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Research article

CONTINUOUS PASSIVE MOTION (CPM) IN REHABILITATION FOLLOWING TOTAL KNEE ARTHROPLASTY: A RANDOMISED CONTROLLED TRIAL

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ABSTRACT

Objective: Continuous passive motion (CPM) has been shown to increase the amount of knee flexion in knee patients at the acute care hospital. Changing postoperative management leads to shorter hospitalisation periods. The objective of the present randomised controlled trial was to assess whether there is additional benefit in CPM use during such a short hospitalisation period.

Design: Forty patients undergoing total knee arthroplasty were randomly allocated to either a group receiving CPM in addition to physical therapy or a group receiving physical therapy alone. Both programmes were delivered during a 5-day postoperative period on an inpatient basis, starting on the first day after surgery. Main outcome measures were mobility and function; secondary measures included muscle strength, pain, satisfaction and length of hospital stay.

Results: The results indicate a significant difference in function score, pain and strength between the CPM group and the control group. Four days after surgery, the CPM group scored an average of 56 points on the Hospital for Special Surgery scale (HSS), versus 45 points in the control group ($P = 0.005$).

Conclusions: The results indicate that, in addition to an improved range of motion, a protocol including CPM seems to have a favourable effect on pain and muscle strength in the first two weeks after surgery.

INTRODUCTION

Early mobilisation, if possible starting on the day of surgery, is the strategy of choice in orthopaedic operations in The Netherlands. Continuous passive motion (CPM) has been used in the rehabilitation of patients after knee surgery ever since Salter and colleagues[1] introduced the device in the early 1980s. The beneficial effects[1,2] claimed for it include pain relief, maintenance of range of motion, improved wound healing, and quicker recovery. The first randomised controlled trials (RCTs) in this field date from the end of the 1980s,[3–5] some 10 years after the introduction of CPM as a treatment modality.

Although CPM is widely used, the debate about its efficacy is still on-going, mainly as a result of controversial findings reported in the literature. A systematic review[6] using an extended Medline search found 12 RCTs[3,5,7–16] addressing CPM use after total knee implantation. There was considerable variety in methodological quality (ranging from poor to good) as well as in the treatments compared. Studies were

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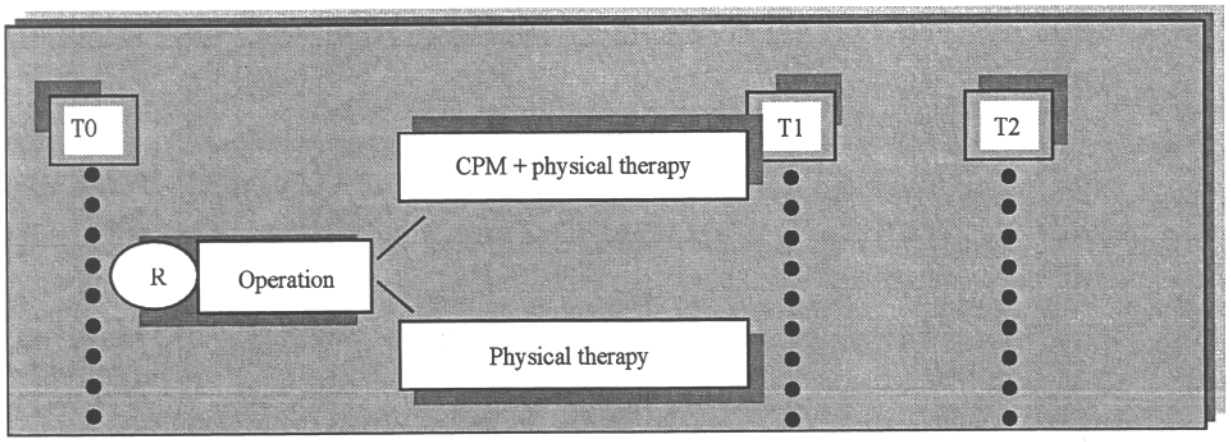

Fig. 1. Research design and outcome assessment. T0, baseline assessment 14 days before surgery; T1, assessment 4 days after surgery; T2, assessment 17 days after surgery.

difficult to compare because they used 18 different outcome measures. Major outcome measures were mobility, which was assessed in all 12 trials, length of hospital stay, assessed in five,[5,10,11,14,15] and drain production, assessed in four.[7,14–16]

Overall, there seem to be short-term beneficial effects on mobility. Of six studies measuring mobility within the first 2 weeks after the operation, five reported positive effects of CPM.[3,7,9–11,15] Reported differences between CPM and control groups range from –1° to +18° in favour of the CPM group. The functional consequences of faster mobility improvement remain unclear, however, and in the long term there do not seem to be advantages to the use of CPM.[6]

Over the last few years, however, treatment protocols following total knee arthroplasty have changed. The formerly common fortnight's hospital stay has gradually been reduced to 4–5 days, and 1 week of bed rest has been replaced by mobilisation of the patients starting on the first or second day after the operation.[7,9,10,15]

These protocol changes raise the question whether the effects on CPM reported in relation to the older protocols are still valid. Rehabilitation now starts on the first day after surgery, resulting in activity during the first two stages of connective tissue repair. It remains unclear what effect intensive exercise and mobilisation have on these first phases of tissue repair, whether they shorten or prolong the bleeding and oedema phase, and whether this could influence clinical outcome. To answer these questions, a randomised controlled trial was performed at the University Hospital of Maastricht. Physical therapy without CPM (control group) was compared with physical therapy with CPM (CPM group) as an adjunct treatment.

The study was approved by the medical ethics committee of the University Hospital of Maastricht.

PATIENTS AND METHODS

Patients

All consecutive patients with osteoarthritis undergoing primary total knee arthroplasty (TKA) from January to May 2001 were screened. Patients with relevant co-morbidity, such as rheumatoid arthritis, were excluded, as were patients for whom a longer stay was expected due to co-morbidity. Figure 1 illustrates the design of the study.

Randomisation

Patients were randomly allocated to one of the treatment groups by means of a computer-generated table, with a block size of eight (Fig.2). An independent orthopaedic secretary without knowledge of the randomisation schedule called up the patients for operation. The patients assigned to the CPM group and those included in the control group were operated on in different weeks, to prevent bias caused by patients of both groups being in the hospital at the same time.

Intervention

On the day of surgery, all patients took bed rest. On the first day after surgery, they began walking. Physical therapy was standardised by means of the Maastricht Hospital protocol for in-patient treatment of total knee patients. This protocol prescribes hospital discharge on the fourth day after the operation.

Physical therapy was aimed at strengthening the m. quadriceps and mobilising the knee (actively as well

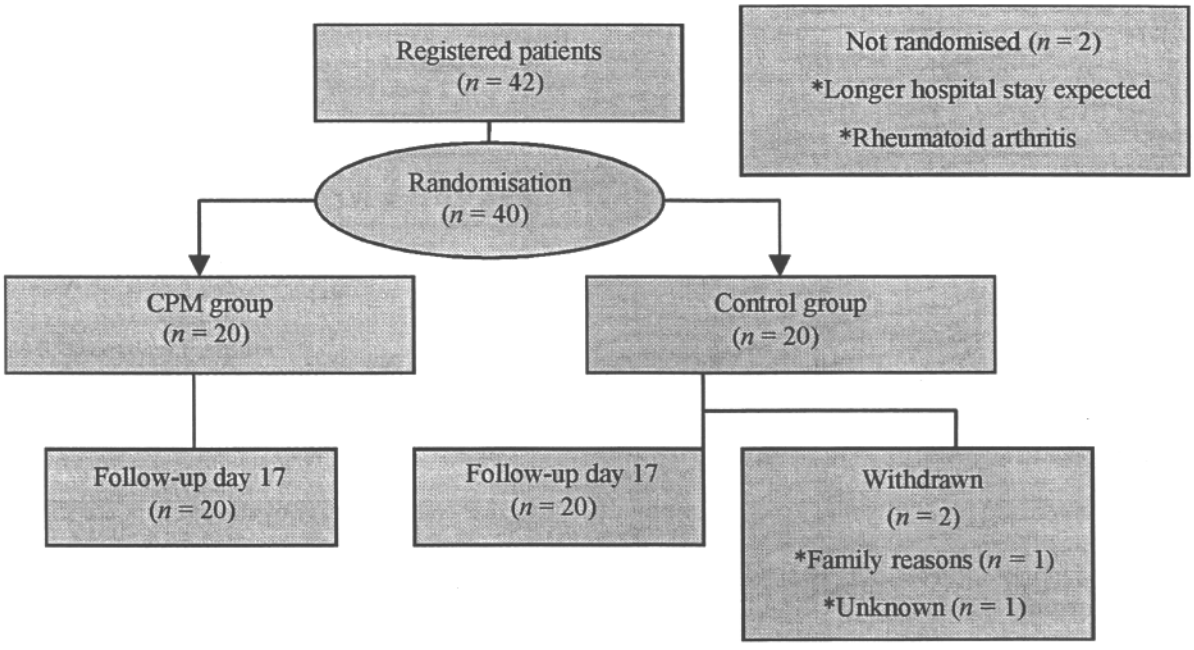

Fig. 2. Study overview from registration to follow-up at day 17.

as passively, using joint distraction and angular mobilisation techniques). Care was taken to restore a proper gait pattern with the help of one elbow crutch upon discharge. The target for mobility in the clinical phase was 80° of knee flexion and no more than 10° of knee extension deficit.

After discharge, all patients received physical therapy treatment at home, three times a week.

The control group received in-hospital physical therapy twice a day for 20 min for 4 days. The CPM group additionally received 4 h of CPM daily. The CPM machines used were 'Toronto medical' devices (Ortho-Logic Ltd, Toronto, Canada) with adjustable upper and lower leg lengths. ROM was increased daily as tolerated.

As a result of this design, the only contrast between the two groups during the hospital stay was the use of CPM in the experimental group. All patients received pain medication in accordance with the hospital protocol, using epidural or i.v. medication for the first 48 h, followed by oral pain medication during the next 2 days.

Outcome assessment

All physical measurements were performed by one, independent, blinded observer. Passive ROM was measured using a 'long arm', hand-held goniometer. Extension was measured with the patient supine, flexion with the patient seated, hips at 90°. Function was evaluated using the 'Hospital for Special Surgery' score.[17] Data on medication and length of hospital stay were abstracted from medical records.

Primary effect measures were mobility and function, both of which were assessed at all three examinations. Secondary effect measures included length of hospital stay, pain, muscle strength, medication, satisfaction about the treatment given by the physical therapist, and satisfaction with attention received from the physical therapist. The total amount of time spent in the CPM machine per day was measured to assess compliance.

Muscle strength was tested using a hand-held dynamometer (Citec™, Centre for Innovative Technics, Haren, The Netherlands) with the patient seated, hips at 90° and knees at 60° of flexion, using the 'make' method. In this method, the patient tries to extend the leg and the observer applies a counterpressure so the knee remains in 60° of flexion. An 11-point scale was used to rate pain and satisfaction with the treatment and attention received from the physical therapists. Pain was rated on three 11-point scales, one for mean pain level in the last 24 h, one for lowest level of pain in the last 24 h and one for worst pain in the last 24 h.

Table 1 presents the measuring instruments used, as well as the timing of the measurements.

Data analysis

The data of all patients were entered in and analysed with SPSS statistical software package, version 9.0 (Norusis, Chicago, IL, USA),[18] by a blinded analyst. Data were analysed according to the 'intention to treat' principle.[19] Primary effect measures were calculated as

Table 1. Effect measures, methods and timing of assessments

	Method	T0 2 weeks prior to surgery	T1 4 days after surgery	T2 17 days after surgery
Mobility*	Long-arm goniometer	X	X	X
Function*	HSS score	X	X	X
Length of hospital stay	Hospital record		X	
Pain	11 point scale	X	X	X
Pain medication	Hospital record		X	X
Satisfaction with physical therapist's treatment	11 point scale		X	
Satisfaction with physical therapist's attention	11 point scale		X	
Muscle strength	Hand-held dynamometer	X	X	X
Hours of CPM per 24 h	Hospital record		X	

*Primary measures of effect.

the differences between T0, T1 and T2. Between-group differences were used in all analyses. A two-tailed *t*-test was used for continuous data, and Mann-Whitney U-tests for HSS scores.

RESULTS

Forty patients were included in the study, 20 of whom received physical therapy twice a day during all 4 days of their hospital stay (PT group), while 20 received CPM in addition to the physical therapy (CPM group).

Table 2. Baseline characteristics

	CPM group (n = 20) Mean (SD)	PT group (n = 20) Mean (SD)
Age	65.0 (9.2)	65.7 (9.5)
Gender (male/female)	6/15	7/12
Passive extension	5.1° (5.3)	5.6° (6.3)
Passive flexion	117.4° (15.6)	120° (15)
HSS score (0–100 points)	62.6 (12.7)	66.1 (8.5)
Strength	163.9 N (52.6)	165.6 N (70.5)
Average pain (0–10 points)	3.6 (2.8)	3.8 (2.7)
Minimum pain (0–10 points)	2.5 (2.6)	1.7 (2.2)
Maximum pain (0–10 points)	7.6 (2.3)	7.9 (1.6)

*In the last 24 h.

Baseline characteristics of the patients are shown in Table 2. Randomisation resulted in a good balance between baseline characteristics in the two groups.

Baseline data on strength were lacking for one patient, due to problems with the dynamometer. Data on muscle strength at discharge were missing for the same patient.

One patient was not evaluated on day 4 because he had suffered a heart attack on day 3 after the operation and was being treated at the intensive care ward on day 4. Evaluation of this person was completed on day 17.

Two patients did not return for the follow-up visit, one because of the death of her husband during the postoperative period, the second one without notice.

Range of motion (ROM)

Table 3 shows a comparison of the data on range of motion. On day 4 as well as day 17 after the operation, the CPM group performed better on passive ROM. Passive flexion declined immediately after surgery, being ~40° less on day 4 than before surgery. The difference was 36° in the CPM group and over 45° in the control group. In absolute values, flexion was 6° less and extension 1.6° less in the control group. On day 17, ROM had improved in both groups, but the difference between the groups remained. The overall ROM difference on day 17 was more than 10°. Only the difference in extension on day 17 was statistically significant (P = 0.029).

Table 3. Passive ROM on days 4 and 17

	Day 4 after surgery (SD)			Day 17 after surgery (SD)		
	CPM	Control (n = 20)	P value (n = 19)	CPM	Control (n = 20)	P value (n = 18)
Extension	4.7° (4.5)	6.2° (4.2)	0.269	4.2° (3.4*)	7.9° (5.9*)	0.029
Flexion	80.3° (11.7)	74.5° (13.3)	0.158	90.2° (13.2)	83.7° (15.1)	0.163
[a]Extension	4.5 (8.0)	–0.6 (7.2)	0.660	1.2 (5.7)	–2.1 (5.8)	0.09
[a]Flexion	–36.2 (17.7)	–45.5 (12.4)	0.069	–27.6 (15.6)	–36.1 (10.6)	0.061

*Statistically significant. [a]Difference with pre-operative value.

Table 4. HSS scores on days 4 and 17

	Day 4 after surgery (SD)			Day 17 after surgery (SD)		
	CPM	Control ($n = 20$)	P value ($n = 19$)	CPM	Control ($n = 20$)	P value ($n = 18$)
HSS	56.5 (9.8)	44.5 (14.9)	0.001	66.2 (10.1)	54.2 (12.8)	0.003
[a]HSS	−5.7 (17.9)	21.6 (13.9)	0.006	4.6 (15.4)	−11.9 (9.7)	0.001

[a]HSS shows difference with pre-operative values.

Table 5. Secondary measures

	Day 4 after surgery (SD)			Day 17 after surgery (SD)		
	CPM	Control ($n = 20$)	P value ($n = 19$)	CPM	Control ($n = 20$)	P value ($n = 18$)
Strength	48.2 (30.1)	24.2 (21.3)	0.008	99.0 (45.6)	80.3 (31.0)	0.161
Average pain	2.6 (1.8)	4.7 (2.6)	0.005	2.3 (2.6)	4.5 (2.4)	0.009
Maximum pain	5.5 (2.7)	8.2 (1.1)	0.001	4.3 (3.3)	7.2 (2.6)	0.005
Minimum pain	1.1 (1.3)	2.3 (2.2)	0.042	0.9 (1.6)	2.9 (2.6)	0.007
Length of stay	6.0 (3.6)	5.6 (1.1)	0.709			
Satisfaction with treatment	9.0 (1.0)	8.6 (1.0)	0.268			
Satisfaction with attention	9.0 (1.1)	8.6 (1.0)	0.282			

Function, as measured with the Hospital for Special Surgery score

The control group received in-hospital physical therapy twice a day for 20 min for 4 days. The CPM group additionally received 4 h of CPM daily. HSS score declined after surgery, as is illustrated in Table 4. The decline in the control group was greater than that in the CPM group. After 17 days, the score was comparable to pre-operative values in the CPM group, whilst the score in the control group was still much lower. All between-group differences were statistically significant.

Secondary effect measures

After 4 days, muscle strength in the CPM group was twice as high as in the control group (48 versus 24 N). After 17 days, strength was about 55% of the pre-operative value and there were no significant differences between the two groups (Table 5).

Pain is presented as median pain level at rest and highest and lowest pain levels during the last 24 h. Although it was not a primary effect measure, differences in pain perception were regarded as a prominent outcome in this study. Pain was perceived as less of a problem in the CPM group at 4 as well as 17 days after surgery. Between-group differences were statistically significant at every evaluation point.

The length of the hospital stay and the level of satisfaction with the treatment and attention provided by the therapists were similar in both groups.

Compliance was measured as the number of hours in the CPM machine per day. Patients in the CPM group received an average of ~3.6 h of CPM treatment per day.

DISCUSSION

Both groups did better than patients reported on by several other studies.[7,9,15] However, differences in ROM between the CPM and control group were not significant in this trial, This difference in ROM was approximately 8° at T1 and 10° at T2. This may be due to the intensive treatment in the control group. Johnson *et al.*[9] immobilised the patients in their control group for 7 days, while Pope *et al.*[7] immobilised all patients in an extension splint between physical therapy sessions during the first 3 days after surgery. Although CPM was not continued in the first week after discharge, the differences in ROM in the current study were found to persist through day 17. The data do not show whether, and if so when, the control group made up this difference.

Differences in function score between the CPM and control groups were found to be marked. Secondary analyses showed that over 50% of this difference was attributable to the difference in pain perception,

which is part of the HSS questionnaire. One might, therefore, question whether this difference really represents a change in overall function, or merely the use of a different kind of pain measurement. Better tools are required to measure functions of daily living in this treatment group.

Secondary measures of effect

Quadriceps' strength levels at 4 days after surgery were much higher in this study than in the study reported by McInnes *et al.*[10] This apparent difference could be due to the fact that we measured strength at about 60° of flexion, whereas they measured at 45° of flexion. However, McInnes and colleagues did not find any significant differences in strength, whereas we found a difference of 50% between the CPM and control groups. A possible explanation for the difference in strength between the two groups could be the fact that CPM is not as 'passive' a treatment as we think it is, and may involve muscular activity while 'resting' in the machine. Why we found a large difference whereas McInnes *et al.*[10] reported no difference remains unclear. The effect on pain was also markedly greater than that reported by previous studies. McInnes *et al.*[10] reported a moderate difference in favour of the CPM group; however, the overall pain scores in their study were smaller compared to our data.

The effect on pain cannot be explained by differences in medication, because pain management was standardised in our trial. A possible explanation is that prolonged passive motion leads to pain reduction through arthokinematic reflex activity.[20]

Compliance in the CPM group was less than the planned 4 h of CPM treatment a day. One possible reason for this could be the use of the hospital's 'living room' facilities during the daytime, which was located about 50 m from the bedrooms. Since it is more difficult to install the CPM machine in a chair than in a hospital bed, physical therapists and nursing staff occasionally skipped this procedure.

The physical therapy treatment in this trial was intensive. In-hospital regimens in The Netherlands usually prescribe one 20-min physical therapy session a day. Hence, the results must be evaluated in the context of a control treatment involving 40 min of physical therapy in its protocol.

Only short-term effects of CPM are described here. We were interested in the short-term effects because a systematic review had found no consistent long-term effects of the treatment, but strong evidence of short-term effect, mainly on ROM. Considering the outcome of the present study, we would also be interested in the medium-term outcome, to examine whether the control group made up this difference with the CPM group and, if so, over what time interval.

Furthermore, we intend to perform a new trial in which CPM application is continued for 2 weeks, as 'dosage' is a possible factor of influence.

CONCLUSIONS

This study indicates that CPM delivered in the first 4 days following surgery seems to lead to better short-term mobility. The increased mobility is present through the 17th day after surgery. Results on function should be interpreted with caution, because pain and function seem closely related in the scoring system used here. Nevertheless, there was a considerable difference in favour of the CPM group in terms of this functional outcome measure. The most striking outcome was the difference in postoperative pain perception, with CPM use leading to an immediate decline in postoperative pain. Finally, muscular strength in our CPM group was better than that in the control group, at day 4 as well as day 17. Future research should concentrate on long-term outcome, longer use of CPM and finding a better outcome tool for functional assessment.

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