A Controlled Evaluation of Continuous Passive Motion in Patients Undergoing Total Knee Arthroplasty

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Objective.—To evaluate the efficacy of continuous passive motion (CPM) in the postoperative management of patients undergoing total knee arthroplasty.

Design.—A randomized controlled single-blind trial of CPM plus standardized rehabilitation vs standard rehabilitation alone.

Setting.—A referral hospital for arthritis and musculoskeletal care.

Patients.—Consecutive patients with end-stage osteoarthritis or rheumatoid arthritis undergoing primary total knee arthroplasty who had at least 90° of passive knee flexion. One hundred fifty-four patients were eligible and 102 patients agreed to participate and were randomized. Ninety-three patients completed the study protocol.

Intervention.—Continuous passive motion machines programmed for rate and specified arc of motion within 24 hours of surgery with range increased daily as tolerated with standardized rehabilitation program compared with standardized rehabilitation program alone.

Main Outcome Measures.—Primary outcomes were pain, active and passive knee range of motion, swelling (or circumference), quadriceps strength at postoperative day 7, as well as complications, length of stay, and active and passive range of motion and function at 6 weeks.

Results.—Use of CPM increased active flexion and decreased swelling and the need for manipulations but did not significantly affect pain, active and passive extension, quadriceps strength, or length of hospital stay. At 6 weeks there were no differences between the two groups in either range of motion or function. In this series, use of CPM resulted in a net savings of $6764 over conventional rehabilitation in achieving these results.

Conclusion.—For the average patient undergoing total knee arthroplasty, CPM is more effective in improving range of motion, decreasing swelling, and reducing the need for manipulation than is conventional therapy and lowers cost.

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THE USE of continuous passive motion (CPM) in the rehabilitation of patients after knee surgery and a variety of disabling knee conditions has grown rapidly since experiments by Salter and colleagues[1-5] in rabbits that demonstrated favorable effects on cartilage injuries, septic arthritis, intra-articular fractures, and the absorption of hemarthrosis. Achieving a full range of motion (ROM) for the knee or a combined 180° of hip and knee flexion is a critical determinant for optimal lower-extremity joint function. Continuous passive motion is now used widely after total knee arthroplasty (TKA), as studies have suggested its value. These studies were short term,[6-13] retrospective,[6,8,13] uncontrolled,[6,9,11-14,16] or nonrandomized.[6-16] None was blinded. Greater flexion and reduced hospital length of stay were found in some studies[9,12,16,17] but not in all.[6,7,15] Less pain achieved with CPM use[14,16] was refuted by Fisher et al[6] and Maloney et al.[15] Two studies differed in the effectiveness of CPM in reducing deep-vein thrombosis.[10,13] In long-term follow-up, two studies report greater ROM in the CPM group, but compare CPM with prolonged immobilization,[16,17] which is not standard rehabilitation after TKA; another study, a nonrandomized trial, showed no difference in ROM after 3 years of follow-up.[15]

We present the perioperative and 6-week results of a single-blinded, prospective, randomized controlled clinical trial of the efficacy and cost-effectiveness of CPM in the postoperative rehabilitation of patients undergoing primary TKA.

PATIENTS AND METHODS

Consecutive patients with osteoarthritis (OA) or rheumatoid arthritis (RA) undergoing primary TKA were screened from 1988 through 1990 for the study. Rheumatoid arthritis was defined by the American College of Rheumatology criteria[18]; OA was defined by roentgeno-

Table 1.—Patient Disposition by Treatment Group

Patient Disposition	No.	Treatment Group	
		CPM*	No CPM
Screened	301	...	...
Eligible†	154	...	...
Refused or surgery cancelled prior to randomization‡	52	...	...
Randomized	102	51	51
Prematurely terminated	9	3	6
Health complications	2	0	2
Refused	2	1	1
Administrative§	5	2	3
Analyzed	93	48	45

*CPM indicates continuous passive motion.

†Of those patients judged ineligible, 36 had other total joint surgery on the same admission; 34 had range of motion criteria not met; 25 were subject to physician refusal; 23 were admitted during a period in which the protocol could not be implemented because of staffing shortages; 18 were not primary total knee replacement patients; 10 suffered from obesity (weighing over 136 kg; six did not have osteoarthritis or rheumatoid arthritis; five did not speak English as their primary language; and five had cognitive/sensory deficits. Total number of criteria is 162 because some patients had more than one criterion for exclusion.

‡Of those patients who refused, 38 definitely wanted CPM treatment; seven did not want to be bothered; four had some other reason; and three were too anxious.

§For four patients, surgery was cancelled after randomization, and one patient's medical record was lost.

gram, ie, demonstration of unequal cartilage loss, eburnation, osteophytes, and subchondral bone cysts in the knee. Patients could not have more than a 20° flexion contracture of the knee measured from neutral or 0° of extension in the supine position. Passive knee flexion had to be at least 90° in the sitting position. Patients were not eligible if they (1) had cognitive or sensory deficits; (2) did not understand or speak English; (3) were undergoing another surgical procedure prior to or during the TKA; or (4) weighed 136 kg or more. Six surgeons performed the surgeries using a variety of implant designs. The informed consent of both physician and patient was obtained before entry into the study. The protocol was approved by the human subjects committee of the Brigham and Women's Hospital, Boston, Mass.

Screening Process

A total of 301 patients scheduled for primary TKA were screened for eligibility (Table 1). One hundred fifty-four were eligible, but 38 were unwilling to be randomized; 14 did not want to be bothered or expressed anxiety regarding the pending surgery/hospitalization.

The remaining 102 eligible patients were randomized into two groups. Of these, four patients had their surgery canceled and not rescheduled; two refused to continue participation after their surgery; two had medical complications that precluded data collection (chickenpox and severe respiratory distress), and one patient's inpatient record was lost. The remaining 93 patients form the basis of the data analysis.

Study Design

A randomized controlled study was conducted to compare CPM plus a standardized rehabilitation program with a control group that received only the standardized rehabilitation program. Range of motion and swelling were assessed by a therapist blinded to whether the patient had received CPM.

All patients received identical rehabilitation with the same goals involving quadriceps muscle strengthening (beginning on postoperative day [POD] 1), active assistive and passive flexion and extension exercises, and transfer techniques (initiated on POD 2) with the aid of a therapist. The rest of the rehabilitation program consisted of gait training, bicycling, and proning. Patients were seen one to two times a day, 7 days a week.

Sutter CPM 9000 or Sutter CPM 2000 machines (Sutter Corporation, San Diego, Calif) individually programmed for rate and specified arc of motion were used. Patients randomized to the CPM group received CPM within 24 hours of surgery. The range was increased daily as tolerated. They were instructed and encouraged to use the CPM machine "as much as possible" outside of therapy sessions. Nighttime CPM was at the surgeon's discretion in consideration of the subject's tolerance and extension ROM.

Concomitant care for all patients followed protocols for analgesics, anticoagulation, and prophylactic antibiotics. Patients were given 300 mg of acetaminophen with 7.5 mg of codeine every 4 hours as needed. Anticoagulation was provided by 600 mg of aspirin taken twice daily until discharge for men, or 10 mg of warfarin sodium 1 day before surgery and titrated to keep the prothrombin time 1.5 times the control value in women. Antibiotic coverage consisted of 1 g of cefazolin given intravenously every 8 hours starting at surgery and continued for 24 hours after. Manipulation was prescribed if a patient's knee ROM was not increasing each day.

Clinical Assessment

Baseline measures included pain, active and passive knee ROM, knee circumference, quadriceps strength, and a functional assessment. The end points for the inpatient phase were pain, active and passive knee ROM, knee circumference and quadriceps strength measures taken on POD 7, length of stay, and complications. Six-week postoperative data included active and passive knee ROM and function. Six patients receiving bilateral total knee replacements were studied. All had these done serially and only the results of the first surgery were studied.

Patients completed a pain Visual Analogue Scale (VAS) daily for 1 week before and after surgery. All postoperative data except self-rated pain and function were collected by a physical therapist not involved with the subject's care and blinded to whether the patient was using CPM. Blinding was accomplished by removing the patients from the CPM machine and transporting them to another location for measurements. Patients were asked not to mention use of CPM.

The total daily dose of medication given during PODs 1 through 7 was abstracted from the medical record. Doses of narcotic medications were converted to equivalent doses of morphine sulfate.[19] For this study, 650 mg of aspirin, 650 mg of acetaminophen, and 65 mg of codeine were considered to be equipotent—even though in one study both 650 mg of aspirin and 650 mg of acetaminophen were superior to 65 mg of codeine in relieving mild to moderate pain due to unresectable cancer.[20] Also, 2400 mg of ibuprofen, 75 mg of indomethacin, 20 mg of piroxicam, and 3900 mg of aspirin were considered equipotent.

Active and passive knee ROM were measured by an International Standard (Alimed Inc, Dedham, Mass) hand-held goniometer. Passive extension was measured with the patient supine. A calcaneal stretch was applied while the blinded rater measured knee extension. For active flexion, patients sat on an examination table with the thigh supported and parallel to the floor and the foot resting on the floor. The patient was asked to bend the operated knee as far as possible with two warm-up bends allowed; the third bend was recorded. For passive knee flexion, the patient remained in the same position while the therapist applied pressure on the distal third of the tibia. The number recorded was that at which the patient began al-

tering his or her posture or told the therapist to stop. For active extension, the patient sat as described above and was asked to straighten the knee as far as possible. After two warm-ups, the third measurement was recorded. The sequence of ROM measurements was passive extension, active flexion, passive flexion, and active extension.

Knee swelling was assessed on POD 7 by measuring the circumference of the knee with a tape measure at the knee joint line and 7.7 cm above and 7.7 cm below the joint line.

Quadriceps strength was tested on POD 7 with the patient seated, hips at 90°, and stabilized with a Velcro belt to prevent extraneous movement. The knee was positioned at 45° and the foot was unsupported to prevent use of the plantarflexor muscles. A Spark hand-held dynamometer (J. A. Preston Corp, Jackson, Miss)[21] was placed distal and perpendicular to the tibia one third of the distance from the lateral malleolus to the knee joint line. A skin marker outlined this position on the leg. After demonstration of the technique on the subject's noninvolved leg, two tests were done on the operated leg 1 minute apart.

Length of stay was taken as the number of days from surgery to discharge or to TKA on the opposite knee, whichever occurred first.

Function was evaluated by the Health Assessment Questionnaire (HAQ),[22] a valid and reliable self-administered functional status measure of performance in activities of daily living, emphasizing difficulty and the need for equipment and physical assistance to complete tasks. Scores on eight subscales were averaged to give a single score.

Medical and surgical complications were ascertained at each postoperative evaluation by physical examination and/or review of the medical record by a physician blinded to the identity of the patient and to whether CPM had been used.

Cost Analysis

To estimate costs, we assumed that the costs of professional fees related to the operation, bed days, nursing services, and medications were the same for both groups.

The time spent by occupational and physical therapists in treating the patient was recorded in 15-minute intervals. Continous passive motion machines are usually purchased or rented by hospitals. Capital outlays for the CPM machines are about $4000 (range, $3000 to $5000) per machine in addition to the consumable supplies and maintenance costs. Charges for supplies, equipment maintenance, and management of CPM were based on hospital charges.

The costs of one manipulation including professional fees for the surgeon, anesthesiology, operating room, recovery room, and supplies is approximately $1840 in our institution.

Statistical Analyses

The 93 patients who completed the protocol through POD 7, until TKA on the opposite knee, or until discharge were included in the statistical analyses. SAS statistical procedures[23] on an IBM PS/2 computer were used to perform data management and statistical analyses.

The success of the randomization was assessed by comparisons of CPM and non-CPM groups with regard to demographic and clinical preoperative characteristics using the χ^2 test or two-sample Student's t tests[24] as appropriate. Adverse events such as knee manipulation and other complications were compared by χ^2 tests. A significance level of .05 was used in each instance, without adjustment for multiple tests because these were descriptive comparisons.

The efficacy analysis compared the CPM and non-CPM groups by analysis of covariance (ANCOVA) with multiple regression models to adjust for several predictor variables simultaneously.[25] The significance level for each outcome-specific treatment comparison was adjusted to minimize type I error (incorrect in declaring a treatment difference) due to multiple testing; a comparison error rate of α=.05/8=.00625, or a P value less than .00625, was used to keep the error rate at .05 or below. After the primary efficacy test for each outcome, exploratory analyses were used to assess possible differential effects of CPM with age, diagnosis, and sex.

Eight outcome variables were analyzed: pain by VAS scores and medications used, active flexion, active and passive extension, quadriceps strength, knee circumference, length of stay, complications and self-reported function (HAQ), and ROM 6 weeks after surgery. Because active and passive flexion outcomes correlated strongly (r=.99), only active flexion was analyzed.

Transformations to normalize variances were applied to preoperative and postoperative VAS pain scores (probit transformation) and strength measures (square-root transformation), both of which were chosen by inspection. Furthermore, preoperative values for each predictor variable were standardized to have a mean of 0.0 and a variance of 1.0.

A preliminary regression model was constructed for each outcome before the efficacy of CPM was tested. The preliminary model always contained the following 12 variables: age, the preoperative variable corresponding to the specific outcome, and indicator variables for bilateral TKA, osteoarthritis as the principal diagnosis, unicondylar prosthesis type, female sex, and six surgeon variables. Other variables were screened by backward selection in SAS PROC REG[23] and included preoperative values of VAS pain score, active flexion, HAQ score, quadriceps strength, and knee circumference; an indicator variable for postsurgical hematoma; plus three indicator variables for "interactions": age-diagnosis, age-sex, and diagnosis-sex. A screened variable was retained in the model if its associated P value was below .15.

After the preliminary model was chosen, colinearity was assessed using condition numbers and variance inflation factors.[19,23] Checks for outliers and highly influential data points were based on formal assessment of RSTUDENT residuals, leverage statistics, and Cook's D influence statistics.[25] No outliers or high-leverage observations were detected.

Treatment efficacy was tested with ANCOVA using SAS PROC REG by adding an indicator treatment variable (CPM or non-CPM) to the preliminary model, a P value of α less than .00625 was taken as evidence of a statistically significant treatment difference. Treatment-specific adjusted mean values were estimated by "least-squares means" in SAS PROC GLM[19] to account for other variables in the regression model. The difference between adjusted treatment means and a 99% confidence interval (CI) were computed to supplement the information provided by the P value. Finally, secondary analyses were conducted for possible interactions of CPM treatment with age, diagnosis, and sex of the patient.

RESULTS

Patient Characteristics

Baseline characteristics of patients are shown in Table 2. Only age differed significantly between group: the CPM group had a mean age of 65.7 years vs 70.2 years for the non-CPM group. Most patients were female (65%) and most had OA (81%). The average presurgery pain score, mean HAQ score, average knee circumference, and mean ROM were comparable between the two groups.

Pain

The CPM-treated group reported less pain on the VAS than the non-CPM group (Table 3); however, the difference was only marginally significant and did

Table 2.—Baseline Characteristics of Patients by Treatment Group

Characteristic	Treatment Group* CPM (n=48)	No-CPM (n=45)	P†
Age, y‡	65.7±1.6	70.2±1.3	.033
Pain, VAS, 0-1 scale‡	0.38±0.04	0.45±0.04	.2
Pain probit‡§	−0.49±0.15	−0.23±0.14	.2
Circumference, cm‡	41.3±0.67	42.1±0.64	.4
Quadricep strength (newton-meters)‡	34.6±2.7	34.5±2.7	>.9
Active ROM‡			
Flexion, degrees	114±1.6	113±1.5	.5
Extension, degrees	−16±1.7	−15±1.6	.5
Passive ROM‡			
Flexion, degrees	118±1.5	117±1.5	.8
Extension, degrees	−5±0.9	−5±1.0	.9
HAQ, 0-3 scale‡	1.3±0.1	1.2±0.09	.6
Sex, %			
M	35	36	...
F	65	64	>.9
Surgery, %			
Unicondylar	10	7	.7
Total knee replacement	90	93	...
Diagnosis, %			
Osteoarthritis	73	89	>.9
Rheumatoid arthritis	27	11	...

*CPM indicates continuous passive motion; VAS, Visual Analogue Scale; ROM, range of motion; and HAQ, Health Assessment Questionnaire.
†*P* values determined by Student's *t* test (continuous variables) or χ^2 test (discrete variables).
‡Values are mean±SEM.
§Pain probit is the probit transformation of pain VAS using the inverse of the standard normal distribution function. VAS values of 0.0 were replaced by ½n; and values of 1.0 by 1−½n, where n=93, representing the number of patients randomized and not terminated for personal or health reasons.

Table 3.—Treatment Efficacy on Postoperative Day-7 Analyses Adjusted for Covariates by Multiple Regression*

Outcome†	Predicted Mean‡ CPM	No-CPM	P	99% Confidence Interval§
Pain score				
Probit VAS	−0.69	−0.41	.044	−0.66 to 0.08
Original VAS‖	0.28	0.36	.067	−0.19 to 0.03
Increase in knee swelling, cm	1.92	2.95	.0008	−1.82 to −0.26
Quadriceps strength (square root of newton-meters)	4.37	4.18	.30	−0.38 to 0.88
Newton-meters	19.1	17.5	.37	−3.12 to 6.33
Active flexion, degrees	82	75	.004	0.8 to 13
Active extension, degrees	−24	−25	.80	−6 to 7
Passive extension, degrees	−7	−6	.39	−3 to 2

*CPM indicates continuous passive motion; and VAS, Visual Analogue Scale.
†For change in knee swelling, n=93; for 6-week HAQ, n=87; and for other outcomes, n=92.
‡Predicted value using mean values for covariates.
§For the difference between the CPM and no-CPM groups.
‖Pain VAS and quadriceps strength also were analyzed using untransformed data, mainly for descriptive purposes.

not meet the Bonferroni critical level. The analysis was repeated with untransformed data yielding adjusted mean pain scores of 0.36 for non-CPM patients and 0.28 for CPM patients (99% CI for difference, −0.19 to 0.03).

Pain medication requirements in milligrams of morphine equivalents for mean daily doses of narcotics and analgesics were similar for CPM and non-CPM users but CPM increased pain medication use slightly. Daily doses decreased sharply from POD 1 (39 mg) through POD 3 (14 mg) but remained around 10 to 11 mg thereafter. The average doses of nonnarcotic analgesics were nearly constant throughout the week. The total dose of narcotics, analgesics, tranquilizers, and hypnotics and epidural narcotics was virtually the same between the two groups (data not shown).

Knee Swelling

This outcome was calculated as the change in knee circumference measured before and after surgery. The preliminary model had 12 core variables but only gender was strongly associated with swelling: women had less swelling than men. From the efficacy analysis, adjusted treatment means were 1.92 cm for CPM patients and 2.95 cm for non-CPM patients, and the difference, 1.02 cm less swelling with CPM, was statistically significant (P=.0008; 99% CI, −1.82 cm to −0.26 cm).

Quadriceps Strength

Quadriceps strength was weaker after surgery than before, by about 16 newton-meters (Nm) in our sample. The preliminary model contained 14 variables with substantial effects from preoperative strength, age, gender, and whether the patient had RA or OA. Quadriceps strength decreased less per year of age among women than among men. Use of CPM did not produce much difference in quadriceps strength (P=.30). Reanalysis with raw data confirmed the result: the CPM group had a higher adjusted mean but the difference was just 1.6 Nm.

Flexion and Extension

Active flexion was roughly 35° less after surgery than before. A positive correlation existed between preoperative and postoperative flexion, men had higher mean flexion than women, and mean flexion differed among patients of different surgeons. The CPM group had higher active flexion than the non-CPM group: the mean was 82° vs 75° after adjustment for covariates, and the difference between groups was statistically significant (P=.004; 99% CI, 0.8° to 13°).

On average, postoperative active extension was 10° to 11° less than the preoperative value and was most strongly associated with diagnosis (less for OA than for RA patients) and age (greater extension with older age). Adjusted mean values were −24° and −25° for CPM and non-CPM groups, respectively. The difference was not significant (P=.80; 99% CI, −6° to 7°).

Passive extension after surgery was associated with several variables: it was greater for men than for women, for RA than for OA patients, and for the group who received total knee replacement prostheses than for those with unicondylar prostheses; it was negatively correlated with preoperative knee circumference and it was positively correlated with preoperative passive extension. The efficacy analysis resulted in adjusted mean values for passive extension of −7° and −6° for CPM and non-CPM groups, respectively. This difference was not statistically significant (P=.39; 99% CI, −3° to 2°).

Length of Stay

The average length of stay among all patients was 10.2 days. Length of stay was correlated positively with patient's age, negatively with preoperative pain

Table 4.—Perioperative Complications

Complication	Continuous Passive Motion (n=45)	Conventional Rehabilitation (n=44)	P*
Manipulations	0	8	.003
Deep-vein thrombosis	1	0	NT
Delayed wound healing†	6	5	>.99
Nerve palsy	2	1	NT
Altered mental status	1	1	NT
Miscellaneous			
Fever without source	3	1	.62
Anemia	5	3	.71
Chest pain	2	0	NT
Atelectasis	1	1	NT
Urinary tract infection	1	1	NT
Gastrointestinal distress	2	0	NT
Herpes zoster	0	1	NT
Increased blood glucose	1	0	NT

*By Fisher's Exact Test. NT indicates not tested because it was not possible to obtain a P value ≤.05 owing to the small number of complications.
†Includes wound hematoma (five patients), wound drainage at 24 to 48 hours (three patients), heel decubitus (one patient), wound healing problem in contralateral total knee replacement (one patient); and delayed healing (one patient).

Table 5.—Cost Comparison of CPM vs Conventional Rehabilitation*

	Direct Patient Care Costs, $ (h)†	Indirect Costs, $‡	Total Cost, $
CPM with conventional rehabilitation	45 364 (515.5)	7796	53 160
Conventional rehabilitation	43 406 (493.3)	1798	45 204
Manipulation			14 720

*CPM indicates continuous passive motion.
†$88 per hour.
‡Includes cost of CPM equipment, consumable supplies, and maintenance.

and active flexion, and it differed by surgeon and was greater for women than for men. Adjusted treatment-group means were 10.1 days for CPM and 10.3 days for non-CPM groups, but the difference was not significant (P=.72; 99% CI, −1.8 days to 1.3 days).

Complications

The prevalence of medical complications was similar in the CPM group and in the controls (Table 4): the CPM group had one case of delayed wound healing and one with documented deep-vein thrombosis. The principal difference between the two groups was in the number of manipulations, eight in all, which only occurred in the non-CPM group.

6-Week Function

The 6-week HAQ and preoperative HAQ were correlated positively; also, the 6-week HAQ scores differed according to the patient's surgeon. Continuous passive motion treatment had little effect: the adjusted means, 1.29 for CPM and 1.24 for non-CPM, did not differ significantly (P=.53; 99% CI, −0.17 to 0.28).

6-Week ROM

Follow-up visits 6 weeks after surgery provided flexion data on 73 patients. With analysis described above, neither CPM nor manipulation showed a positive benefit (difference of 3° for CPM vs non-CPM, P=.8; difference of 1.8° for manipulation vs no manipulation, P=.7).

Cost Comparison

The costs of CPM supplementing conventional rehabilitation were $53 160 (Table 5), but also required eight manipulations costing $14 720 ($1840 for each of eight manipulations). Thus, use of CPM would have lowered costs by $6764.

COMMENT

This study is the second randomized controlled evaluation of CPM plus conventional rehabilitation compared with conventional rehabilitation alone and is the only study with blinded assessment of outcomes. For the average patient undergoing TKA with good preoperative ROM, the greatest benefit of CPM appears to be in avoiding manipulation. Other studies have reported that manipulation is less common in patients receiving CPM.[7,9,10] In our study, no manipulations were required by patients in the CPM group; but eight patients in the non-CPM group were slow to improve ROM and required manipulation. Surgical manipulation after TKA is only a temporary solution for achieving better ROM and no long-term benefits have been documented.[26] By 6 weeks, the ROM in the two groups were virtually identical.

Continous passive motion patients achieved earlier motion and had 7° more active flexion on POD 7 than did those patients who did not receive CPM. At 6 weeks after surgery, the differences in active flexion between the two groups was only 3°; this confirms two other studies.[6,7] Use of CPM was routinely discontinued once the patient achieved 90° of active motion, typically on POD 7. Earlier motion of the knee renders a patient more mobile and better able to do transfers. Use of CPM also reduced the amount of edema at the operative site.

Although CPM users had slightly more quadriceps muscle strength, the difference was not statistically significant. Both groups achieved independence in straight-leg raising on POD 6.

Patients in the CPM group were encouraged to use the CPM machine "as much as possible" and the amount of actual use is of interest. In the first 72 hours after surgery, CPM use averaged 12.4 hours per day; subsequent use averaged 6.3 hours per day with an average CPM use in the first week of 8.9 hours per day. The time and duration of application of CPM are quite variable[7-9,11,15-17] and currently there is no consensus on the optimal length of CPM use. Basso and Knapp[11] reported no difference between a group that used CPM for a minimum of 5 hours and a group that used CPM for a maximum of 20 hours. Most studies have limited the daily use of CPM to 16 to 20 hours.[7,9,16,17]

Use of CPM did not significantly affect the number of days patients were hospitalized after TKA. The patients using CPM were discharged 0.2 days earlier than non-CPM users but this is not clinically significant.

Implant design and surgical technique may be critical factors in the achievement of ultimate motion after TKA.[27] In our sample, both active flexion (P=.002) and length of stay (P=.07) were influenced by which surgeon did the procedure. The implant design and use of a patella button did not have any effect.

When no differences are found in a study, one might question whether the correct interventions or patient subsets were studied, whether the measures were sensitive enough to pick up differences, and whether adequate numbers were studied to avoid a type II error. The measures selected were largely ratio scales and the raw data had narrow confidence intervals. The HAQ has been shown to be sensitive to the changes seen in total joint arthroplasty.[28,29] Statistical power was examined for each outcome by setting the two-tailed significance level at .00625,

taking the standard error for the treatment difference from the relevant regression model, and using a t distribution with 76 df.

For most outcomes, the population differences needed for 80% power were realizable with the possible exception of passive extension. Therefore, any failure to detect a statistically significant difference between the CPM and non-CPM groups suggest that CPM and conventional rehabilitation are of equal effectiveness for those outcomes and our sample size provides sufficient power to detect those differences, even accounting for multiple testing.

In conclusion, the use of CPM plus standard rehabilitation avoids the need for manipulation, improves early active flexion, decreases swelling, and lowers cost compared with standard rehabilitation alone but does not affect pain, active and passive extension, strength, length of stay, or overall function or ROM at 6 weeks after the operation.

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