p=2.800)
<24	1 (5.3%)	18 (94.7%)	
24-47	0 (0%)	0 (0%)	
48-71	1 (5.0%)	19 (95%)	
72-95	0 (0%)	7 (100%)	
>96	6 (17.1%)	29 (82.9%)	

X^2 Statistically significant at p-value<0.05 determined by Chi-square test

Table 5 Comparison of variables between groups (n = 81) (continuous variables).

		N	Mean	SD	t	df	Sig	95% CI	
								Upper	Lower
Age	dead	8	79.25	8.22	1.277	79	.205	-2.144	9.823
	survive	73	75.41	8.06					
BMI*	dead	8	18.29	2.94	-2.757	79	.007	-5.865	-.947
	survive	73	21.69	3.35					
Admission cost	dead	8	75008.88	23120.45	-.360	79	.720	-16801.971	11658.597
	survive	73	77580.56	18771.51					

*Result: There was difference in BMI between groups (t = -2.757; p = .007) but no difference in age and admission cost. df: degree of freedom

Table 6 Comparison of mortality rate with postoperative complications.

Complications	Death	Survive	X^2
Pneumonia	0 (0%)	3 (100%)	0.341 (p=0.559)
UTI*	5 (38.5%)	8 (61.5%)	14.215 (p=.0001)
PE	0 (0%)	1 (100%)	0.111 (p=0.739)
DVT	0 (0%)	0 (0%)	-

X^2 Statistically significant at p-value<0.05 determined by Chi-square test

Table 7 Odd ratio of mortality and postoperative urinary tract infection.

Exp (B)	P	OR (CI)
UTI	.002	13.542 (95% CI 2.710-67.661)

Table 8 Logistic regression analysis of UTI, BMI, and mortality.

Exp (B)	P	OR (CI)
UTI	.008	10.140 (95% CI 1.847 – 55.683)
BMI	.044	1.394 (95% CI 1.008 – 1.927)

Table 9 Postoperative complications and time to surgery.

	< 72 hours (n=44)	> 72 hours (n=37)	X^2
Pneumonia			
No	43 (97.73%)	35 (94.59%)	0.553 (P=0.457)
Yes	1 (2.27%)	2 (5.41%)	
UTI			
No	40 (90.91%)	28 (75.68%)	3.462 (P=0.630)
Yes	4 (9.09%)	9 (24.32%)	
Pulmonary embolism			
No	43 (97.73%)	37 (100%)	3.544 (P=0.998)
Yes	1 (2.27%)	0	
Surgical site infection			
No	43 (97.73%)	36 (97.30%)	0.015 (P=0.901)
Yes	1 (2.27%)	1 (2.70%)	

X^2 Statistically significant at p-value<0.05 determined by Chi-square test

Table 10 HHS and time to surgery.

		N	Mean rank	U	P
HHS score	<72 hours	41	40.04	490.50*	.098
	>72 hours	31	31.82		

*Determined by Mann Whitney U test

DISCUSSION

Elderly patients with fractures around the hip have a higher mortality rate than patients without fracture[1]. The association between timing to surgery and mortality rate is controversial[14-17]. The study of Schermann et al. did not find any statistical difference between 30 days-mortality and time to surgery[18]. Mitchell et al. also did not find an adverse affect outcome at 30 days from delay in hip fracture surgery[19]. Earlier surgery was associated with a lower risk of death and lower rates of postoperative complications such as pneumonia and pressure sores among elderly patients[20]. Some studies show that early surgery was not associated with improved function or mortality. However, it was associated with reduced pain and LOS and probably major complications among patients medically stable at admission[21]. Nowadays, the majority of studies show the benefits of early surgery. Our results demonstrated that delayed surgery up to 72 hours in elderly femoral neck fracture does not significantly affect the one-year mortality rate. However, early surgery improved the mean survival time and survival rate in the early group compared with patients without preoperative medical conditions but in the delayed group. It should be recognized that if we followed up with a longer period of more than one year, the mortality rate would be statistically significant between the early and delayed groups.

The association between postoperative complications, functional outcome (Harris hip score) and surgery timing were not statistically significant. However, the patients with lower body mass index and postoperative urinary tract infection were more likely to die within one year after hospitalization.

As described above, we suggest that elderly patients with femoral neck fractures should be prioritized to avoid a longer immobilization period, decrease postoperative complications such as urinary tract infections and improve survival time.

There are several limitations to this study. First, the small sample size may not allow for generalization to other populations. Additionally, data on the severity of comorbidities that could affect one-year mortality was not available. Finally, a longer follow-up period than one year may be necessary to find a statistically significant difference in mortality rate.

CONCLUSIONS

There was no statistical significance in the one-year mortality rate between the early and delayed groups. However, we suggest that elderly patients with femoral neck fractures should be prioritized because the result shows that early surgery improves mean survival time and significantly lowers one-year mortality in subgroup analysis between patients in the early group compared to the delayed group without a preoperative medical condition. Early surgery would be beneficial to avoid a longer immobilization period, decrease postoperative complications such as urinary tract infections and improve mean survival time.

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Factors Affecting Postoperative Functional Outcomes in Older Patients with Hip Fractures at a Large Public Hospital in Thailand

Adisorn Chongmuenwai, MD [1], Phumin Silathong, MD [2], Tana Rattanakitkoson, MD [3], Thanyaphon Sukpongthai, MD [4], Nualchavee Permthongchoochai, RN [5]

[1,2,3] *Department of Orthopedics, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand*
[4] *Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand*
[5] *Community Nurse Department, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand*

Purpose: To identify prognostic factors for 6-month postoperative functional outcomes in older patients with hip fractures.
Methods: This single-center prospective cohort study was conducted from January 2020 to December 2020. Patient factors and the preinjury Barthel index were collected from the patients at admission. The Barthel index was assessed again 6 months postoperatively to define functional outcomes. Minimal clinically important differences (MCIDs) between preinjury and 6-month functional outcomes were used to classify patients into satisfactory or unsatisfactory groups. The 6-month mortality rate was evaluated. Multiple logistic regression was used to analyze prognostic factors for postoperative functional outcomes.
Results: In total, 320 patients were included in the analysis. The 6-month mortality rate was 11.8%. The average age and body mass index were 75.74±10.53 years and 20.98±3.96, respectively. Of the patients, 243 were female (75.94%), 210 were diagnosed with intertrochanteric fractures (65.83%), and 54 underwent surgery within 72 h (16.88%). In total, 249 patients (77.81%) had no complications. Multivariate analysis indicated that a time to surgery of < 72 h (odds ratio, 10.51; 95% confidence interval (CI), 5.42 to 20.37; p-value <0.01) was a significant prognostic factor for a satisfactory 6-month outcome.
Conclusions: Time to surgery is a prognostic factor for a satisfactory functional outcome. Early surgery results in better functional outcomes in older patients with hip fractures.

Keywords: older person, hip fracture, time to surgery, fragility fracture, functional outcome, prognostic factor

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Correspondence to: Adisorn Chongmuenwai, MD
Department of Orthopedics, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand
E-mail: Adisorn.ch@cpird.in.th

With the aging world population, hip fractures in older patients are among the most critical problems due to their impact on quality of life and medical costs [(1,2)]. The incidence of hip fractures was 238.5 per 100,000 person-years in Nan province, Thailand, in 2017, and the incidence tends to increase annually [(3)]. These fractures also increase disability and mortality [(1)]. The 1-year mortality rate at a large public hospital in 2010 was 23.6% [(4)]. Re-evaluation in 2015 found that non-operative treatment, age, more than one comorbidity, chronic kidney disease, and in-hospital complications were significantly related to 1-year mortality [5].

Compared with conservative treatment, surgical treatment results in better functional outcomes and lower mortality rates among patients with hip fractures [6,7]. However, various factors, such as age, sex, body mass index (BMI), comorbidities, preinjury ambulation status, complications, and fracture type, affect functional outcomes in patients who undergo surgery [8-10]. Preinjury ambulatory status, BMI, hemoglobin level, and functional outcomes at discharge were found to be independent predictors of 1-year postoperative functional outcomes in older patients who underwent intertrochanteric fracture surgery in Thailand [11]. The study period may also have affected patient outcomes. A recent study demonstrated lower postoperative functional outcomes at 3 months in older patients with hip fractures during the coronavirus disease (COVID-19) pandemic [12].

There are limited studies on the functional outcomes of patients with hip fractures in Thailand. This study aimed to identify prognostic factors for functional outcomes in older patients with hip fractures to improve their management.

METHODS

This single-center prospective cohort study focused on older patients (age, > 50 years) with hip fractures who underwent surgery at a large public hospital during a 1-year period (January 2020 to December 2020). The study protocol was approved by the institutional review board (IRB) of our institution. According to the policies and regulations of the study authorizing entity, informed consent was obtained from all participants.

The inclusion criteria were as follows: 1) age > 50 years, 2) diagnosis of a single closed fracture from low-energy trauma, 3) diagnosis of intertrochanteric fracture or femoral neck fracture, and 4) surgery. The exclusion criteria were as follows: 1) refracture, 2) pathological fractures, 3) isolated fractures of the lesser or greater trochanter, 4) periimplant and periprosthetic fractures, and 5) nonoperative treatment.

Data collection

Demographic data, including age, BMI, sex, comorbidity, diagnosis, and vitamin D levels, were collected at the time of admission. The time to surgery and the length of hospital stay were recorded before discharge. The preinjury Barthel index (Pre-BI) was also recorded by the healthcare provider at the time of admission.

At the 6-month follow-up, the community health team collected data on the post-injury Barthel index (Post-BI) and mortality rate [13]. This study used minimal clinically important differences (MCIDs) to classify patients into satisfactory and unsatisfactory groups. We used the MCID as 10 points, as previously described [14]. Patients with a difference of > 10 points between the pre-BI and post-BI were classified into the unsatisfactory group.

In our institute, surgical intervention for intertrochanteric and femoral neck fractures is by fixation and arthroplasty, respectively. Patients entered the standard rehabilitation protocol according to fracture type and treatment.

Statistical analysis

Data on patient characteristics are expressed as mean ± standard deviation or median and range. Categorical variables were compared using the chi-square test or Fisher's exact test. Continuous variables were compared using the t-test or Mann–Whitney U-test. Association factors were determined using logistic regression analysis. The results are expressed as odds ratios (ORs), 95% confidence intervals (CIs), and p-values. Statistical significance was set at $P < 0.05$. All analyses were performed using STATA, version 14 (StataCorp LLC, College Station, TX, USA).

RESULTS

This 1-year study included 363 older patients with hip fractures. Of these, 43 patients died within 6 months. The 6-month mortality rate for patients who underwent surgery was 11.8%.

Therefore, 320 patients were included in the analysis. The demographic data and factors determining 6-month functional outcomes are shown in Tables 1 and 2. The average age and BMI were

75.74±10.53 years and 20.98±3.96, respectively. The most common comorbidity was hypertension (58.44%). Of the patients, 243 were female (75.94%), 210 were diagnosed with intertrochanteric fractures (65.83%), and 54 underwent surgery within 72 h (16.88%). Thirty-six patients (11.25%) stayed in the hospital for less than 7 days, 172 (53.75%) had low vitamin D levels, and 71 (22.19%) had complications (urinary tract infection, 40; delirium, 22; pneumonia, 7; pulmonary embolism, 7; pressure sore, 5; acute myocardial infarction, 3; stroke, 1; deep vein thrombosis, 2; atrial fibrillation, 1; acute renal failure, 1; upper gastrointestinal tract bleeding, 1; implant failure, 2; and surgical wound infection, 1).

Table 1 Demographic data of 320 older patients with hip fractures.

Characteristic	n	%
Age	75.74±10.53	
BMI	20.98±3.96	
Sex		
Female	243	75.94
Male	77	24.06
Comorbid		
Hypertension	187	58.44
Diabetic mellitus	53	16.56
Dyslipidemia	71	22.19
Heart disease	17	5.31
Stroke	36	11.25
Chronic kidney disease	20	6.25
COPD/asthma	15	4.69
Vitamin D level		
≤ 30	172	53.75
> 30	148	46.25
Diagnosis		
Intertrochanteric fracture	210	65.83
Femoral neck fracture	109	34.17
Time to Surgery		
≤ 48 hours (percent)	22	6.88
> 48 hours (percent)	298	93.13
≤ 72 hours (percent)	54	16.88
> 72 hours (percent)	266	83.13
LOS		
≤ 7 days (percent)	36	11.25
> 7 days (percent)	284	88.75
Complication		
No	249	77.81
Yes	71	22.19

BMI, body mass index; COPD, chronic obstructive pulmonary disease; LOS, length of stay

Table 2 Factors determining 6-month functional outcomes.

	Unsatisfactory Group (%) N=233	Satisfactory Group (%) N=87	*P*-value
Age	76.42±10.38	73.93±10.78	0.059
BMI	21.56±11.85	21.44±4.26	0.927
Sex			
Female	171 (73.39)	72 (82.76)	0.081
Male	62 (26.61)	15 (17.24)	
Comorbid			
Hypertension	138 (73.80)	49 (26.20)	0.639
Diabetic mellitus	38 (71.70)	15 (28.30)	0.842
Dyslipidemia	52 (73.24)	19 (26.76)	0.927
Heart disease	12 (70.59)	5 (29.41)	0.832
Stroke	26 (72.22)	10 (27.78)	0.933
Chronic kidney disease	18 (90.00)	2 (10.00)	0.116
COPD/asthma	9 (60.00)	6 (40.00)	0.253
Time to Surgery (h)			
≤ 48	7 (3.00)	15 (17.24)	
> 48	226 (97.00)	72 (82.76)	<0.001
≤ 72	16 (6.87)	38 (43.68)	
> 72	217 (93.13)	49 (56.32)	<0.001
Length of hospital stay (days)			
> 7	214 (91.85)	70 (80.46)	
≤ 7	19 (8.15)	17 (19.54)	0.004
Complication			
no	182 (78.11)	67 (77.01)	0.833
yes	51 (21.89)	20 (22.99)	

BMI, body mass index; COPD, chronic obstructive pulmonary disease

Table 3 Multivariate analysis of factors determining 6-month functional outcome.

	Odds Ratio	95%CI	*P*-value
Time to surgery (h)			
≤ 48	6.08	2.36, 15.62	<0.001
≤ 72	10.51	5.42, 20.37	<0.001
Vitamin D level (ng/mL)			
≤ 30	1.47	0.83, 2.59	0.176

CI, confidence interval

Multivariate analysis indicated that the significant prognostic factors for a 6-month satisfactory outcome (Table 3) were times to surgery of ≤ 48 h (OR 6.08, 95% CI 2.36 to 15.62, p-value <0.001) and ≤ 72 h (OR 10.51, 95% CI 5.42 to 20.37, p-value <0.001). Vitamin D levels were not significantly associated with functional outcomes.

DISCUSSION

Our study demonstrated that performing surgery within 72 h significantly correlated with a better 6-month Barthel index, which assesses the ability to perform activities of daily living. The early surgery rate in our hospital was 16.12%, while the rate of hospital stays of <7 days was 11.25%. At

6 months, only 27% of the patients had satisfactory outcomes after hip surgery, 22% had complications, and the mortality rate was 11.8%.

Vitamin D levels are associated with muscle function, strength, and performance. Vitamin D depletion can cause muscle impairment and body imbalance [15]. A recent retrospective study showed that vitamin D levels do not significantly affect functional outcomes after hip fracture surgery in older patients [16]. However, severe preoperative vitamin D deficiency (≤ 10 ng/mL) is correlated with poor functional outcomes in older patients with hip fractures [17]. The current study demonstrated that low vitamin D levels (≤ 30 ng/mL) are not significantly associated with functional outcomes. Only seven patients had severe vitamin D deficiency in this study. Further prospective studies on vitamin D levels in older patients with hip fractures should be conducted.

Surgery is the mainstay of treatment in hip fractures in older patients due to the higher functional outcomes after surgery, less time to return to function, and lower complication rates compared with conservative treatment [18,19]. Previous studies have shown that the timing of surgery is associated with a low mortality rate and fewer complications, such as urinary tract infection, aspiration pneumonia, and bedsores. Early surgery also improves the functional recovery of the patient [20-24]. This protocol also provides early rehabilitation which helps patients to gain function. Our results are similar to those of previous studies that have reported better functional outcomes after early surgery. In addition, prolonged hospital stay for hip fractures increases the risk of death 30 days after discharge [25]. Although the length of stay in this study was not significantly associated with functional outcomes, early surgery decreased the length of hospital stay by decreasing the preoperative waiting time and postoperative rehabilitation time.

Some studies disagree with the early surgery protocol [26-28]. Comorbidities play an essential role in delaying surgery. Preoperative medical consultation is necessary to reduce the risk of morbidity and mortality in patients with multiple or critical comorbidities. Other causes of delayed surgery in our hospital were the unavailability of operating rooms and staff shortages. Preoperative family counseling is also an essential part of care because sometimes older patients cannot decide for themselves, and a family member is usually the caregiver. Therefore, although early surgery performed within 72 h was correlated with better functional outcomes in older patients with hip fractures, there are some limitations to proceeding with this protocol. This study has several limitations. First, the sample size in this study may not be large enough to generalize the results to the larger population. Second, the retrospective design and lack of control group for comparison so it is difficult to determine the cause-and-effect relationship between the timing of surgery and functional outcomes. These limitations suggest that further studies with larger sample sizes, controlled design, and consideration of other factors are needed to fully understand the impact of the timing of surgery on functional outcomes in older patients with hip fractures.

CONCLUSIONS

Time to surgery is a prognostic factor for satisfactory functional outcomes in older patients with hip fractures. Early surgery results in better functional outcomes in older patients with hip fractures., but it is also important to consider other factors such as patient comorbidities and availability of operating rooms and staff. Preoperative medical consultation and family counseling are essential to minimize the risk of morbidity and mortality.

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RAPTOR: The Innovation for Making Long Leg Standing Radiography for Total Knee Arthroplasty from Conventional Radiography

Pakorn Srithongkul, MD [1], Atorn Koomchaya [2], Patarawan Woratanarat, MD, PhD [3], Warodom Limsricharoen, MD [1], Kittipong Yusuwan, MD [1], Katcharin Kowsomjeen, BSc [4]

[1] *Department of Orthopaedics, Chaophraya Yommarat Hospital, Suphan Buri, Thailand*
[2] *Head of Division Mechatronics and Robotics Suphanburi Technical college, Suphan Buri, Thailand*
[3] *Department of Orthopaedics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand*
[4] *Department of Radiology, Chaophraya Yommarat Hospital, Suphan Buri, Thailand*

Purpose: To evaluate the reliability and validity of femoral anatomical-mechanical angle (fAMA), hip knee ankle angle (HKA), and overlap of long leg standing radiography (LLSR) obtained using a Rapid Orthoroentgenography Making Machine (RAPTOR) compared with a standard X-ray generator.

Methods: This observational study was conducted between July 2021 and August 2021, including patients diagnosed with primary knee osteoarthritis that underwent preoperative LLSR for total knee replacement. Three orthopedic surgeons blindly evaluated LLSR (fAMA, HKA, overlap of the femoral shaft) twice within one-month using the Visio program. Intra- and interobserver reliability and validity were analyzed.

Results: Three evaluators assessed 30 LLSRs. The intraobserver agreement levels were -0.951–1.062° for fAMA, -10.338–11.076° for HKA, and -0.418–0.418 mm for overlap of RAPTOR, while for the standard X-ray generator the agreement levels were -1.359–1.114° for fAMA, 11.844–12.467° for HKA, and 0 mm for overlap. The intraclass correlation was 0.55–0.99 for all RAPTOR measurements and 0.56–0.99 for standard X-ray generator. The interobserver's levels of agreement were -1.441–1.175° for fAMA, -7.453–7.475° for HKA, and -0.681–0.637 mm for overlap of RAPTOR, whereas those of the standard X-ray generator were -1.149–1.424° for fAMA, -4.789–6.171° for HKA, and 0 mm for overlap. The intraclass correlation was 0.69–0.97 for all RAPTOR measurements and 0.71–0.95 for the fAMA and HKA standard X-ray generator measurements. The mean and 95% limits of agreement of the comparison between RAPTOR and standard X-ray generator were -0.131° (-1.187, 0.925) for fAMA, -0.126° (-4.724, 4.471) for HKA, and 0.363 (-) mm for overlap. Only overlap was significantly different between the two methods ($p=0.0243$). Intraclass correlations between the two radiographic methods were 0.75 (0.63, 0.88) for fAMA and 0.93 (0.89, 0.97) for HKA.

Conclusions: Estimation of fAMA, HKA, and overlap had moderate to excellent reliability and inter- and intra-rater reliabilities in both RAPTOR and standard X-ray generator. Only overlap was different between the two methods.

Keywords: femoral anatomical mechanical angle, hip knee ankle angle, limb length discrepancy, orthoroentgenography, overlap

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Correspondence to: Pakorn Srithongkul, MD
Department of Orthopaedics, Chaophraya Yommarat Hospital, Suphan Buri, Thailand
E-mail: pop.ortho99@gmail.com

Successful total knee arthroplasty (TKA) requires restoration of the mechanical axis, joint line, soft tissue balance, equalization of flexion and extension gap, and patella femoral joint alignment (1). Infection, instability, osteolysis, periprosthetic fracture, mechanical loosening (1-3), and mechanical failures are common causes of revision TKA. These may result from unacceptable alignment of the mechanical axis within 180 ± 3° (4-6) of which prosthetic loosening is 24% compared with 3% in knees with mechanical axis alignment within 180 ± 3° (17). Thorough preoperative planning is crucial for reducing mechanical failures resulting from surgical technique, and it should also consider the optimal implant position and soft tissue balance (3,7). Long-leg standing radiography (LLSR) is a reliable standard for the preoperative planning of TKA (10,12,13), being superior to short films in measuring the hip knee ankle angle (HKA), femoral anatomical-mechanical angle (fAMA), coronal laxity, deformity, and hip and ankle pathology (8,9).

Preoperative planning for TKA on the femoral side and distal femoral cut is performed perpendicular to the mechanical axis to restore the axis of the limb using the measured fAMA. Determining the fAMA for the distal femoral cut using an LLSR is an inexpensive method that can be used to achieve an acceptable mechanical axis of femoral side during TKA (6).

In our hospital, we do not have an X-ray generator to obtain LLSRs, and we cannot preoperatively plan TKAs using patients' fAMA, distal femoral cuts, and proximal tibial cuts. An X-ray machine, such as iQuia GC85A FDR Visionary Suite or SAMSUNG FUJIFILM Visionary Suite, and an X-ray generator, such as Optimus 80 PHILIPS, can be used to obtain LLSRs. These machines are 2-3 times more expensive than the X-ray generators used in most public hospitals. A novel low-radiation-dose EOS™ imaging system, which enables three-dimensional full-length weight-bearing images in one session, is a new reliable radiographic method for assessing knee osteoarthritis using the fAMA and limb lengths and is comparable to LLSR (16). This model has been widely used in medical schools. In our setting, many public hospitals in rural areas have limited access to expensive and specialized X-ray equipment. Instead, they must use short films for preoperative planning.

To create an LLSR, the Suphan Model 4.0 was developed in 2016(19). This new method consists in manual movement of a Suphan Model 4.0 detector holder, at the level of the hip, knee, and ankle center. The radiograph is taken while the radiological technician moves the detector to each of the radiation locations positioned at levels of the hip, knee, and ankle center. In this study, some length loss of radiography, lack of validation of the fAMA and HKA, and overlap of the femur image with standard LLSR were observed (19).

In the present study, a device called the Rapid Orthoroentgenography Making Machine (RAPTOR) was devised to create an orthoroentgenography/LLSR. This device can be installed at public hospitals in every province to enable common X-ray machines to create an LLSR at an affordable cost. The RAPTOR is used in conjunction with digital radiography and a stitching program. We hypothesized that the LLSRs created by our newly-developed RAPTOR would be equivalent to the standard LLSR from the standard X-ray generator and could be used for preoperative planning of TKA. The aim of this study was to assess the reliability and accuracy of the fAMA, HKA, and overlap of the femur image of an LLSR created by RAPTOR compared to the standard X-ray generator.

METHODS

This observational study was conducted at our hospital from July 2021 to August 2021. The study included 30 patients who were diagnosed with primary knee osteoarthritis and knee pain. Weight-bearing knee radiographs showed a joint space narrowing < 3 mm, subchondral sclerosis, marginal osteophytes, subchondral cysts, deformity of the femoral condyles, and tibial plateau. Radiographic severity was determined using the Kellgren and Lawrence (KL) score (18) and LLSR was performed for preoperative TKA planning. The inclusion criteria were age > 55 years, varus angulation < 30°, flexion contracture < 20°, and being able to stably stand up. The exclusion criteria were hip osteoarthritis; avascular necrosis of the femoral head; previous hip, femur, knee, or ankle surgery; secondary osteoarthritis, such as posttraumatic osteoarthritis or rheumatoid arthritis, and recurvatum of the knee; or having received a repeated X-ray more than twice due to unavailable true knee anteroposterior (AP) view in which the femoral and tibial condyles should be symmetrical; the head of the fibula was superimposed at one-third or one-fourth of the lateral tibial condyle, and the patella position was at the center of the distal femur; knee joint pain during LLSR which shows a Numeric Rating Scale score higher than 4. LLSR was obtained for all 30 patients using a standard X-ray generator (Optimus 80 PHILIPS, Hamburg, Germany) and RAPTOR on the same day at two different hospitals. This study was approved by the relevant Institutional Review Board.

The evaluators of this study were two orthopedic surgeons with more than ten years of professional experience and one orthopedic surgeon who had five years of experience; they were blinded for evaluation of the radiographs. The patients' baseline characteristics included age, sex, weight, height, and body mass index (BMI). The desired outcomes included fAMA (°, degrees), HKA (°, degrees), and overlap (mm). All LLSRs were processed using the Microsoft Visio 2010 Model 64-bit Service Pack 2 for Education software (Microsoft Corporation, Redmond, WA, USA) [20.21].

LLSRs from RAPTOR were originally taken with 10–20° of internal rotation of the foot, and a 30-cm gap between the two feet; the patient's position was adjusted until the tibial tuberosity and patella faced forward to the head tilt unit (Fig. 1).

A 240-cm distance was set between the head tilt unit and detector. A 120-cm metal ruler was placed upright at the lateral malleolus, facing 90° to the head tilt unit. The hip, knee, and ankle heights were identified, and the positions of the hip, knee, and ankle center were set at equal distances from the RAPTOR detector holder. Subsequently, a radiograph was taken while the radiographer moved to each radiation position. A

(a) (b)

Fig. 1 Patient's position for LLSR capturing using (**a**) RAPTOR and **(b)** standard X-ray generator. LLSR, long leg standing radiography; RAPTOR, Rapid Orthoroentgenography Making Machine.

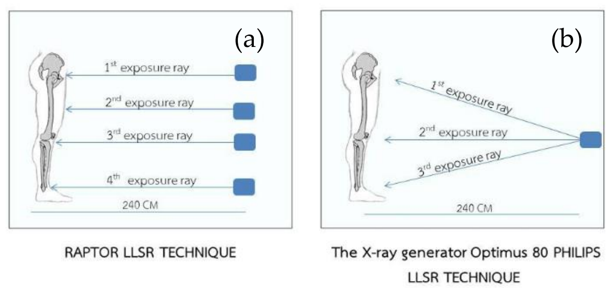
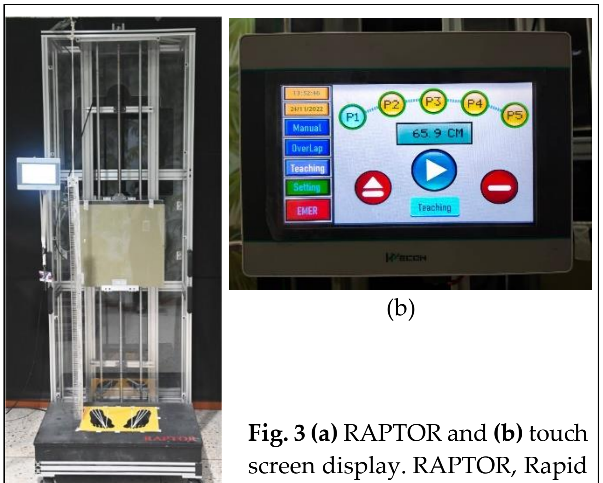


Fig. 2 LLSR imaging techniques of the **(a)** RAPTOR and **(b)** standard X-ray generator. LLSR, long leg standing radiography; RAPTOR, Rapid Orthoro-entgenography Making Machine.

10-m radiofrequency remote control directed the RAPTOR detector holder to be in relation to and in continuity with the hip, knee, and ankle preset height (Fig. 2). RAPTOR is a semiautomatic machine that has manual and semiautomatic operative modes, which have two functions for determining the detector position, a teaching function that can preset the detector position by users, and an overlap detector position between 0–20 cm. The RAPTOR determines the movement of the detector by a servomotor at 0.06 m/s, and a working distance of 240 cm. Safety switches and torque protection were used for emergency stops in the case of unexpected events. The RAPTOR was controlled by a Programmable Logic Controller and incorporated into a user interface with a touchscreen display. Images in five defined positioning heights were captured manually and automatically (Fig. 3).

The radiographs were then digitally stitched, the new image was checked for whether it met the standards for a true AP knee radiography, and finally recorded in a picture archiving and communication system (PACS). For the standard X-ray generator, LLSR was performed using the same positioning technique as in RAPTOR, and the standard radiographic technique of the standard X-ray generator was used. Before a radiograph was obtained, the head tilt unit of the standard X-ray generator was set to face the knee joint position and then face toward the hip joint. The process was then repeated on the knee and ankle joints (Fig. 3). The radiograph was then stitched using an automatic stitching program and checked to determine whether it met the standards for a true AP knee radiography, and finally recorded in a PACS. The distance resolution was set as 0.0001 mm. The angle resolution was 0.001°, measured using a tool for engineering measurements [20,21].

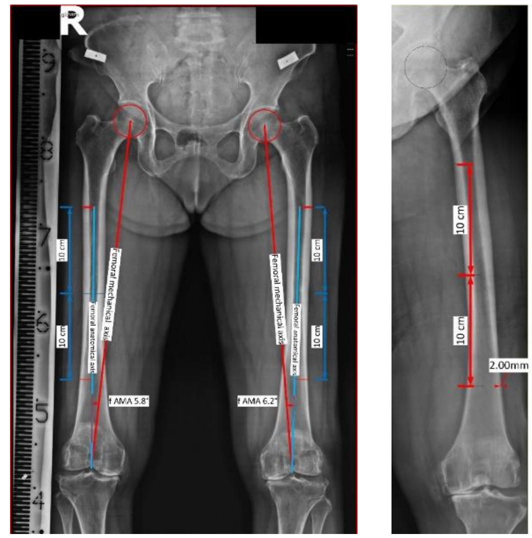


(a) (b)

Fig. 3 (a) RAPTOR and **(b)** touch screen display. RAPTOR, Rapid Orthoroentgenography Making Machine.

Radiographic quality assessment by orthopedists

The center of the hip joint was determined using a digital Mose's circle. Then, the hip center was determined by choosing the circumference that touches the 11, 3, and 5 o'clock positions of the hip joint radiograph. The center of the knee was defined as the top of the distal femoral intercomdylar notch. The center of the ankle was specified as the center of the talus.

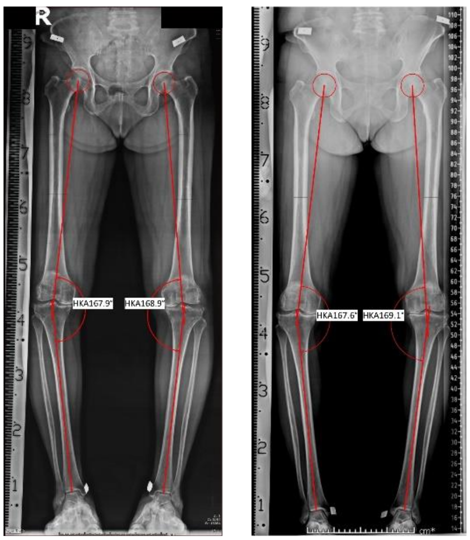


(a) (b)

Fig. 4 (a) The femoral anatomical (in blue) and mechanical (in red) axes and fAMA. **(b)** The 2-mm overlap of the femoral shaft at 10 cm below midshaft of the femur. fAMA, femoral anatomical mechanical angle.

Regarding the anatomic femoral axis, a line was drawn along the femoral diaphyseal axis by connecting the two points in the middle of the medullary canal. The first point was 10 cm above the midshaft of the femur and the second point was 10 cm below the midshaft of the femur. The femoral mechanical axis was drawn from the center of the hip to the knee center (Fig. 4a). Overlap was measured using an area 10 cm above and below the midshaft of the femur (Fig. 4b). The fAMA was evaluated using the angle from the intersection of the femoral anatomic and mechanical axes (Fig. 4a). The HKA was quantified using the angle from the intersection between the mechanical axis of the femur and the line drawn from the center of the ankle to the mid-point of the interspinous tibia (Figs. 5a and b). The methods of measurement and display of orthoroentgenography/ LLSR from RAPTOR and those from the standard X-ray generator are shown in Figs. 5a and b.

All evaluators received a one-hour measurement training from the author, who was trained for measurements by an engineer with approximately 30 LLSR films. The training session consisted of a 5-minute overview, 30 minutes of workshop, and 25 minutes of discussion, questions, and answers. LLSRs were measured twice by the three evaluators with a 30-day interval between measurements. The LLSR details were blinded and randomized. During the 30-day interval, all measurements were monitored and audited by all evaluators to ensure the same standard.



(a) (b)

Fig. 5 Orthoroentgenography/LLSR created by **(a)** RAPTOR and **(b)** standard X-ray generator. LLSR, long leg standing radiography; RAPTOR, Rapid Orthoroentgenography Making Machine.

Baseline continuous variables are presented as mean and standard deviation, and categorical data are presented as frequencies and percentages. Intra and interobserver's reliabilities for measurement of fAMA, HKA, and overlap were analyzed using mean difference and 95% limits of agreement by Bland and Altman, and intraclass correlations with 95% confidence intervals (CI). The fAMA, HKA, and overlap from three observers were averaged and the 95% limits of agreement between the RAPTOR and the standard X-ray generator were obtained. All statistical analyses were performed using STATA 16.1, StataCorp, College Station, Texas, USA). The significance level was set at $p < 0.05$.

Intraclass correlation coefficient (ICC) values lower than 0.5 indicate poor reliability; values between 0.5 and 0.75, moderate reliability; values between 0.75 and 0.9, good reliability; and values greater than 0.90 indicate excellent reliability.

From a pilot study, the sample size was determined based on alpha 0.05 and beta 0.2. The acceptable difference between the RAPTOR and standard X-ray generator was set at 1° for either fAMA or HKA, or 1 mm of overlap, standard deviation 1.95°. The calculated sample group comprised 30 patients.

RESULTS

A total 30 patients (45 knees) underwent TKA. The average age of the patients was 66.7 ± 8.0 years, there were 24 (53.3%) right-side knees, and 25 of the patients (83.3%) were female. The average body weight and height were 64.2 ± 11.2 kg and 157.6 ± 7.0 cm, respectively, resulting in an average BMI of 26.4 ± 4.3 kg/m^2. Five patients were classified as KL grade 3 and 25 as KL grade 4.

The intraobserver reliabilities for the RAPTOR and the standard X-ray generator of each observer are shown in Table 1. Mean differences with 95% limits of agreement were -0.951–1.062° for fAMA; -10.338–11.076° for HKA; and -0.418–0.418 mm for overlap using the RAPTOR; and -1.359–1.114° for fAMA; 11.844–12.467° for HKA; and 0 mm for overlap using the standard X-ray generator. The ICC was 0.55–0.99 for all measurements of the RAPTOR and 0.56–0.99 for the fAMA and HKA measurements of the standard X-ray generator.

The interobserver reliability is shown in Table 2. The mean differences with 95% limits of agreement between three observers were -1.441–1.175° for fAMA, -7.453–7.475° for HKA, and -0.681–0.637 mm for overlap using the RAPTOR; and -1.149–1.424° for fAMA, -4.789–6.171° for HKA, and 0 mm for overlap using the standard X-ray generator. The ICC was 0.69–0.97 for all measurements of the RAPTOR, and 0.71–0.95 for the fAMA and HKA measurements of the standard X-ray generator.

Table 1 Intraobserver reliability.

Variable	*Mean (SD)*, Mean difference (95% limits of agreement)								
	Observer 1			Observer 2			Observer 3		
	Time 1	Time 2	Difference	Time 1	Time 2	Difference	Time 1	Time 2	Difference
RAPTOR									
f AMA, °	*5.470 (0.860)*	*5.540 (0.903)*	-0.069 (-0.762, 0.624)	*5.570 (0.890)*	*5.600 (0.930)*	-0.027 (-0.850, 0.797)	*5.710 (0.840)*	*5.660 (0.880)*	0.056 (-0.951, 1.062)
HKA, °	*168.410 (7.240)*	*169.000 (6.920)*	-0.596 (-4.651, 3.460)	*168.930 (6.650)*	*168.600 (6.040)*	0.336 (-6.443, 7.114)	*168.400 (5.820)*	*168.030 (5.66)*	0.369 (-10.338, 11.076)
Overlap, mm	*0.360 (1.040)*	*0.360 (1.040)*	0.000 (-0.418, 0.418)	*0.380 (1.090)*	*0.360 (1.030)*	0.022 (-0.270, 0.314)	*0.360 (1.020)*	*0.380 (1.090)*	-0.022 (-0.314, 0.270)
Standard X-ray generator									
f AMA, °	*5.660 (0.780)*	*5.710 (0.830)*	-0.051 (-0.811, 0.709)	*5.790 (0.910)*	*5.810 (0.740)*	-0.020 (-1.084, 1.044)	*5.630 (0.802)*	*5.760 (0.900)*	-0.122 (-1.359, 1.114)
HKA, °	*169.160 (7.160)*	*168.850 (7.020)*	0.309 (-2.026, 2.644)	*168.440 (6.660)*	*168.750 (6.820)*	-0.309 (-6.449, 5.831)	*168.620 (6.820)*	*168.300 (6.400)*	0.312 (-11.844, 12.467)
Overlap, mm	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*	*0.000 (0)*

SD, standard deviation; fAMA, femoral anatomical mechanical angle; HKA, hip knee ankle angle.

Table 2 Interobserver reliability.

Variable	Observer	Mean difference (95% limits of agreement)	
		2	3
RAPTOR			
fAMA, °	1	-0.104 (-1.008, 0.799)	-0.238 (-1.102, 0.626)
	2		-0.133 (-1.441, 1.175)
HKA, °	1	-0.522 (-5.358, 4.313)	0.011 (-7.453, 7.475)
	2		0.533 (-6.377, 7.444)
Overlap, mm	1	-0.022 (-0.681, 0.637)	0.000 (-0.418, 0.418)
	2		0.022 (-0.488, 0.532)
Standard X-ray generator			
fAMA, °	1	-0.129 (-1.124, 0.866)	0.024 (-1.149, 1.198)
	2		0.153 (-1.117, 1.424)
HKA, °	1	0.722 (-4.727, 6.171)	0.546 (-4.789, 5.882)
	2		-0.176 (-4.273, 3.921)
Overlap, mm	1	0.000 (0)	0.000 (0)
	2		0.000 (0)

SD, standard deviation; fAMA, femoral anatomical mechanical angle; HKA, hip knee ankle angle.

Table 3 Limits of agreement between RAPTOR and standard X-ray generator.

Variables, degree Mean (SD)	RAPTOR (N = 30)	Standard X-ray generator (N = 30)	Mean difference (95% limits of agreement)
fAMA	5.590 (0.830)	5.720 (0.740)	-0.131 (-1.187, 0.925)
HKA	168.560 (5.880)	168.690 (6.350)	-0.126 (-4.724, 4.471)
Overlap	0.360 (1.040)	0	0.363 (-)

The data presented is the average of the values measured by 3 observers at 2 different measurement moments. SD, standard deviation; fAMA, femoral anatomical mechanical angle; HKA, hip knee ankle angle.

The average values of the two assessments by the three observers are summarized in Table 3. The mean and 95% limits of agreement compared between the RAPTOR and standard X-ray generator were -0.131 (-1.187, 0.925)° for fAMA, -0.126 (-4.724, 4.471)° for HKA, and 0.363 (-) mm for overlap (Table 3). Only the overlap measurement differed significantly between the two methods ($p = 0.0243$). ICC between the two radiographic methods was 0.75 (0.63, 0.88) for fAMA and 0.93 (0.89, 0.97) for HKA. The average operating times of RAPTOR and the standard X-ray generator were 37.6 ± 5.5 and 20.2 ± 2.5 seconds, respectively. The difference between two methods was 17.4 ± 5.1 seconds, with a significant $p < 0.0001$.

DISCUSSION

LLSR is a standard and reliable method for assessing the mechanical alignment and preoperative planning in patients undergoing TKA [10,12,33]. Many general hospitals cannot obtain LLSR owing to technological and budgetary limitations. RAPTOR is an innovative method that enables the creation of LLSRs using conventional X- ray machines in hospitals. However, the accuracy and precision of LLSRs from RAPTOR and those from standard X-ray generator need to be further explored by orthopedic surgeons. This study aimed to validate the overlap of LLSR images on the coronal axis, fAMA, and HKA obtained from a digital X-ray machine.

The fAMAs obtained using the RAPTOR and standard X-ray generator had moderate to excellent intra- and inter observer reliabilities. The lowest reliability was registered in Observer 3 with an intraobserver ICC of 0.72 (-0.122; 95%CI -1.359, 1.114) for the standard X-ray generator, and an interobserver ICC of 0.690 (-0.133; 95%CI -1.441, 1.175) for RAPTOR. We found that the years of experience of the evaluators may have affected the reliability of the radiographic assessments. Observers 1 and 2 had more than 10 years of work experience compared to Observer 3, who had only five years of experience. The results of our study are compatible with those of Anto et al., who found moderate to excellent inter-observer reliability for fAMA measurement [23]. There, a single measure intraclass correlation of 0.733 and an average measure intraclass correlation of 0.943 were reported.

The HKA values obtained using the RAPTOR and standard X-ray generator had moderate to excellent intra- and interobserver reliabilities. The lowest ICC was registered in Observer 3 with an intraobserver ICC of 0.550 (0.369; 95%CI -10.338, 11.076) and an interobserver ICC of 0.83 (0.011; 95%CI -7.453, 7.475) for the RAPTOR. Our study was compatible with the study by Vaishya et al., who found that the results of HKA measurement had a better agreement between the observers as the experience of the surgeons increased, with an ICC of 0.7 (95%CI -2.2, 3.1) [24]. Nonetheless, our results for all observers' levels of agreement in HKA had a wider range, especially in Observer 3 (95%CI 10.380, 11.0760).

However, as the level of agreement was not significantly different between the observers, we found that the measurement technique may have affected reliability and validity. The individual variations in finding the center of the hip, knee, and ankle center can be attributed to inter-observer variability.

The data demonstrated less intra-interobserver reliability in HKA. The lack of clarity of the femoral head border, especially in obese patients, affects the accuracy of the hip center position when using a digital Mose's circle. Radiographic techniques must be performed to improve clarity. Furthermore, the radiological technician's skills and right stitching techniques can reduce anatomic femoral overlap.

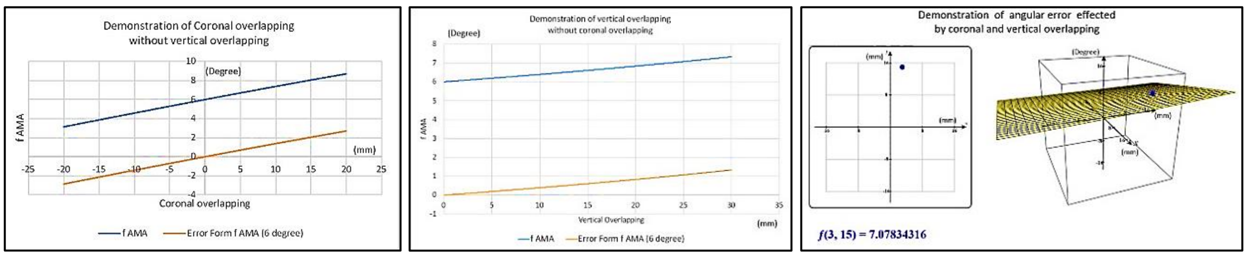
It was found that the clarity of the intertibial spine and midpoint of the ankle landmarks affected the measurement. In severe deformities of the knee, the intertibial spine is not clear enough in radiographs to allow determination of the exact point. In some cases, the ankle had osteoarthritis, which affected landmark determination. All these unclear landmarks affected the precision when determining HKAs between the two lines, and the apex of the angle affected the measurement's accuracy, especially in Observer 3.

After one week of observer evaluation of LLSRs, we found that observer 3 had errors in the determination of the landmarks of the three points of the hip center and angle measurement. After re-training the measurement methods, Observer 3 tended to measure the hip center more centrally.

Overlaps can be caused by simultaneous coronal, vertical, both coronal and vertical overlapping. From our mathematical calculations, it was found that coronal overlapping alone had an effect on fAMA of 1° when coronal overlapping was 7 mm to the lateral side of the femur and 8 mm when it was on the medial side (Fig. 6a). This coronal overlap may have been caused by patient movement [13] and prolonged radiographic time. We found that RAPTOR required longer periods to obtain LLSRs than the standard X-ray generator, with a mean difference of 17.4 ± 5.1 seconds. This prolonged time might also cause coronal overlapping.

We found that vertical overlapping could occur with LLSR length loss or incorrect stitching technique. Vertical overlapping can be identified by the simultaneous overlapping of both sides of the femoral cortex with a loss of length of 120 -cm ruler in the same area. From our mathematical calculations, it was found that vertical overlapping alone had a 1° effect on fAMA when vertical overlapping was 23 mm (Fig. 6b). In our practice, vertical overlapping can be minimized by using a 120-cm ruler as a landmark for the stitching technique, while keeping the standing distance between the patient and the head tilt unit at 240 cm for diminished length loss.

From the pilot study, we found that the coronal overlap of all LLSRs from RAPTOR was < 3 mm; therefore, we used mathematical calculations of both coronal and vertical overlapping by fixed coronal overlapping at 3 mm and variable vertical overlapping. We found that a 1° change in fAMA resulted from coronal overlapping medially for 3 mm with vertical overlapping at 15 mm (Fig. 6c).



(a) (b) (c)

Fig. 6 (a) Demonstration of angular error affected by coronal overlapping without vertical overlapping. **(b)** Demonstration of angular error affected by vertical overlapping without coronal overlapping. **(c)** Demonstration of angular error affected by a fixed 3 mm coronal overlapping with variable vertical overlapping

The ICC between RAPTOR and standard X-ray generator was 0.75 (-0.131; 95%CI -1.187, 0.925) for fAMA and 0.93 (-0.126; 95%CI-4.724, 4.471) for HKA. They exhibit moderate to excellent reliability. This information confirms the excellent reliability and validity within 1° of fAMA in practical measurements. The average limits of agreement for HKA between RAPTOR and standard X-ray generator had a wide range of 5° (-0.126; 95%CI -4.724, 4.471). This wide HKA range may have been affected by coronal laxity and flexion contracture, combined with some rotation of the foot position between the two radiographs. Therefore, we recommend enforcing the same standard patient standing position every time LLSR is performed.

In this study, the interobserver reliability depended on the number of years of practice and training. The levels of agreement between Observers 1 and 2, who had more surgical experience, were closer to each other than to Observer 3.

The strength of our study was the adequate sample size. In the pilot study, the number of enrolled patients was eight; here, we included 30 patients; blinded observers' evaluation; assessment of both intra- and interobserver reliabilities, and ICCs of fAMA, HKA, and overlap; and validation with orthopedic surgeons. The Visio program allowed experienced users to determine the point of the hip center in the same way as when using Mose's circle. This is different from the PACS, which determines the point using an oval and adjusts it to the circumference of the hip joint. Although radiography, different timings, places, and radiological techniques affected the positioning of the patients, using the same specified protocol produced similar LLSRs in both RAPTOR and the standard X-ray generator. This demonstrates the reproducibility and accuracy of the two machines.

The limitations of this study are as follows: 1) the accuracy of radiographic measurement.

Variations in the rotation of the lower extremity and orientation of the X-ray beam may alter true projections. External rotation increases the varus angle of the knee, whereas internal rotation decreases it [14]. Malrotation between 20° external rotation and 20° internal rotation has demonstrated a 2.5° modification of angulation [15]. This would have impacted our results more significantly if the patient had flexion contracture [16]. The most common error is placement of the foot with less internal rotation. In severe cases of knee osteoarthritis, knee alignment involves extreme external rotation. To obtain a true knee AP radiograph, the feet should be placed with more internal rotation, and sometimes higher than 20°. 2) The clarity of radiograph affected landmark determination of the femoral head, interspinous tibia, and ankle, causing inaccuracy in fAMA and HKA measurements. 3) Severe varus angulation radiograph might have affected the observers' measurement bias due to the recognition of radiography at the first measurement. 4) Measurement techniques were performed using the Visio program, which is unfamiliar to orthopedic surgeons. This might have affected the determination of landmarks and resulted in a lack of expertise and understanding of the tool use, thereby causing measurement errors. After one week of the repeated training, it was found that measurement techniques and the determination of points were more precise. 5) LLSR is a new technique in our hospital, but the training of radiological technicians and the stitching technique using a 120-cm ruler were indicators of radiograph precision. After more than 10 radiological technicians training sessions, no overlap was found. 6) As the radiographs were obtained on the same day, patients may have experienced fatigue when taking a second radiograph.

CONCLUSIONS

Many public hospitals in rural areas have limited access to LLSRs for preoperative TKA planning and evaluation of fAMA and HKA. We invented the RAPTOR device to allow the use of LLSRs in public hospitals. The RAPTOR's orthoroentgenographic technique combined X-ray generator with radiographic image stitching using the Visio program can create LLSRs.

In this study, LLSRs from the RAPTOR and standard X-ray generator had moderate to excellent intra-interobserver reliability and were comparable in terms of fAMA and HKA. Only the overlap was different between the two methods.

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Functional Outcomes of Varus Osteotomy with Locking Compression Plate Fixation in Legg-Calve-Perthes Disease

Duangjai Leeprakobboon, MD, Sermsak Sukpanichyingyong, MD, Thananit Sangkomkamhang, MD, PhD

Department of Orthopaedics, Khon Kaen Hospital, Khon Kaen, Thailand

Purpose: Patients with Legg-Calve-Perthes disease are treated to preserve the roundness of the femoral head. Surgical treatment includes the proximal femur or acetabulum operations, however, remains controversial. Herein, we investigated the clinical findings and outcomes of varus osteotomy with locking compression plate fixation.

Methods: We reviewed 19 children (20 hips) with Legg-Calve-Perthes disease who underwent varus osteotomy with locking compression plate fixation at our hospital. The time to re-ossification, Stulberg classification, and Harris hip score were recorded preoperatively and at the final follow-up.

Results: We included 16 boys and two girls with unilateral hip involvement and one girl with bilateral hip disease. The mean age at the time of surgery was 7.9 years. Based on the Catterall classification, one, 10, and nine patients were classified as grades II, III, and IV, respectively. All patients were followed for 33 months. The mean time to re-ossification was 167 days. At final follow-up, based on the Stulberg classification, seven, nine, and four patients were categorized as class II, III, and IV, respectively. Based on the Harris hip score, 21.1%, 47.7%, and 31.6% of patients showed excellent, good, and fair functional outcomes, respectively. The Harris hip scores at the final follow-up were significantly improved compared to preoperative values. Following adjustment for sex and disease severity, age at disease onset and time of surgery were associated with Harris hip scores.

Conclusions: Varus osteotomy with locking compression plate fixation yields good results and significantly improves functional outcomes, although patient age affects the outcomes.

Keywords: Legg-Calve-Perthes disease, femoral varus osteotomy, outcomes, Harris hip score

Legg-Calve-Perthes disease is an idiopathic avascular necrosis of the femoral head, observed in children aged 4–9 years and is more commonly observed in boys [(1)]. The goal of treatment is to maintain the roundness of the femoral head in the acetabular socket to prevent head deformity and secondary osteoarthritis of the hip joint [(2)]. This reduces the patient's range of motion, with consequent difficulty in walking, sitting, and performing activities of daily living. Non-surgical management includes spica cast immobilization, bed rest, traction, and non-weight walking [(3)]. Surgical approaches aimed at femoral head containment include femoral varus or valgus osteotomy and pelvic osteotomies, such as innominate (Salter) pelvic osteotomy, lateral shelf osteotomy, and triple osteotomy. Femoral varus osteotomy and salter innominate osteotomy are

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Correspondence to: Duangjai Leeprakobboon, MD
Department of Orthopaedics, Khon Kaen Hospital, Khon Kaen, Thailand
E-mail: duangjai44@gmail.com

conventional surgical treatments; comparison between these approaches did not show significant differences with regards to radiographic outcomes; a recent study showed that combined osteotomy is the most effective procedure in severe cases [4]. Few studies have compared femoral varus osteotomy with conservative treatment [5-8]. They found that the femoral procedure was superior to brace treatment for late-onset disease [9].

There are various fixations for femoral varus osteotomy, such as locking plates, blade plates, and external fixators. In our cases, locking plates were applied because of the advantage of the fixed-angle device, fewer hardware complications, loss of fixation, and implant-related fractures compared with blade plates [10], avoiding pin tract infection, hip contracture, nonunion, and refracture that occurred in external fixation [11]. Regarding the Harris hip scores, the literature in 2022 mentioned Legg-Calve-Perthes disease outcomes, but no correlation between the Harris hip scores and type of fixation was reported [12].

In this study, we investigated the clinical findings and outcomes of varus osteotomy with locking compression plate fixation performed for Legg-Calve-Perthes disease and the factors associated with Harris hip scores.

MATERIALS AND METHODS

In this descriptive, retrospective study, we analyzed the medical records and radiographic data of 19 children (20 hips) who underwent surgical management for Legg-Calve-Perthes disease between 2013 and 2020. All patients underwent varus osteotomy with locking compression plate fixation. The inclusion criteria were age < 8 years with hip disease categorized as > grade II or age > 8 years with disease category ≥ grade II (Catterall classification), and lateral pillar classify-cation of B/C during the fragmentation stage. Patients with prior hip surgery were excluded from this study.

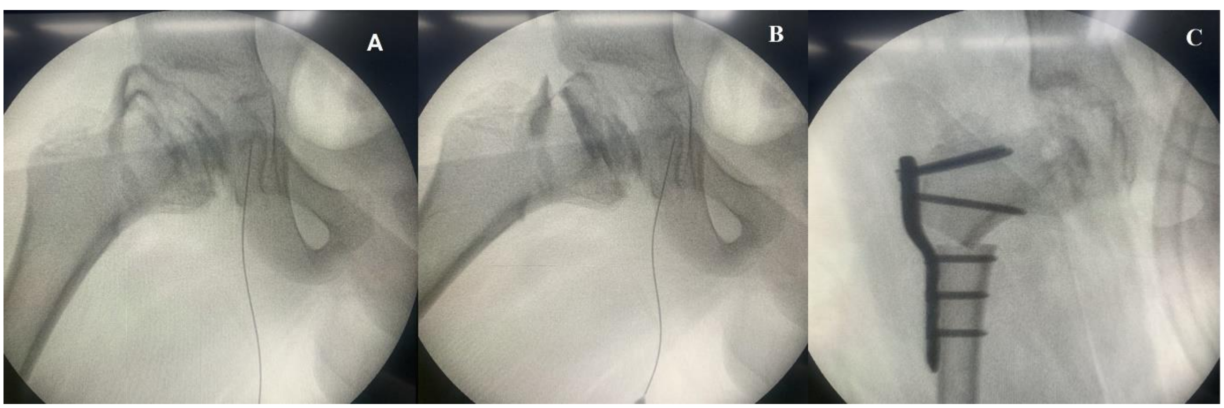

Fig. 1 (A) Arthrogram showing lateral subluxation findings of Legg-Calve-Perthes disease of the right hip in a 7-year-old boy. **(B)** AP radiograph obtained at 30° of hip abduction showing adequate femoral head containment and disappeared lateral subluxate. **(C)** Image showing femoral varus osteotomy using a locking compression plate.
AP: anteroposterior

Regarding the operative technique, the varus angle was selected for fixation following adductor tenotomy and arthrography. We performed osteotomy below the level of the lesser trochanter via the lateral approach, an open wedge was created, and a specific angle-locking plate with three proximal and distal locking screws (Pediatric hip locking plate, B. L. Hua Co.,Ltd) was used for internal fixation (Figure 1. A-C). The surgical goal was femoral head containment within the acetabulum with nearly 100% coverage and greater trochanter position. Subsequently, the patient was transitioned to protected weight-bearing until healing of the osteotomy site was confirmed.

Radiographic parameters, including the Catterall and lateral pillar classification, neck-shaft angle, and leg-length discrepancy were evaluated preoperatively. Changes in the neck-shaft angle, postoperative neck-shaft angle, leg-length discrepancy, Stulberg classification, functional outcomes, and time to re-ossification were evaluated after healing, as described by Waldenstrom. Harris hip scores for pain, function, absence of deformity, and range of motion were reviewed preoperatively and at the final follow-up, information from parents was obtained by interviews, and examination by orthopedic surgeons was also performed. Scores were interpreted as follows: a total score < 70, 70–80, 80–90, and 90–100 represented poor, fair, good, and excellent outcomes, respectively [13]. Data were analyzed by two orthopedic surgeons, and inter-rater reliability was confirmed using the Kappa statistic.

All statistical analyses were performed using STATA version 11 (Stata Corp., College Station, TX, USA), and statistical significance was set at $P < 0.05$. Fisher's exact test was used to assess independence between two dichotomous variables, and an independent *t*-test was used for parametric variables. We used crude odds ratios (OR), adjusted odds ratios (adjusted OR), and 95% confidence intervals to determine factors associated with functional scores based on the literature reviewed (e.g., sex and severity according to Catterall classification) to determine which factors affect patient outcomes [14].

RESULTS

The study included 16 boys and two girls with unilateral disease and one girl with bilateral hip disease. The mean patient age at the time of surgery was 7.9 years (range: 6–11 years). Based on the Catterall classification of Legg-Calve-Perthes disease, one, 10, and nine patients were categorized as Catterall grades II, III, and IV, respectively, and 11 and nine patients were categorized as lateral pillar grades B and C, respectively. All patients underwent follow-up for 2.8 years (range: 1.2–5.4 years) after varus osteotomy with locking compression plate fixation. The mean postoperative time to re-ossification was 5.5 months. The mean limb length discrepancy was 1.0 cm (range: 0.3–2.5 cm) at the time of the last follow-up. Based on the Stulberg classification, seven (35%), nine (45%), and four (20%) patients were categorized as classes II, III, and IV, respectively. Based on Harris hip scores, 21.1%, 47.7%, and 31.6% of the patients showed excellent, good, and fair functional outcomes,

Table 1 Patient demographic data and radiographic parameters with regards functional outcome.

	Good and Excellent outcome (n=14)	Fair outcome (n=6)	p-value
Age at onset (Mean (SD))	7.07 (0.28)	9.33 (0.55)	0.0009
Age at surgery (Mean (SD))	7.28 (0.26)	9.33 (0.55)	0.0014
Catterall classification			0.740
2 (frequency (percent))	1 (7.14)	0 (0.00)	
3	6 (42.86)	4 (66.67)	
4	7 (50.00)	2 (33.33)	
Lateral pillar			> 0.9999
B (frequency (percent))	8 (57.14)	3 (50.00)	
C	6 (42.86)	3 (50.00)	
Stulberg classification			0.03
2 (frequency (percent))	7 (50.00)	0 (0.00)	
3	6 (42.86)	3 (50.00)	
4	1 (7.14)	3 (50.00)	
Preoperative NS angle (degrees) (Mean (SD))	142.92 (1.79)	140.66 (3.31)	0.5245
Postoperative NS angle (degrees) (Mean (SD))	130.42 (2.06)	129.66 (1.72)	0.8243
NS angle change (degrees) (Mean (SD))	12.50 (1.66)	11.00 (3.41)	0.6610
Preoperative LLD (mm) (Mean (SD))	4.64 (0.95)	6.16 (1.62)	0.4075
Time to reossification (months) (Mean (SD))	4.00 (0.93)	6.14 (1.05)	0.2328

SD, Standard deviation; NS angle, Neck-shaft angle; LLD, Leg length discrepancy

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Table 2 Factors that affected Harris hip functional scores.

Factors	Odds ratio	Adjust for sex and severity		p-value
		Adjusted odds	95% CI	
Age at disease onset	0.26	0.27	0.001-0.91	0.044
Age at surgery	0.25	0.04	0.002-0.77	0.033
NS angle change	1.01	0.95	0.705-1.29	0.765

CI, Confidence interval; NS, Neck-shaft

respectively. The Harris hip scores recorded at the final follow-up were significantly improved compared with the preoperative values; the preoperative scores were 78. The Kappa statistic for inter-rater reliability was 0.80, indicating substantial agreement.

Table 1 shows a significant difference in age at disease onset and age at the time of surgery ($p < 0.01$) between patients with excellent/good and fair Harris hip scores. Comparison of the preoperative and postoperative neck-shaft angles, preoperative leg-length discrepancy, and time to re-ossification did not show statistically significant differences between functional outcomes. Postoperative leg-length discrepancy was significantly associated with hip kinematics and function; therefore, this variable was not included in the analysis [15].

After adjustment for sex and disease severity, factors that affected the Harris hip score included age at disease onset (OR, 0.26 [0.10–0.78]; adjusted OR, 0.27 [0.001-0.91]; $p > 0.05$) and age at the time of surgery (OR, 0.25 [0.10–0.79]; adjusted OR, 0.04 [0.002-0.77]; $p > 0.05$). The postoperative neck-shaft angle change did not differ between the outcomes ($p > 0.05$) (Table 2).

DISCUSSION

The goal of the surgical management of Legg-Calve-Perthes disease is femoral head containment within the acetabulum during remodeling and ossification, improved sphericity of the femoral head, resolution of clinical symptoms, and improved functional outcomes. Femoral varus osteotomy and salter innominate osteotomy are conventional surgical approaches used in such cases. Femoral varus osteotomy can improve femoral head coverage and sphericity, and does not cause postoperative joint pressure or articular rigidity [1,16,17]. However, weakness of the abductor

Fig. 2 (A-B) Radiographs of bilateral hips in a 7-year-old boy with Catterall grade III Legg-Calve-Perthes disease of the left hip. **(C)** Radiographs of locking compression plate fixations. **(D-E)** Images showing type 3 Stulberg classification; the patient had excellent functional outcomes 2 years postoperatively.

Fig. 3 (A-B) Radiographs of bilateral hips in an 8-year-old boy with Catterall grade III Legg-Calve-Perthes disease of the right hip. **(C)** Radiographs of locking compression plate fixations. **(D-E)** Images showing type 3 Stulberg classification; the patient had good functional outcomes 6 years postoperatively.

mechanism and limb shortening, which are not associated with residual shortening, are disadvantages of this operation [18].

Considering the many advantages of femoral varus osteotomy, this method was selected as the first-line surgical approach for Legg-Calve-Perthes disease. We observed good-to-excellent functional outcomes of up to 68.4% in our study population comprising 19 children (20 hips). Figure 2 (A-E) shows a patient whose functional score improved to excellent (93 points) and Figure 3 (A-E) shows a patient with good outcomes with a postoperative functional score of 81. Similarly, our study showed that Harris hip scores at the final postoperative follow-up were significantly improved compared to the preoperative values. A previous study recommended intertrochanteric varus femoral osteotomy as an acceptable method for managing patients with Legg-Calve-Perthes disease. This operation was associated with reduced pain (assessed using the visual analog scale), limp, and increased range of motion [19]. Similarly, an article on early proximal femoral varus osteotomy shortened the fragmentation phase [20] and the benefits of femoral varus osteotomy during the fragmentation stage were mentioned [21].

With regards to factors that affected function, based on the Harris hip scores, we observed that following adjustments for sex and disease severity, the patients' age at disease onset and at the time of surgery were statistically significant. A meta-analysis reported operative treatment by age [6,7,22]; moreover, a study also reported that disease severity was a statistically significant factor [13]. An agreement study performed in 2008 reported that femoral head involvement ≥ 50% served as the strongest predictor of radiological outcomes, followed by age at the time of diagnosis and disease severity based on the lateral pillar classification [23,24].

With regards to radiographic parameters, such as changes in the neck-shaft angle and preoperative leg-length discrepancy, we observed a disassociation between these parameters and functional outcomes. In this study, the neck-shaft angle in the excellent and good outcome groups was 12.5°, consistent with previous studies which recommend a 10–15° varus correction to achieve a Stulberg radiographic outcome [25].

The strengths of this study are as follows: (a) all patients belonged to the same age group; (b) all patients were treated by the same surgeon; (c) all patients underwent the same surgical procedure; and (d) the same clinical and radiographic rating systems were used for evaluation in all patients.

The limitations of this study are as follows: (a) this is a case series without a comparison group and (b) this was a single-center study.

CONCLUSIONS

Varus osteotomy with locking compression plate fixation is a safe procedure that significantly improves functional outcomes in patients with Legg-Calve-Perthes disease; however, patient age has been shown to significantly affect functional outcomes.

CONFLICTS OF INTEREST

The authors report no conflicts of interest, financial or otherwise, with regards to the materials or methods used or the findings described in this study.

ETHICAL CONSIDERATIONS

This study was approved by the Research Ethics Committee of our institution.

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Short-Term Global Instability and Genu Recurvatum Outcomes of Revision Total Knee Arthroplasty with Rotating-Hinged Knee Prosthesis

Pichate Sripadet, MD, Saradej Khuangsirikul, MD, Danai Heebthamai, MD, Ong-Art Phruetthiphat, MD, Thanainit Chotanaphuti, MD

Department of Orthopaedic, Phramongkutklao College of Medicine, Bangkok, Thailand

Purpose: Primary revision total knee arthroplasty (TKA) is associated with bone loss and ligamentous insufficiency. After TKA, patients may have global knee instability or genu recurvatum and require revision TKA with a rotating-hinged knee (RHK) prosthesis. However, several studies have reported variable outcomes. This study aimed to: 1) evaluate the outcomes of revision TKA with an RHK prosthesis; and 2) compare the outcomes and satisfaction of patients with global instability and genu recurvatum following revision TKA.

Methods: The cases of 18 patients (mean age, 71 ± 8.5 years; mean follow-up time, 24 months (range, 12–38 months) who underwent revision TKA with an RHK prosthesis in 2015–2018 were retrospectively reviewed. Patients were further classified into the global instability group (n=11), those who were diagnosed with periprosthetic joint infection (8 patients), TKA dislocation (2 patients), and periprosthetic fracture with a complete tear of the medial collateral ligament (1 patient); and the genu recurvatum group (n=7). Clinical evaluations were performed preoperatively, at 1 year postoperative, and at the last follow-up. Outcomes were assessed using the Knee injury and Osteoarthritis Outcome Score (KOOS), pain visual analog scale (VAS), range of motion (ROM), complications, and radiographic data. Patient satisfaction was assessed at the 1-year follow-up using a self-administered scale.

Results: Overall, the mean KOOS at the 1-year follow-up was significantly improved versus preoperative (71.39 ± 8.65 vs. 22.56 ± 11.58, p<0.001). The mean 1-year postoperative KOOS (50 vs. 47, p=0.028), surgical satisfaction score (p=0.005), home activity satisfaction score (p=0.0029), and recreational activity satisfaction score (p=0.024) were significantly higher in the global instability versus genu recurvatum group, whereas the mean pain VAS score was significantly higher in the global instability versus genu recurvatum group (6 vs. 4, p=0.037). The mean ROM improved from 30° to 90° in the global instability group and from -20° to 0° in the genu recurvatum group. No surgical complications or signs of prosthesis loosening were observed.

Conclusions: Revision TKA with an RHK prosthesis showed better functional outcomes in patients with global instability versus genu recurvatum. Furthermore, patients with global instability showed higher satisfaction with surgery, home, and recreational activities than those with genu recurvatum.

Keywords: rotating-hinged knee prosthesis, recurvatum after primary TKA, global instability, functional outcome, patient satisfaction

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Correspondence to: Pichate Sripadet, MD
Department of Orthopaedic, Phramongkutklao College of Medicine, Bangkok, Thailand
E-mail: slam_dome@hotmail.com

Revision total knee arthroplasty (TKA) is challenging, and its incidence is steadily increasing. Some authors estimate that the number of revision TKA will increase by 601% in 2030 versus 2005. The most common etiologies for revision TKA are infection (36.1%), aseptic loosening (21.6%), periprosthetic fracture (13.7%), and instability (6.7%) [1,2]. Conventional implants are used in most cases, but some patients present with severe deformities, severe involvement of the ligamentous structure, or bone loss requiring a more constrained implant [3].

Fixed-hinge prostheses have the disadvantages of higher stress transmission to the bone–implant interface, a high rate of failure, and frequent complications including infection, loosening, and component failure [4]. The rotating-hinge knee (RHK) prosthesis is the evolution of a fixed-hinge model that combines flexion–extension movement with axial rotation to improve mechanics and decrease stress transmission [5]. Several indications exist for the use of RHK prostheses, including severe primary knee osteoarthritis with neuromascular disorders, rheumatoid arthritis, and severe bone loss. In revision TKA, the RHK prosthesis is necessary to resolve severe bone loss following infection or aseptic loosening, instability including global instability, and genu recurvatum [6,7].

Global instability, defined as instability in all planes, can occur after periprosthetic joint infection, aseptic loosening, and severe bone loss. In more severe cases of global instability, symmetrical and balanced flexion and extension gaps may not be achievable and an RHK prosthesis may be necessary [8,9]. The outcomes of revision TKA using RHK prostheses in patients with global instability vary. Some studies showed excellent outcomes [10,11], while others showed a high complication rate. In a series with a high complication rate, postoperative infection, the most frequent complication, occurred in approximately 45% of patients [12].

Genu recurvatum (hyperextension instability) occurs in only 0.5–1% of patients undergoing TKA [13]. Patients with severe recurvatum (hyperextension > 10°) after TKA have the worst functional outcomes and highest risk of revision surgery for laxity [14]. Genu recurvatum may require the use of a lifelong brace, an RHK prosthesis, or arthrodesis [15]. Cottino et al. [8] recommended the use of an RHK prosthesis with an extension stop to reduce the risk of postoperative hyperextension instability. In patients with poliomyelitis or neuromuscular disease, genu recurvatum presents as a result of quadriceps weakness and ankle equinus, which is compensated for by walking with the knee locked in hyperextension. An RHK prosthesis can be used in these patients [16]. Data are limited on the outcomes of revision TKA with RHK in patients with postoperative genu recurvatum and consist of only case series or case reports [16,17], which showed successful outcomes.

Patients with global instability and severe genu recurvatum after TKA are treated with an RHK prosthesis. However, different etiologies may result in varying outcomes. No studies to date have documented differences in outcomes or satisfaction among groups. We performed a retrospective study to evaluate and compare the outcomes of revision TKA using an RHK prosthesis including satisfaction of patients with global instability versus genu recurvatum.

MATERIALS AND METHODS

This retrospective study received institutional review board approval (no. R186h/62) and included all patients who underwent revision TKA using RHK prostheses (S-ROM RHK prosthesis; DePuy Orthopedics, Johnson & Johnson Co., Warsaw, IN, USA; S-ROM design group) between January 2015 and January 2018. Patients were classified into two groups: group 1, global instability after TKA; and group 2, genu recurvatum (hyperextension > 20°) after TKA (Figure 1). The exclusion criteria were revision TKA not treated with the S-ROM design and unreachable. The S-ROM RHK prosthesis Figure 2) was used by the same surgeon at our hospital for all patients. Eighteen patients underwent revision TKA using the medial parapatellar approach and received perioperative antibiotic prophylaxis (cefazolin 2–3 g). In the case of two-stage revision arthroplasty due to a periprosthetic joint infection, antibiotic therapy was chosen according to microbiological cultures and sensitivity and administered for at least 6 weeks between revision stages and for 12 weeks after the second-stage procedure using the S-ROM RHK prosthesis.

Fig. 1 An 82-year-old woman with knee instability following total knee arthroplasty. (A) Valgus–varus stress test for assessment of collateral ligaments of the knee. (B) Intraoperative image of complete tear of the medial collateral ligament.

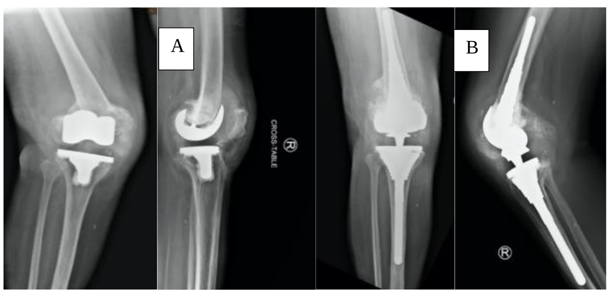

Fig. 2 (A) Preoperative radiographs showing the supracondylar periprosthetic fracture with insufficiency of the medial collateral ligament. (B) Radiographs taken after implantation of an S-ROM rotating-hinge knee prosthesis (DePuy Orthopedics) confirming favorable composition.

We collected the data by reviewing the outpatient department card and operative notes and filled in the incomplete data by telephoning. Demographic data included sex, age, body mass index, comorbidities, cause of revision, and follow-up duration. Patient outcomes were evaluated using the Knee injury and Osteoarthritis Outcome Score (KOOS) and pain visual analog scale (VAS). Range of motion (ROM) was measured passively using a goniometer with the patient in the supine position. The Thai version of the KOOS was created and validated by Chaipinyo in 2009 [18]. Examinations were recorded before surgery, at 1 year postoperative, and at the last postoperative follow-up. At 1 year postoperative, patient satisfaction was assessed using a self-administered satisfaction scale consisting of four criteria focusing on the patient's overall satisfaction with surgery, pain relief, ability to do home or yard work, and ability to engage in recreational activities [19,20]. Serial standard anteroposterior and lateral radiographs of the knees were reviewed, including the assessment of alignment, signs of loosening such as component migration, radiolucent lines, presence of cement fracture or periprosthetic fracture, and osteolysis. Complications included surgical site infection, periprosthetic joint infection, periprosthetic fracture, extensor mechanism problems, aseptic loosening, implant failure, instability, or neurovascular problems.

Demographic data are expressed as number and percentage or mean ± standard deviation. The results were based on functional scores, including the KOOS. The pre- and postoperative KOOS scores were compared using the Wilcoxon signed-rank U test. The KOOS were compared between groups using the Mann-Whitney U test (significance at $p < 0.05$). The ROM was described in detail between pre- and postoperative revision TKA for each group. Patient satisfaction scores were compared between groups using the chi-squared test with values of $p < 0.05$ considered statistically significant. The statistical analyses were performed using STATA version 12 (StataCorp LLC, College Station, TX, USA).

RESULTS

Eighteen patients underwent revision TKA using the S-ROM RHK. The indications were global instability in 11 (61%) patients and genu recurvetum after TKA in seven (39%) patients. The patients' demographic data are summarized in Table 1. The minimum follow-up period was 12 months, while the mean follow-up duration was 24 (range, 12–38) months. The mean KOOS at 1-year follow-up in all patients was significantly improved versus preoperative (71.39 ± 8.65 vs. 22.56 ± 11.58, p<0.001). The mean VAS score significantly improved in all patients (6.50 ± 2.12 vs. 1.11 ± 1.13, p<0.001) (Table 2). The 1-year postoperative KOOS was significantly higher in patients with global instability than in those with genu recurvatum after TKA (50 vs. 47, p=0.028). Although the mean pain

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VAS score was significantly improved in both groups, it was significantly higher in the global instability versus genu recurvatum group (5.91 ± 1.14 vs. 4.57 ± 1.13, respectively; p=0.037). Additionally, the mean ROM improved compared to the preoperative value in both groups (30° to 90° in the global instability group and -20° to 0° in the genu recurvatum group). No signs of prosthetic loosening or subsidence were observed at 1 year postoperative or at the last follow-up in either group. No surgical complications (surgical site infection, periprosthetic joint infection, periprosthetic fracture, extensor mechanism problem, or neurapraxia) occurred in either group.

Table 1 Demographic data of patients who underwent rotating-hinge knee prosthesis implantation.

Characteristic	Data
Patients (knees)	18
Age, years	71.67 ± 8.64
Body mass index	25.15 ± 3.35
Sex	
Female	13 (72%)
Male	5 (28%)
Comorbidity	
Hypertension	15 (83%)
Diabetes mellitus	5 (27%)
Rheumatoid arthritis	1 (5%)
Other	7 (38%)
Indication	
Genu recurvatum	7 (39%)
Global instability	11 (61%)
Periprosthetic joint infection	8 (73%)
Knee dislocation	2 (18%)
Supracondylar periprosthetic fracture with complete tear of medial collateral ligament	1 (9%)

Data are shown as mean ± standard deviation or n (%) as appropriate. “Other” conditions include dyslipidemia, chronic obstructive pulmonary disease, ischemic heart disease, and chronic kidney disease.

Table 2 Mean pre- and postoperative KOOS and VAS of all patients at 1-year follow-up.

Score	Preoperative	Postoperative	P value
	Mean ± SD	Mean ± SD	
KOOS	22.56 ± 11.58	71.39 ± 8.65	<0.001
VAS	6.50 ± 2.12	1.11 ± 1.13	<0.001

KOOS, Knee injury and Osteoarthritis Outcome Score; VAS, visual analog scale; SD, standard deviation

Table 3 Mean KOOS and VAS scores of the global instability versus genu recurvatum groups at 1-year follow-up.

Time	Global instability	Genu recurvatum	P value
	Mean ± SD	Mean ± SD	
Preoperative KOOS	17.45 ± 5.15	30.57 ± 14.6	0.013
Preoperative VAS	7.36 ± 1.63	5.14 ± 2.19	0.027
Δ pre- vs. postoperative	50.91 ± 4.72	45.57 ±5.29	0.028
Δ pre- vs. postoperative VAS	5.91 ± 1.14	4.57 ± 1.13	0.037

KOOS, Knee injury and Osteoarthritis Outcome Score; VAS, visual analog scale; SD, standard deviation

Patient satisfaction was significantly different between groups, except for satisfaction with pain (Figure 3). The global instability group had significantly higher satisfaction scores for home and recreational activities than the recurvetum group (p=0.029 and p=0.024, respectively), including satisfaction with the surgery (p=0.005).

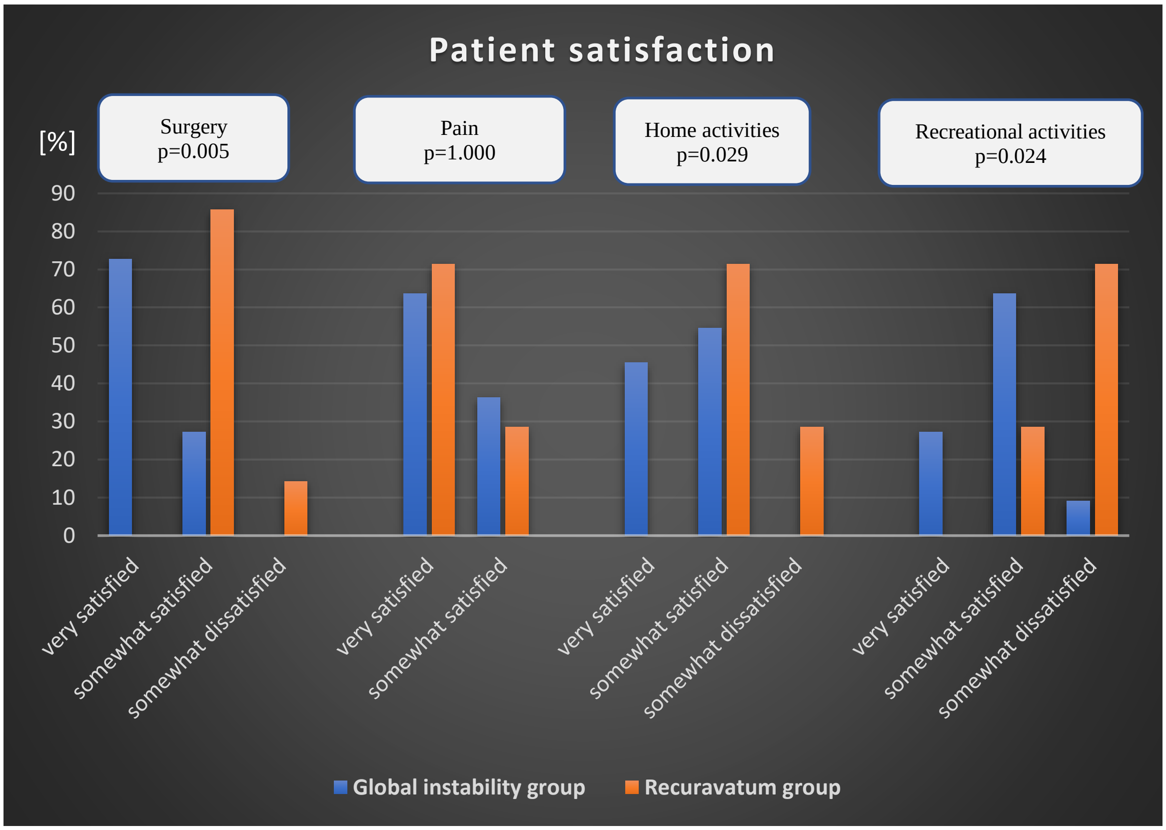

Fig. 3 Patient satisfaction in the global instability versus genu recurvatum groups.

DISCUSSION

At the short-term follow-up, revision TKA with the RHK prosthesis in our study resulted in good outcomes. All patients showed improved functional scores and satisfaction. The outcomes of RHK prosthesis in revision TKA were evaluated in several studies, with results varying from poor to good. Neumann et al. [21] reported a small series of 24 patients with improved functional scores. No implant loosening was observed, and only one patient required revision due to patellofemoral subluxation. Bistolfi et al. [22] studied 33 revision patients; almost half of them developed postoperative complications, while three required re-revision. In a larger series of 79 knees, Kearns SM et al. [23] reported a complication rate of 38.7% (periprosthetic joint infection, periprosthetic fracture, and extensor mechanism rupture) and defined periprosthetic joint infection as the most frequent complication of the RHK prosthesis, while our study had no cases of periprosthetic joint infection at the final follow-up, probably because of our strict perioperative management. In a previous study, Deehan et al. [24] reported 36 S-ROM hinge prostheses (four primary, 33 revision), of whom four patients required patellar resurfacing for persistent pain. Although this study defined anterior knee pain after RHK prosthesis placement, no incidence of anterior knee pain was observed in our study because all patients underwent patellar resurfacing without patellar maltracking.

Barrack et al. [4] reported satisfactory results in a series of 23 knees (S-ROM RHK) after 2–9 years of follow-up; all but one patient indicated satisfaction with the surgery or the degree of pain relief and function. In our study, patient satisfaction differed among subcategories. Patients with global instability were significantly more satisfied with their home and recreational activities, but not with their pain. This is probably because patients with global instability may be more susceptible to their pathologies than those with genu recurvatum, including completely limited daily and soft sports activities. After revision TKA, all patients showed improved functional outcomes and returned to their normal activities; thus, they were more satisfied.

Our study has some limitations. First, it included a small number of patients from a single institution, which does not allow conclusions about the definitive outcome of the RHK prosthesis (S-ROM design) to be drawn. Second, the follow-up period was short, with a mean follow-up period of 24 months and a minimum of 12 months. Mid- to long-term follow-up should be performed to draw definitive conclusions about complications and survival rates.

CONCLUSIONS

This study demonstrated that the S-ROM RHK prosthesis provided good functional and radiologic outcomes and high satisfaction at short-term follow-up. Revision TKA with an RHK prosthesis showed better functional outcomes for patients with global instability than those with genu recurvatum following TKA. Furthermore, the former group showed higher satisfaction with home and recreational activities. We believe that good surgical technique and good perioperative care are key elements to good outcomes after revision TKA with an RHK prosthesis.

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Efficacy of Intra-Articular Ketorolac and Bupivacaine on Postoperative Pain Relief after Arthroscopic Anterior Cruciate Ligament Reconstruction: A Randomized Double-Blind Study

Suphasak Sathonphanit, MD, Sakda Thani, MD, Pachin Thanomsingh, MD

Department of Orthopedic Surgery, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand

Purpose: The purpose of our study was to determine whether there is any additional benefit to adding ketorolac, a non-steroidal anti-inflammatory drug (NSAID), to bupivacaine compared to bupivacaine alone in patients undergoing anterior cruciate ligament reconstruction (ACLR) surgery.

Methods: Fifty-two American Society of Anesthesiology I-II patients undergoing arthroscopic ACLR under spinal anesthesia were randomly assigned to one of two groups: group A (10 mL of bupivacaine 0.25% with ketorolac 60 mg) and group B (10 mL of bupivacaine 0.25%). At the end of the procedure, 10 mL of each drug was administered intra-articularly. The dose of intravenously administered analgesic medication (morphine) was calculated based on the patient's body weight and visual analog scale (VAS) score. The postoperative time to rescue analgesia, 24-hour analgesic requirement, VAS score at time of rescue (T-rescue), and findings at rest and during movement were observed.

Results: The VAS score at the time of rescue analgesic significantly lower in group A than in group B (33.85 ±19.61 ; 56.15±21.92) ($p < 0.001$). Group A had significantly lower 24-hour analgesic consumption than group B (0.28±0.07 ; 0.39±0.09) ($p < 0.001$).the mean duration of analgesia was longer in group A than in group B (320 minutes ; 235 minutes)($p = 0.194$) however, this difference was not statistically significant.

Conclusions: Intra-articular administration of a combination of ketorolac and bupivacaine resulted in a significantly longer duration of analgesia and reduced morphine use in the 24-hour postoperative period and is an effective option for reducing postoperative pain.

Keywords: intra-articular injection, ketorolac, anterior cruciate ligament reconstruction, postoperative pain, bupivacaine

Anterior cruciate ligament reconstruction (ACLR) is a common knee surgery that can cause intense pain at the sites of graft harvest and tibial and femoral tunnels, leading to a slower recovery and increased morbidity. Postoperative pain can negatively impact quality of life and work performance[1]. Numerous studies have been conducted on the use of various drugs and combinations of drugs administered intra-articularly to improve analgesic efficacy. However, many patients experience moderate-to-severe pain 24 hours after knee arthroscopy, which can disrupt sleep and affect activity levels[2].

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Correspondence to: Suphasak Sathonphanit, MD
Department of Orthopedic Surgery, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand
E-mail: s.sathonphanit@gmail.com

Ketorolac, non-steroidal anti-inflammatory drug (NSAID), can be used locally as an analgesic or as an intra-articular injection. In its active form, ketorolac acts on synovial tissue. It has a high degree of protein and tissue binding, which slows drug transport across the synovium and out of the joints[3]. It may also prevent the release of proinflammatory cytokines such as interleukin-1, which is associated with excessive cartilage degradation under inflammatory conditions.

In an animal study[4], no differences were found between ketorolac (NSAID) and saline (SAL) injection groups for any parameter measured at any time point. This study evaluated knee kinematics, including measured forces (propulsion, vertical, medial, lateral, and braking), paw placement (stride width and length), and timing (speed, rate of loading, and stance time) of ambulation, for both the NSAID and SAL groups. Ge et al.[5] found that the use of NSAIDs after ACLR is relatively safe and could decrease the adverse side effects caused by opioid drugs. Constantinescu et al.[6] conducted a systematic review and found insufficient data to definitively state the effects of perioperative NSAIDs on soft tissue healing. The use of NSAIDs should be considered on a case-by-case basis and may not affect healing rates after meniscal, ACL, rotator cuff, or Bankart repair.

This study aimed to investigate whether the combination of ketorolac and bupivacaine has a synergistic effect in reducing pain and the use of opioids. The effects of both drugs on different pathways were evaluated.

METHODS

This study included a sample group of patients with ACL who underwent surgery between 2018 and 2020 performed by two experienced surgeons. The study was approved by the institute's ethics committee, and 52 American Society of Anesthesiology I-II patients were randomly assigned to one of two groups: group A received 10 mL of bupivacaine 0.25% with 60 mg of ketorolac, and group B received 10 mL of bupivacaine 0.25%. At the end of the procedure, 10 mL of each drug was administered intra-articularly. The postoperative time to rescue analgesia, 24-hour analgesic requirement, and visual analog scale (VAS) scores at rest and during movement were recorded. (Table 1)

Randomization was performed using computer-generated random numbers and the sealed-envelope technique. Patients were divided into two groups: group A received an intra-articular injection of 10 mL of bupivacaine 0.25% combined with ketorolac 60 mg, whereas group B received 10 mL of 0.25% bupivacaine only. The injections were administered through the anterolateral arthroscopy port immediately before skin closure. The patients were instructed to use the VAS for postoperative pain evaluation and were unaware of their group allocation. All patients received spinal anesthesia in accordance with standard protocols. After standard monitors (electrocardiogram, noninvasive blood pressure monitor, and pulse oximeter) were attached, patients were preloaded with 10 mL/kg of crystalloid and then given heavy spinal anesthesia (3 mL of bupivacaine 0.5%) using strict aseptic precautions while in the lateral position. A tourniquet was applied 10 minutes later at approximately T10 at a pressure of 100 mmHg above systolic blood pressure.

Smith & Nephew arthroscopic equipment was used for ACLR with an ipsilateral quadruple hamstring tendon graft (semitendinosus and gracilis double-folded) with an endobutton for femoral fixation and a bioabsorbable interference screw for tibial graft fixation via a two-portal technique. The treatment of patients with meniscal lesions involves using the all-inside technique for meniscal repair with the Fast-Fix 360 device from Smith & Nephew. At the end of the procedure, a blinded individual administered the drug combinations through the anterolateral port site using preloaded, unlabeled syringes prepared by another person. The tourniquet was gradually deflated after 10 minutes, and a compression bandage was applied along with an additional crepe bandage. The knees were immobilized using a knee brace.

After surgery, patients received postoperative care in the post-anesthetic care unit for approximately 1 hour. Pain was assessed using the 100 mm VAS (100 mm) every 4 hours for 24 hours after surgery. Pain relief medication (morphine) was administered according to the level of pain reported by Aubrun et al.[7] Patients with a VAS score <30 were administered 0.075 mg/kg of morphine, those with a VAS score of 30-70 were given 0.1 mg/kg of morphine, and those with a VAS score >70 were given 0.15 mg/kg of morphine. The time to the first request for analgesics (T-rescue) and VAS findings (VAS T-rescue) were recorded. Tourniquet pressure and duration were also recorded along with demographic parameters, duration of surgery, and total dose of morphine administered within 24 hours. Pain intensity was monitored using a VAS (0 = no pain, 100 = worst possible pain). Any side effects such as nausea, vomiting, sedation, pruritus, or urinary retention were noted and treated as needed. Hemodynamic parameters (blood pressure, heart rate, pulse oximetry saturation, and respiratory rate) were recorded every 15 minutes for 2 hours postoperatively. Both groups received baseline pain medication in the form of paracetamol 500 mg orally every 6 hours to reduce pain.

RESULTS

Fifty-two randomized patients completed the study. The demographic data of the patients showed no significant differences between the two groups. The median age was 29.6 years and both groups were comparable in terms of age, weight, and height. There were more male (n = 46) than female (n = 6) patients. Two surgeons with 8 and 5 years of experience performed surgeries on 30 (57.7%) and 22 (42.3%) patients, respectively. There were no differences between the groups in terms of tourniquet or surgery duration (Table 1). The effect of meniscal repair surgery on postoperative pain has been observed in a patient population within the study. However, owing to the randomization, it can be concluded that the factors related to meniscal repair had equal effects in both groups. Group A had significantly lower 24-hour analgesic consumption than group B (0.28±0.07 ; 0.39±0.09) (p < 0.001) and the mean duration of analgesia was longer in group A than in group B (320 minutes ; 235 minutes) (p = 0.194), but this was not statistically significant. The VAS score at the time of rescue analgesic significantly lower in group A than in group B (33.85 ±19.61 ; 56.15±21.92) (p < 0.001). (Table 2). No adverse effects of ketorolac or bupivacaine were observed in any patient.

Table 1 Demographic data.

Variables	All	Ketorolac + bupivacaine	Bupivacaine	p-value
Age (years) mean ± SD	29.62 ± 8.58	29.62 ± 9.01	29.62 ± 8.30	1.00
BMI (kg/m^2) mean ± SD	24.55 ± 4.45	24.20 ± 3.59	24.91 ± 5.22	0.570
Sex, n (%)				
Male	46 (88.46)	23 (88.46)	23 (88.46)	1.00
Female	6 (11.54)	3 (11.54)	3 (11.54)	
ACL side, n (%)				0.575
Right	22 (42.31)	10 (38.46)	12 (46.15)	
Left	30 (57.69)	16 (61.54)	14 (53.85)	
ACLR technique, n (%)				0.579
Tranportal	26 (50)	12 (46.15)	14 (53.85)	
Trantibial	26 (50)	14 (53.85)	12 (46.15)	
Meniscus lesion, n (%)				0.535
None	7 (13.46)	3 (11.54)	4 (15.38)	
Meniscus lesion	45 (86.54)	23 (88.46)	19 (84.62)	
Tourniquet duration (min)	61.31 ± 14.09	61.92 ± 17.66	60.69 ± 9.62	0.756
Duration of surgery (min)	56.73 ± 12.57	56.35 ± 14.48	57.12 ± 10.61	0.828

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index.

Table 2 Results.

Variables	All (n = 52)	Ketorolac + bupivacaine (n = 26)	Bupivacaine (n = 26)	p-value
Time to first request for analgesic (min)	267.5 (90-655)	320 (120-645)	235 (90-655)	0.194
VAS score at T-rescue (scale of 100)	45 ± 23.47	33.85 ± 19.61	56.15 ± 21.92	<0.001
24-hour morphine requirement (mg/kg)	0.33 ± 0.10	0.28 ± 0.07	0.39 ± 0.09	<0.001

VAS, visual analog scale.
Results are shown as mean (range) or mean ± standard deviation.

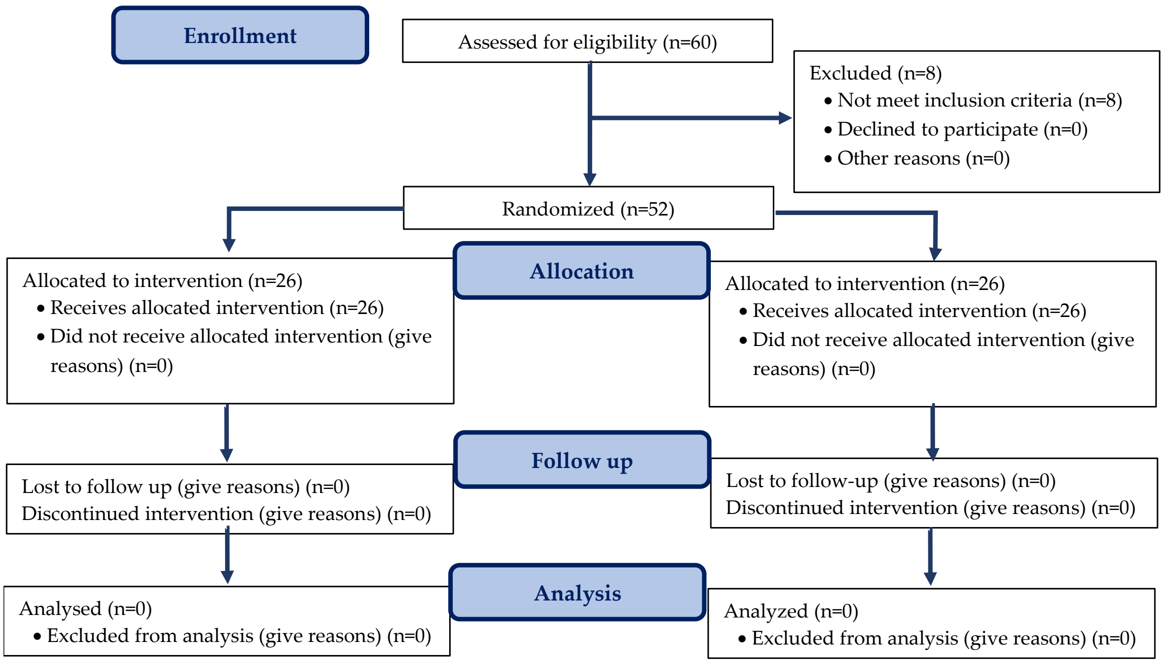

Fig. 1 CONSORT 2010 flow diagram.

DISCUSSION

The intra-articular administration of ketorolac and bupivacaine in patients undergoing ACLR helped reduce the use of morphine within 24 hours postoperatively.

Pain during arthroscopic surgeries is mainly due to surgical tissue handling and resection, causing irritation of the nerve endings in the synovial tissue, joint capsule, and anterior fat pad[8]. Bupivacaine, which has anesthetic effects and reduces pain, has been found to be effective in reducing pain and the use of opioids when used intra-articularly. Ketorolac has a high level of protein and tissue binding, which slows its transport across the synovium and out of the joints. NSAIDs act by inhibiting the production of COX-1 and COX-2, enzymes responsible for inflammation. It is used for the short-term management of moderate-to-severe pain in adults. Our study showed that the administration of a combination of ketorolac and bupivacaine resulted in a significantly longer duration of analgesia and reduced morphine use in the 24-hour postoperative period.

Guler et al.[9] compared intra-articular tenoxicam with morphine and saline and found that intra-articular tenoxicam injection significantly reduced pethidine use in patients after ACLR compared with morphine and saline.

Calmet et al.[10] compared the analgesic effects of intra-articular ketorolac, morphine, and bupivacaine in patients undergoing arthroscopic knee surgery. Adding ketorolac to bupivacaine significantly reduced the dose of intravenous tramadol for postoperative pain relief. However, no studies have been conducted on intra-articular ketorolac in patients who underwent ACLR.

Vintar et al.[11] reported a significant difference in pain relief with an intra-articular mixture of ropivacaine, morphine, and ketorolac compared to placebo. However, there has never been a comparative study of formulations containing active NSAIDs such as ketorolac with other drugs. The purpose of this study was to determine whether analgesia combining ketorolac and bupivacaine compared to intra-articular bupivacaine alone could more effectively relieve pain in patients undergoing arthroscopic surgery.

In clinical practice, there are concerns regarding the effects of NSAIDs on ligament reconstruction healing. However, according to Ge et al.[5], the use of NSAIDs after ACLR is considered relatively safe and may decrease adverse side effects associated with opioid drugs. A systematic review by Constantinescu et al.[6] found that there are insufficient data available to determine the effect of perioperative NSAIDs on soft tissue healing. The use of NSAIDs should be evaluated on a case-by-case basis and may not affect healing rates following meniscal, ACL, rotator cuff, or Bankart repair.

This study has several limitations. First, short-term data were collected, with a period of 24 hours as the maximum time point. Second, a VAS was used as a subjective outcome measure, which may have introduced variability in the results. Third, although statistical differences were observed between the VAS scores at T-rescue and T-rescue, the clinical significance of these differences was not clearly defined. Patients with meniscal tears were enrolled in both randomized study groups and underwent repair using various techniques. However, data on the number of repairs performed in each group were not available, which could potentially affect postoperative pain outcomes.

CONCLUSIONS

The intra-articular administration of a combination of ketorolac and bupivacaine is an effective option for reducing postoperative pain.

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Short-Term Outcomes of Anterior Cruciate Ligament Reconstruction with Hamstring Tendon Graft: A Randomized Trial Comparing Risk of Injury to the Infrapatellar Branch of Saphenous Nerve in Terms of Knee Hypoesthesia Among Different Oblique Incision Angles

Kraiwut Sooksanit, MD

Department of Orthopedic Surgery, Buriram Hospital, Buriram, Thailand

Purpose: To study the short-term outcomes of anterior cruciate ligament reconstruction (ACLR) with hamstring grafts by comparing the risk of injury to the infrapatellar branch of the saphenous nerve (IPBSN) in terms of the incidence of knee hypoesthesia using 30°, 45°, and 60° oblique incisions.

Methods: We conducted a randomized controlled trial among patients who underwent ACLR with hamstring grafts in our hospital between December 1, 2020 and December 31, 2021. We randomly allocated 111 patients to three groups of 37 patients each, and each group underwent either a 30°, 45°, or 60° oblique incision for hamstring graft harvesting. When incisions were being performed, the age, sex, body mass index, diagnosis, incision length, and operating time were recorded. The incidence and area of knee hypoesthesia were evaluated at 1-, 3-, and 6- month follow-ups.

Results: Demographic and surgical data were similar in all three groups. The incidence of knee hypoesthesia was significantly lower in the 45°-incision group than that in other groups at 1-, 3-, and 6-month follow-ups. At the 6-month follow-up, the incidence was 8.1% in the 45° group, 45.9% in the 30° group, and 35.1% in the 60° group. The area of sensory loss in the 45° group was significantly smaller than that in the other two groups at 3- and 6-month follow-ups.

Conclusions: Performing a 45° oblique incision reduced the risk of the IPBSN injury after ACLR with a hamstring graft more significantly than a 30° or 60° incision. This technique is safe, uncomplicated, and efficacious.

Keywords: anterior cruciate ligament reconstruction (ACLR), infrapatellar branch of saphenous nerve (IPBSN), oblique incision, knee hypoesthesia

Knee hypoesthesia after anterior cruciate ligament reconstruction (ACLR) is a common complication of injury to the infrapatellar branch of the saphenous nerve (IPBSN). The saphenous nerve is the longest branch of the femoral nerve and contains pure sensory fibers. After exiting the adductor canal, it passes behind the sartorius muscle, travels along the anterior of the gracilis tendon on the posteromedial side of the joint, and divides into the infrapatellar and sartorial branches[1]. The infrapatellar branch innervates the skin over the anteromedial aspect of the knee and anteroinferior knee joint

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Correspondence to: Kraiwut Sooksanit, MD
Department of Orthopedic Surgery, Buriram Hospital, Buriram, Thailand
E-mail: isa_onn2014@outlook.com

capsule[2,3]. In most cadaveric specimens, a branch of the IPBSN was observed to pass between the apex of the patella and the tibial tubercle[4]. Therefore, the nerve is susceptible to injury during knee surgeries, including sensory disturbances, neuropathic pain, and even painful neuroma[3]. The incidence of sensory disturbances after ACLR varies between 14.9%–88%[5-7]. Cohen et al.[8] reported that the overall incidence of patient-reported numbness in ACLR for all graft types was 69.8%. Sanders et al.[9] reported that 52% of hamstring tendon graft recipients experienced knee hypoesthesia.

The incidence of postoperative knee hypoesthesia did not differ significantly between the bone-patellar tendon-bone (BPTB) and hamstring tendon autografts[10,11]. However, more severe complications, such as anterior knee pain, kneeling pain, and extensive loss of sensation, were associated with the surgical incisions and techniques used during BPTB graft harvesting[12]. A large surgical incision for the BPTB graft further complicates aesthetic outcomes. Although the severity of numbness reported by patients that underwent ACLR using the allograft technique was significantly lower than that of the other two techniques[8], the risk of graft failure and joint laxity has left allografts controversial[13]. With hamstring tendon autografts, IPBSN injury is common because of the proximity of the tendon to the IPBSN in the pes anserinus. The high variation in IPBSN anatomy makes the nerve more vulnerable, because the position and direction of the incision are important factors in the IPBSN injury[14].

Recently, many studies have confirmed that an oblique incision for hamstring graft harvesting can minimize the risk of the IPBSN injury compared with that in vertical and transverse incisions[15-16]. Henry et al.[15] reported that in cadaveric studies, the risk of IPBSN injury was significantly reduced using an oblique incision (27.6%) as compared with that from vertical (64.7%) and horizontal incisions (50%). To determine the safest angle of oblique incision for ACLR with a hamstring graft, this study proposed 30°, 45°, and 60° oblique incisions and compared the risk of the IPBSN injury to the incidence of knee hypoesthesia among the three groups.

METHODS

This study was approved by the medical ethics committee of our hospital (No. 52, Nov 24, 2020). All patients provided informed consent before the study. Patients who underwent ACLR in our hospital between December 1, 2020 and December 31, 2021 were enrolled in the study according to the following inclusion criteria: age 18–60 years with ACL rupture on physical examination, no history of knee injury or knee surgery on the operated side, and no peripheral neuropathy. Patients with diabetes, morbid obesity (body mass index [BMI] ≥ 40), and multiple ligament injuries were excluded. We randomly allocated 111 patients (104 males and seven females), aged 18–54 years into three groups (37 patients each) by block randomization. All the surgeries were performed by the same surgeon. ACLR was performed using the single-bundle technique with standard arthroscopic instruments. The anterolateral portal was used as the viewing portal, and the anteromedial portal was used as the instrumentation portal. The semitendinosus and gracilis tendons from the operated knee were used as 4-stranded hamstring tendon grafts and fixed to the femur with Endo Button (Smith and Nephew). The tibia was fixed using an absorbable interference screw. The tibial tunnel was drilled under the same incision for graft harvesting, with the guide angle adjusted to 50–55°.

The incision for semitendinosus and gracilis graft harvesting was made with the knee flexed at 90° and the hip externally rotated at 15°. A location along the upper border of the tendon in the pes anserinus area was identified to perform the incision; it was located 3 finger breadths below the knee joint line and 2 fingerbreadths medial to the tibial tubercle. A sterile goniometer was used to measure this angle. The 30°, 45°, and 60° oblique incisions were made in the 30°, 45°, and 60° patient groups, respectively, and extended as required.

Age, sex, BMI, diagnosis, incision length, and operating time were recorded. The occurrence of knee hypoesthesia and the area of sensory loss were evaluated by a well-trained nurse in the outpatient department at the 1-, 3-, and 6-month follow-ups. For the sensory evaluation, the area of skin numbness was marked using a 1-cm² transparent measurement grid and measured using the pin-prick sensation. Other complications, such as infection, graft retear, posterior thigh pain, and neuropathic pain, were also assessed during follow-up.

Statistical analyses were performed using SPSS (version 15.0; IBM Corp., Armonk, NY, USA). Data were analyzed using descriptive statistics (means, standard deviations [SDs], and percentages). Categorical variables were compared using the chi-square test, and continuous variables were compared using the Kruskal–Wallis test. P <0.05 was considered to be statistically significant. The sample size was calculated by the N4study program. The estimated incidence of knee hypoesthesia based on literature data was 69.8% (P control = 0.698, P treatment = 0.349, alpha = 0.05, beta = 0.1, N = 37).

RESULTS

Demographic and surgical data were comparable among the three groups (Tables 1 and 2). The incidence of knee hypoesthesia was significantly lower in the 45° group than in the other groups at 1-, 3-, and 6-month follow-ups (Table 3). In the first month, eight patients (21.6%) in the 45° group developed knee hypoesthesia, whereas the incidence in the 30° and 60° groups was 51.4% and 37.8%, respectively (P = 0.030). Three months after surgery, two of eight patients in the 45° group who had previously developed knee hypoesthesia recovered from the symptom. Therefore, the incidence significantly decreased to 16.2%, lower than the incidences in the 30° (45.9%) and 60° (37.8%) groups (P = 0.020). In 6 months, only three patients (8.1%) in the 45° group still presented with knee hypoesthesia, whereas the incidences in the 30° and 60° groups were 45.9% and 35.1%, respecttively (P = 0.001) (Table 3). In addition, the area of sensory loss in the 45° group was lower than that in the other two groups throughout the follow-up period. However, the difference was significant at 3- and 6-month follow-ups. Herein, the presence and severity (represented by the area of sensory loss) of knee hypoesthesia in all groups declined within 6 months (Table 3).

No complications, including infection, graft retear, posterior thigh pain, or neuropathic pain, were observed.

Table 1 Demographic data.

Demographic data	30°	45°	60°	*P*-value
Age, years (mean ± SD)	29.7 ± 10.5	26.0 ± 7.2	27.3 ± 6.9	0.472*
Sex				0.859**
Male (%)	35 (94.6%)	34 (91.9%)	35 (94.6%)	
Female (%)	2 (5.4%)	3 (8.1%)	2 (5.4%)	
BMI (mean ± SD)	23.5 ± 3.7	24.0 ± 2.9	24.4 ± 2.9	0.321*

* Kruskal–Wallis Test ** Chi-square
SD, standard deviation; BMI, body mass index.

Table 2 Surgical data.

Surgical data	30°	45°	60°	*P*-value
Diagnosis				0.156**
ACL injury (%)	32 (86.5%)	25 (67.6%)	28 (75.7%)	
ACL with meniscus injury (%)	5 (13.5%)	12 (32.4%)	9 (24.3%)	
Incision length (cm) (mean ± SD)	2.97 ± 0.29	3.02 ± 0.33	2.95 ± 0.30	0.325*
Operating time (min) (mean ± SD)	98.3 ± 32.2	87.0 ± 21.0	85.4 ± 29.6	0.264*

* Kruskal–Wallis Test ** Chi-square
ACL, anterior cruciate ligament; SD, standard deviation.

Table 3 Results of surgical incisions by group.

Results		30° N=37	45° N=37	60° N=37	*P*-value
Number of patients with	1 month	19 (51.4%)	8 (21.6%)	14 (37.8%)	0.030**
knee hypoesthesia	3 months	17 (45.9%)	6 (16.2%)	14 (37.8%)	0.020**
(%)	6 months	17 (45.9%)	3 (8.1%)	13 (35.1%)	0.001**
Area of sensory loss	1 month	16.6 ± 26.0	9.0 ± 22.6	14.4 ± 25.8	0.061*
(mean ± SD)	3 months	11.6 ± 19.0	5.8 ± 19.7	10.9 ± 20.8	0.032*
cm^2	6 months	8.6 ± 14.0	3.8 ± 16.5	8.4 ± 17.9	0.003*

* Kruskal–Wallis Test ** Chi-square
SD, standard deviation.

DISCUSSION

The incidence of an IPBSN injury during hamstring tendon harvesting is directly related to the type of surgical incision[17]. Recent cadaveric studies have reported that oblique incisions are less likely to damage the IPBSN than vertical and horizontal incisions because they are more parallel to and farther away from the IPBSN[17,18]. Horizontal incisions are closely associated with sartorial branch injuries[6,9,19]. Henry et al. reported that the incidences of the IPBSN injuries were 64.7%, 50%, and 27.6% for vertical, horizontal, and oblique incisions, respectively. Meanwhile, Pekala et al. reported that the risks of injuries for these groups were 51.4%, 22.4%, and 26%, respectively.

Kerver et al.[3] proposed the concept of a safe area for surgical incisions in relation to the IPBSN anatomy based on a cadaveric study. However, the number of cases in the study was limited, and the variation in nerve location was high. Therefore, safe zones must be used with caution in clinical practice. Zhu et al.[20] designed a modified oblique incision (MOI) within the safe area proposed by Kerver et al. and reported that the incidence of knee hypoesthesia at 1 year with the MOI was lower than that with a standard oblique incision (9.4% vs. 33.3%). Differences were considered statistically significant. The MOI technique moves the surgical incision away from the IPBSN and beyond the hamstring tendon. This may result in technical difficulties in graft harvesting, and put the nerve at risk of a blunt injury during skin traction, subcutaneous dissection, or passage of a tendon-harvesting device. In our study, an oblique incision was made at the pes anserinus using the standard technique. Three angles of oblique incision were studied based on the hypothesis that the angle of the incision affects the distance between the incision and the nerve[15]. The incision made with the appropriate angle protected the nerve from injury. Our study demonstrated that the incidence of knee hypoesthesia at 6 months after surgery with an oblique 45° incision was significantly lower (8.1%) than that with 30° and 60° oblique incisions.

Blunt nerve injury has been reported during graft harvesting procedures; however, its occurrence appears to be lower compared to nerve injuries caused by incisions[19]. Injury was caused mainly by tendon harvesting devices, and affected the sartorial branch, resulting in a sensory loss in the medial and distal tibial ridges and the anteromedial region of the knee joint. Previous studies have suggested that when the knee is flexed at 90° with the hip externally rotated, the saphenous nerve moves backward and away from the site of the procedure[21]. Therefore, this study used this technique to avoid nerve damage during incision and graft harvesting. Additionally, the incision length may be related to the risk of IPBSN injury. A previous cadaveric study found that the distances between various types of incisions and nerves varied from 8.2–8.7 mm.[15], which was a relatively low variance. Therefore, the incision length should be minimized as much as possible without excessive stretching during graft access. In this study, incision lengths in 30°, 45°, and 60° groups were 2.97 ± 0.29, 3.02 ± 0.33, and 2.95 ± 0.30 cm, respecttively. There were no significant differences between the groups. The average length of incision in this study was similar to that of the other study (2.3–3.9 cm)[20].

This study had some limitations. Nerve injury may occur during procedures other than surgical incisions, such as graft harvesting, portal placement, tibial tunnel drilling, skin traction, and subcutaneous dissection[21]. These confounding factors could not be controlled during surgery; therefore, to minimize them, the same surgeon performed grafts on all the patients in this study. Another limitation of this study is the method used to assess the extent of sensory loss. Sensory evaluation by pinprick sensation relies on the patient's perception and the intensity of pressure that the assessor applies during the assessment; therefore, it seems unreliable compared with electrophysiological studies. A transparent measurement grid is also not an ideal tool to measure the area of abnormal sensation, as reading and systematic errors during measurements can easily cause data discrepancies. However, this tool was used as it is convenient for use in clinical practice. Relevant to clinical applications of the study, the patients' BMI in the study ranged from 20–26, and therefore this landmark would not be reproducible in patients of extreme size. A surgeon in the outpatient department evaluated function and range of motion, but the outcomes were not analyzed. However, all the patients returned to normal activity within 6 months.

CONCLUSIONS

An oblique 45° incision could lower the risk of an IPBSN injury after ACLR with a hamstring graft compared with that by 30° and 60° incisions, which was evident in both the incidence and area of knee hypoesthesia at 1, 3, and 6 months after surgery. Despite some limitations, this technique is safe, uncomplicated, and effective for clinical application.

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Efficacy of Post-Operative Logbook-Based Quadriceps Exercises on Functional Outcome after Total Knee Arthroplasty

Chatchapol Ongkosit, MD, Ruengsiri Panuwet, RN

Department of Orthopedic Surgery, Nong Bua Lamphu Hospital, Nong Bua Lamphu, Thailand

Purpose: Most patients who undergo total knee arthroplasty (TKA) are elderly. Some patients have recognition impairments and cannot correctly perform home-based rehabilitation effectively. This study aimed to compare the functional outcomes between logbook- and non-logbook-based quadricep exercises.
Methods: In this prospective cohort study with retrospective case controls scheduled for unilateral primary/bilateral TKA, we compared 57 patients who received post-operative home-based rehabilitation and seated knee extension exercises (non-logbook group) with 60 patients who received the same protocol but were provided a logbook with paper handouts containing the schedule, date, time, and record form (logbook group). The modified Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores and data pertaining to range of motion (ROM) were collected pre-operatively and at 6, 12, and 24 weeks post-operatively.
Results: The logbook group showed a significant improvement in the mean difference in function and total WOMAC scores at 6-weeks post-operatively ($p < 0.05$). There was no significant difference in the pre- and post-operative ROM at any follow-up time point between the groups.
Conclusions: Logbook-based quadriceps exercises resulted in significant early improvement in the functional outcomes. Logbooks may help patients who have undergone TKA to perform their home-based exercise regimens accurately.

Keywords: Total knee arthroplasty, knee exercise, rehabilitation, logbook, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Total knee arthroplasty (TKA) reduces pain, restores range of motion (ROM), and improves functional performance and quality of life of patients with end-stage knee osteoarthritis (OA). The post-operative functionality of TKA is closely related to appropriate physiotherapy. Rapid recovery of muscle function and early mobilization are key to successful rehabilitation following TKA[1]. Quadricep muscle strength is particularly crucial for functional performance, such as climbing stairs, rising from a seated position, walking, and survival of artificial implants. Finally, high lower limb muscle strength is associated with a lower mortality risk[2].

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Correspondence to: Chatchapol Ongkosit, MD
Department of Orthopedic Surgery, Nong Bua Lamphu Hospital, Nong Bua Lamphu, Thailand
E-mail: ongkosit.c@gmail.com

Home exercise programs (HEPs) are used to treat several musculoskeletal conditions. HEPs are usually provided to patients in the form of paper handouts(1). The prescription of HEPs encourages patients to take responsibility for their rehabilitation and to self-manage their condition in the long term(3). Most patients who undergo TKA are elderly and have multiple comorbidities. Some have recognition impairment and thus cannot always remember HEPs, and therefore cannot exercise correctly(4). Beinart et al. reported that up to 70% of patients do not perform HEPs as prescribed, and adherence tends to decline over time(5). Thiengwittayaporn et al. reported greater accuracy of quadriceps isometric exercises after using a quadriceps educational device (QED)(6).

Seated knee extension is an easy exercise for quadricep muscle strength, and is commonly used in patients following TKA(7). It can also be used as HEPs. Early initiation of muscle strengthening exercises reduces pain and improves the ROM. Other studies have reported that post-operative rehabilitation prevents knee stiffness following TKA(8).

Maltz et al. reported that it usually takes a minimum of about 21 days for any perceptible change in a mental image. According to Maltz, "These, and many other commonly observed phenomena tend to show that it requires a minimum of about 21 days for an old mental image to dissolve and a new one to jell(9)."

In provinces where most of the people work in agriculture and have a relatively low socioeconomic status, paper handouts are easy and economical method to communicate information. If patients are provided a logbook that is easy to use and contains detailed explanation, schedule, time, and frequency of exercises for each day, it would remind them to perform their rehabilitation regimen correctly.

This study aimed to compare the functional scores of patients (following TKA) who performed logbook-based quadriceps exercises for 28 days with those of patients who did not. We hypothesized that patients who perform logbook-based quadriceps exercises for 28 days would remember them better and form a healthy habit that would be reflected in improved functional outcomes.

MATERIALS AND METHODS

We conducted a prospective cohort study with retrospective case-controls scheduled for unilateral primary/bilateral TKA between January 30, 2021 and February 25, 2022. This study was approved by the ethics committee of our hospital's institutional review board.

The inclusion criteria were patients (aged 50–80 years) with primary knee OA who consented to comply with the study protocols. The exclusion criteria were as follows: (1) any infection, (2) body mass index >40 kg/m^2, (3) uncontrolled hypertension and/or diabetes mellitus, (4)patients with renal insufficiency (creatinine clearance <30 mL/min) and/or active hepatic disease who did not receive the general peri- and post-operative pain medicine protocol, (5) patients with a brain disease and/or any symptoms that prevents them from exercising by themselves, and (6) patients with mental disorders with a score <14 on the Thai Mini-Mental State Examination.

All surgeries were performed by the first author using the same technique. Only spinal blocks were used in the present study. All patients received the same post-operative analgesic protocol.

Two weeks post-operatively, the patients were advised to perform home-based rehabilitation as usual, including seated knee extension exercises, sitting down on a chair, active extension and holding of the affected knee for 20 sec, which were to be performed ten times every 2 h (at 8 am, 10 am, 12 pm, 2 pm, and 4 pm).

We recruited participants who had received post-operative HEPs between January 30, 2021 and November 1, 2021 as the historical control group. This group constituted the 'non-logbook group.' Next, we conducted a prospective study of participants recruited between November 2, 2021 and February 25, 2022 who received the same protocols but were provided a logbook consisting of a paper handout containing schedule, date, time, record form (Appendix 1), and advised to return for an appointment for the next 4 weeks (6 weeks post-operatively). This group constituted the 'logbook group.' All participants received the same medication for pain, including naproxen (250 mg twice a day), tolperisone (thrice a day), gabapentin (300 mg once a day), and acetaminophen (500 mg 2 tabs every 6–8 h). The medications were administered for two weeks in both groups. After the 2^{nd} post-operative week and until the end of the study all participants received the same medications, including tolperisone (three times a day) and acetaminophen (500 mg 2 tabs every 6–8 h) for pain. None of the participants used any over-the-counter painkillers.

Outcome measurement

Primary outcome was assessed using the modified Western Ontario and McMaster Universities Arthritis Index (WOMAC), which was performed by a blinded outpatient department nurse pre-operatively and at 6^{th}, 12^{th}, and 24^{th} week post-operatively. The secondary outcome was ROM, which was assessed in the patients pre-operatively and at 6^{th}, 12^{th}, and 24^{th} week post-operatively. Active knee flexion and extension ROM were measured in degrees using a standard long-arm universal goniometer.

Data analysis

Sample size was calculated based on data collected from ten patients in our pilot study. The results showed that the mean difference in WOMAC between the logbook and non-logbook groups at post-operative 12^{th} week was 46.04 (±13.94) and 39.12 (±15.24), respectively. The correlation between follow-up measurements was 0.7. The correlation between baseline and follow-up was 0.3 based on ANCOVA method. A multilevel regression model analysis was performed by considering repeated outcome measurements at multiple time points. We estimated that a sample size of at least 54 patients per group would have 80% power to detect mean differences. A two-sided alpha level of 0.05 was considered acceptable.

The mean differences in WOMAC scores were compared between the groups. Statistical significance was set at $p < 0.05$ for Fisher's exact test, two-sample t-test, and multilevel Gaussian regression for the WOMAC Score change (mixed-effects ML regression) adjusted for sex, age, body mass index (BMI), physical status class, number of knee replacements, operative time, pre-operative WOMAC score, and p-value for repeated measurement at multiple time points.

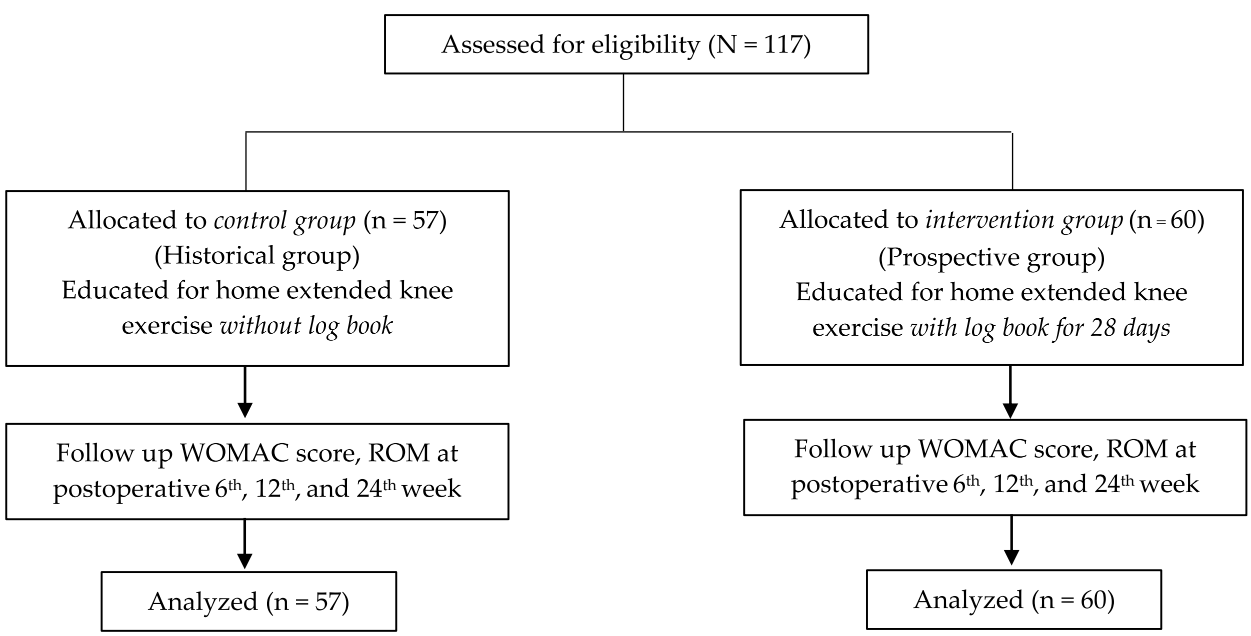


Fig. 1 Flow diagram.

Table 1 Demographic information.

Characteristics	Non-logbook (n = 57)		Logbook (n = 60)		p-value
	n	%	n	%	
Sex					0.262
Male	9	15.8	5	8.3	
Female	48	84.2	55	91.7	
Age (yrs), mean (±SD)	64.7 (±9.0)		65.9 (±9.0)		0.440
BMI, mean (±SD)	27.2 (±4.1)		26.3 (±3.6)		0.243
Physical status class (A)					0.202
I	7	12.3	14	23.3	
II	31	54.4	24	40.0	
III	19	33.3	22	36.7	
Number of knee replacements					1.000
Unilateral	38	66.7	40	66.7	
Bilateral	19	33.3	20	33.3	
Operative time (min), mean (±SD)	90.0 (±35.9)		91.6 (±35.2)		0.812
Pre- Operative WOMAC Score					
Pain	9.8 (±4.1)	10.4 (±3.4)	0.366	9.8 (±4.1)	10.4 (±3.4)
Stiffness	4.5 (±1.6)	4.7 (±1.7)	0.544	4.5 (±1.6)	4.7 (±1.7)
Function	36.0 (±14.0)	38.9 (±12.2)	0.223	36.0 (±14.0)	38.9 (±12.2)
Total WOMAC Score	50.3 (±18.1)	54.1 (±15.4)	0.224	50.3 (±18.1)	54.1 (±15.4)
Pre-operative ROM, mean (±SD)	121.5 (±11.9)	118.5 (±15.1)	0.238	121.5 (±11.9)	118.5 (±15.1)

Fisher exact probability test for proportions independent t-test for two independent mean.

Table 2 Clinical outcome.

Mean difference of WOMAC Score	Non-logbook (n=57)		Logbook (n=60)		Mean difference regression	95%CI	p-value*
	mean	(SE)	mean	(SE)			
Pain WOMAC Score							
WOMAC Score at 6-week	-5.8	(0.4)	-6.4	(0.3)	-0.6	-1.5, 0.4	0.255
WOMAC Score at 12-week	-7.5	(0.5)	-7.9	(0.5)	-0.4	-1.8, 0.9	0.519
WOMAC Score at 24-week	-8.4	(0.9)	-9.2	(0.8)	-0.8	-3.2, 1.6	0.523
Stiffness WOMAC Score							
WOMAC Score at 6-week	-2.4	(0.2)	-2.9	(0.2)	-0.5	-1.1, 0.4	0.067
WOMAC Score at 12-week	-3.0	(0.3)	-3.2	(0.3)	-0.2	-0.9, 0.6	0.645
WOMAC Score at 24-week	-3.6	(0.5)	-3.7	(0.4)	-0.1	-1.4, 1.2	0.876
Function WOMAC Score							
WOMAC Score at 6-week	-22.0	(1.2)	-26.1	(1.1)	-4.1	-7.3, -0.8	0.014†
WOMAC Score at 12-week	-28.7	(1.7)	-31.8	(1.6)	-3.2	-7.8, 1.4	0.176
WOMAC Score at 24-week	-32.3	(3.2)	-33.1	(2.9)	-0.8	-9.2, 7.6	0.852
Total WOMAC Score							
WOMAC Score at 6-week	-30.2	(1.5)	-35.4	(1.4)	-5.2	-9.3, -1.1	0.013†
WOMAC Score at 12-week	-39.1	(2.1)	-42.9	(2.1)	-3.8	-9.7, 2.1	0.209
WOMAC Score at 24-week	-43.9	(3.7)	-45.8	(3.7)	-1.9	-12.9, 9.1	0.734

*p-value for Mixed-effects REML regression for WOMAC score change adjusted for sex, age, BMI, physical status class, number of knee replacement, operative time, and pre- operative WOMAC score.

† Denotes significance at the $p < 0.05$ level.

Table 3 Mean ROM pre-operatively and at 6, 12, and 24 weeks post-operatively.

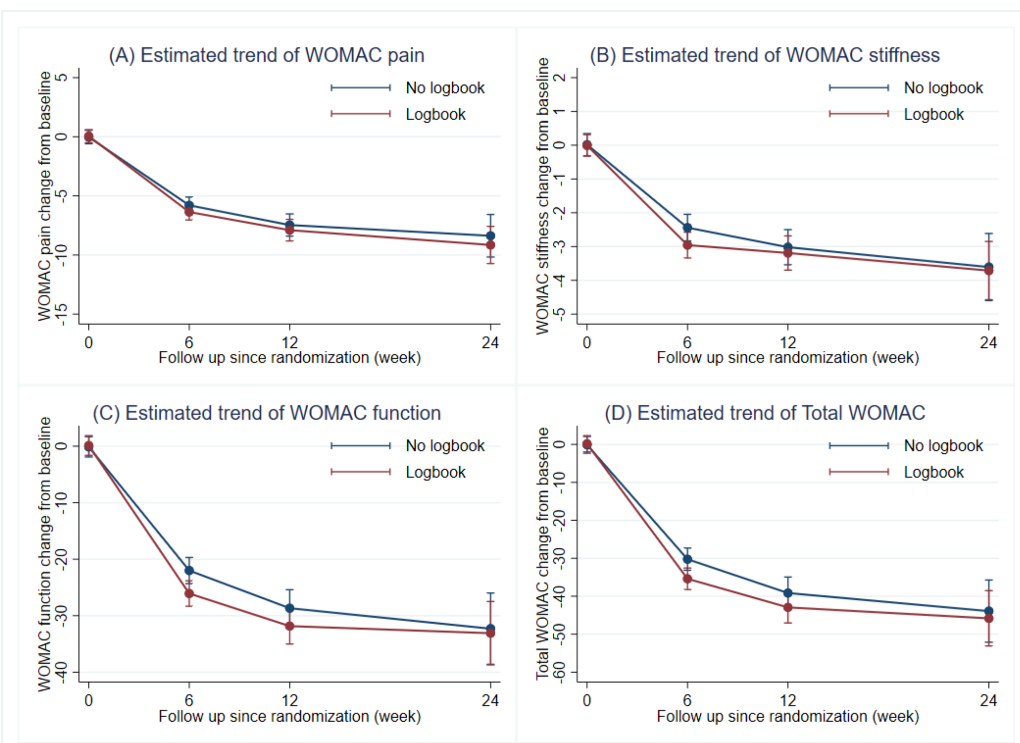
Clinical outcome	Non-logbook (n = 57)		Logbook (n = 60)		p-value
	mean	(±SD)	mean	(±SD)	
Pre- operative range of motion (ROM)	121.5	±11.9	118.5	±15.1	0.238
Post-operative ROM					
At 6-week	114.8	±14.4	114.9	±11.9	0.952
At 12-week	120.1	±10.7	120.6	±11.5	0.778
At 24-week	120.0	±7.1	127.5	±9.1	0.263

RESULTS

The study included 117 patients, who were divided into two groups: non-logbook (n = 57; 9 males, 48 females) and logbook (n = 60; 5 males and 55 females) groups. There were no significant differences in age, BMI, American association of anesthesiologist (ASA) classification, or operative time between the groups. Nineteen patients in the non-logbook and 20 in the logbook group underwent bilateral TKA. There were no significant differences in the pre-operative 5-point Likert WOMAC score (pain, stiffness, daily activity, and total score) or ROM between the groups (Table 1).

The logbook group showed a greater mean difference in function and total WOMAC scores at 6-week post-surgery ($p < 0.05$). Both the groups (non-logbook and logbook) showed no statistically significant improvement in pain and stiffness WOMAC scores in all dimensions following TKA (Table 2). There was no significant difference in pre- and post-operative ROM between the groups at all follow-up time points evaluated. There was no significant difference between the time points ($p < 0.952$) (Table 3).

Fig. 2 Mean difference in WOMAC pre-operatively and at 6, 12, and 24 weeks post-operatively.



DISCUSSION

The results showed that patients who performed logbook-based quadricep exercises improved their mean difference in function and total WOMAC scores compared with those in the control group at 6-week post-operatively. These results differ from that reported in the Kauppila et al. study that compared a 10-day multidisciplinary outpatient rehabilitation program with conventional care. They reported no significant difference in the improvement of the early WOMAC scores[10].

For early and superior functional outcome following TKA, the process of post-operative rehabilitation is crucial. However, it has multifactorial influences, including patient education, perceptions, socioeconomic status, and mental status all of which remain challenging, especially in developing countries owing to lower patient educational and economic status, and difficulty in visiting physical therapists. Moreover, the ongoing COVID-19 pandemic, low contact time, and overcrowding in outpatient departments may have all contributed to lower functional outcomes. The limited options for face-to-face training sessions affects patient rehabilitation outcomes. Smith et al. identified that the barriers to engagement in physical activity includeed lack of the information on recovery, expected capabilities, and fear of 'damaging' the recovery process and implant[11]. A previous study by Thiengwittayaporn et al. compared mobile applications and paper handouts for home-based exercises for knee OA. The results showed significantly higher overall exercise accuracy, daily activity, quality of life, and ability to perform sports and recreational activities in the mobile application group[12]. Although the study showed marked benefit of technology in helping patients adhere to home-based exercise programs, paper handouts continue to play significant a role in patient recovery, particularly in rural areas where technology may be inaccessible. Additionally, our study showed that paper handouts are applicable and adaptable to everyone, and may be used to remind patients to perform the home-based exercises.

In our study, both groups demonstrated similar yet significant post-operative improvement in active knee flexion. The mean pre-operative knee flexion in the two groups were 121.5° and 118.5°, respectively. Both groups achieved pre-operative knee flexion levels at 12-week post-operatively. The improvement in knee flexion was better in the logbook group than that in the non-logbook group at 24-week post-operatively, although the difference was not statistically significant ($p = 0.263$). Similarly, McGinn et al. studied early outpatient physical therapy within six weeks and found that early post-operative physical therapy resulted in greater knee flexion and extension than late physical therapy[13].

The main limitations of our study were its non-blind nature and lack of long-term follow-up. Furthermore, we did not thoroughly evaluate the intensity of self-physical therapy, mental status, educational level of individual caregivers, or other environmental factors.

CONCLUSIONS

Our study demonstrated that logbooks constitute an effective method that may help patients to perform home-based exercises accurately following TKA. The study demonstrated a statistically significant difference in the total WOMAC scores between the intervention and control groups at 6-week post-operatively.

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CONFLICTS OF INTEREST

The authors had no conflicts of interest to declare in relation to this article.

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Appendix 1. Example of a logbook-based quadriceps exercise instructions.

แนวทางการกายภาพบำบัดผู้ที่ได้รับการผ่าตัดเปลี่ยน ข้อเข่าเทียม

โดย นพ. แผนกศัลยกรรมกระดูก
เชี่ยวชาญด้านการผ่าตัดข้อเข่าเทียมและข้อสะโพกเทียม
โรงพยาบาล

1. ให้ผู้ป่วยนั่งที่เก้าอี้หรือเตียง เท้า 2 ข้างแตะถึงพื้น
2. ออกแรงเกร็งกล้ามเนื้อขาข้างที่ผ่าตัดให้เข่าเหยียดตรง โดยออกแรงเกร็งกล้ามเนื้อค้างไว้ 20 วินาที แล้วคลายกล้ามเนื้อ
3. ทำซ้ำ 10 ครั้งต่อรอบ วันละ 5 รอบ และจดบันทึกในตาราง

ห้ามผู้ป่วยเตะขาหรือแกว่งขาเร็วๆ เพราะข้อเข่าจะเสียดสีกัน

ชื่อ – นามสกุล ....

กรุณาทำเครื่องหมาย O เมื่อท่านได้ออกกำลังกายท่านั้นๆตามจำนวนที่กำหนด

		1 รอบ 08.00 น.	2 รอบ 10.00 น.	3 รอบ 12.00 น.	4 รอบ 14.00 น.	5 รอบ 16.00 น.
1	วัน............ เดือน......... ปี.............	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10
2	วัน............ เดือน......... ปี.............	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10
3	วัน............ เดือน......... ปี.............	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10
4	วัน............ เดือน......... ปี.............	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10
5	วัน............ เดือน......... ปี.............	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10

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