Continuous passive motion compared with intermittent mobilization after total knee arthroplasty. Elaboration of French clinical practice guidelines

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Abstract

Objective. – To develop clinical practice guidelines concerning the use of continuous passive motion (CPM) compared with intermittent mobilization after total knee arthroplasty (TKA).

Method. – We used the SOFMER (French Physical Medicine and Rehabilitation Society) methodology, combining systematic literature review and collection of everyday clinical practice concerning postoperative rehabilitation techniques and external review by a multidisciplinary expert panel, to develop the guidelines.

Results. – The literature contains no evidence of the advantages of CPM over other techniques of mobilization, although CPM could be adjuvant therapy used to accelerate short-term recovery. However, in France, CPM remains widely used after TKA, both in orthopedic surgery units and in physical medicine and rehabilitation services.

Conclusion. – Good methodological quality studies are needed to assess different CPM modalities and compare them to alternative intermittent mobilization techniques, particularly those with therapy starting from a flexed position.

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Keywords: Osteoarthritis; Knee arthroplasty; Postoperative rehabilitation; Recommendations; Guidelines; Clinical practice; Physiotherapy; Physical therapy; Arthroplasty; Continuous passive motion

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1. Introduction

The objective of total knee arthroplasty (TKA) is to restore the joint to a pain-free, stable and mobile state. Recovery of a good range of motion, particularly in flexion, is important for activities of daily living. It is estimated that 65° of flexion is necessary to walk properly, 90° to go downstairs, and 105° to get up from a low chair [4,5]. Early mobilization rapidly became an important part of rehabilitation protocols after TKA, advancing classical practices, which maintained immobilization in extension to preserve wound healing.

Continuous passive motion (CPM) treatment for cartilage healing was demonstrated in a rabbit model, by Salter in 1970. The method has been rapidly used after TKA, mainly to restore mobility but also to decrease postoperative hemarthrosis and edema via a “pump effect” [18] and to obtain well-oriented, good-quality collagenous healing of the operative wound. But the role of CPM after TKA remains controversial, both in its modalities and in its use as compared with classical rehabilitation techniques, which have evolved, and other, new strategies (notably alternate immobilizations) to obtain quicker recovery of range of motion.

We aimed to develop clinical practice guidelines using the methodology of SOFMER (French Physical Medicine and Rehabilitation Society) concerning the use of CPM after TKA [20].

2. Method

The SOFMER 3-stage method for developing guidelines involves systematic literature review, collection of information about professional practice and final scientific committee review [20].

2.1. Systematic literature review

2.2.1. Study selection

Literature search professionals systematically searched the PubMed, Pascal Biomed, and Cochrane Library databases. They used search terms defined by the scientific committee, created as one of the requirements of the SOFMER methodology. Keywords were proposed by the steering committee, which consisted of physicians in physical medicine and rehabilitation (PMR) and rheumatology and orthopedic surgeons. The keywords were in English arthroplasty, replacement, hip, knee, therapy, rehabilitation, exercise, physical therapy, CPM and in French “kinésithérapie, mobilisation, physiothérapie, rééducation, exercice, hanche, genou, arthroplastie, prothèse et mobilisation passive continue”. Selected were abstracts of studies of all design that included an abstract, were published in English or French, and investigated adult human patients. The literature search professionals sent abstracts to the scientific committee, which then narrowed the selection of abstracts by ensuring that “rehabilitation intervention” was present in the abstract and then requested the full-length articles from the professional literature searchers. Two experts from two different medical specialties (JMP, an orthopedic surgeon, and PT, a PMR physician) selected articles related to postoperative rehabilitation. Finally, pertinent abstracts of articles cited in references were investigated.

The quality of each manuscript was assessed according to the grading scale of the French Agency for Accreditation and Evaluation in Healthcare (Anea) [20]. Low-quality studies were excluded because of inadequate randomization, insufficient number of subjects and/or unclear interventions.

2.2.2. Data analysis

Data were analyzed by two independent reviewers, JMP and PT.

2.3. Daily practice

Data on physicians’ daily practice for postoperative rehabilitation were collected at the national congresses of rehabilitation (SOFMER Congress, Rouen, France, October 18, 2006) and orthopedic surgery [Société française de chirurgie orthopédique et traumatologique (SOFCOT) National Congress, Paris, November 7, 2006] with use of an electronic voting device. After the data collection, one of the two medical experts (PT)
presented the results of the literature search. Then, the session was open for questions and comments. A medical secretary took notes during the question-and-comment period.

2.4. Elaboration of guidelines and external review by a reading committee

Practice guidelines based on daily practice data as collected above and literature review were written. These guidelines were reviewed by the scientific committee before validation by a reading committee [20].

3. Results

The scientific committee selected 147 manuscripts from PubMed, 60 from Pascal Biomed, and 10 from the Cochrane database. A total of 21 papers were selected by the two experts. Eleven deserved an ANAES level 1 score, the other 10 a level 2 score. Randomized controlled trials reporting a calculated power of more than 80% and/or those including more than 100 patients were considered to have high power.

Among the 11 level 1 papers, two reported the results of the same meta-analysis [4,5]. Nine were of randomized controlled trials [1–3,8–10,14,19,23]. The results of one were described in two different papers [2,8]. Another paper could be considered slightly off topic because it compared two different modalities of CPM [23].

Among the 10 level 2 papers, six were of randomized controlled trials [6,7,12,13,16,17] and four controlled clinical trials without randomization but with good methodological quality [11,15,21,22]. One compared two different modalities of CPM [11].

3.1. Meta-analysis

Brosseau et al. [4,5] reported in two different papers the results of a meta-analysis addressing articles published between 1990 and 2002. The authors mainly studied the process of selecting the papers and the modalities of the statistical analysis. From 178 papers, 14 randomized studies of 952 patients comparing isolated physiotherapy with physiotherapy and CPM combined were selected on the basis of the following criteria: included patients aged 18 or older and investigated knee arthroplasty, osteoarthritis or rheumatoid arthritis. The papers with poor statistical data (e.g. S.D. not reported) were excluded. The modalities of CPM were variable, ranging from 5 to 20 hours of application per day, for a total duration of treatment ranging from 18 hours to 2 weeks. For some studies, the beginning of mobilization in the control group was CPM postponed for several days. The authors concluded that CPM associated with classical rehabilitation at 2 weeks postoperatively provided clinically poor but significant improvement of flexion, at a range of 4° (in 286 patients from nine studies). This modest result was not confirmed at 1 year follow-up. The recovery of more than 90° of flexion was observed with a mean of 4.7 days sooner release from therapy after use of CPM. Active and passive extension was not significantly improved (in 113 patients from three studies). The use of CPM was associated with a slightly shorter length of hospital stay (mean 0.7 days from six studies), but the criteria for discharge was often ill defined. CPM could lessen the need for use of mobilization under general anesthesia (relative risk 0.12 from three studies) and could contribute to lessening pain and swelling of the knee (clinically irrelevant but significant difference).

The authors pointed out the poor methodological quality of most of the studies (related in part to the difficulty in performing properly blinded studies), the lack of accuracy concerning particularly the modalities of assessment of the range of motion (active or passive?), and the variety of the implants used at surgery.

3.2. High-power level 1 randomized controlled trials

The high-power randomized controlled clinical trials can be divided in two categories according to modalities of CPM: “progressive” and “advanced.”

3.2.1. Progressive CPM (Table 1)

For five trials (including the two studies dealing with the same population [2,8]), CPM was started at less than 40° of flexion and then progressively increased, usually according to the patient’s tolerance. CPM was initiated in the recovery room [9,10] or began the next day (the ill-defined “second operative day” was used in two studies [2,8] and day 1 or 2 in one study [1]). The duration of treatment was variable, usually about 1 week. Two studies [2,8] added auto-mobilization exercises on a sliderboard to classical CPM (three series were compared: standard CPM with a 10-min exercise on the board, idem with two more 10-min sessions on the board, then idem with CPM). In the control group, the mobilization began on the first or second operative day, except in one series, in which it began on day 7 [10].

For three of the five trials, the mean range of flexion at day 7 for the CPM group was significantly higher than that of the control group, but for three of the four trials with longer follow-up, this improvement was not maintained. For one trial [10] patients who received CPM showed increased flexion at long-term follow-up, but the control group had delayed mobilization. Only one trial [9] found a significant improvement of extension at 2 weeks. In the other series, the extension was not improved by CPM, either at short- or long-term follow-up.

Only one trial [10] found CPM allowing for a shortened length of hospital stay. In terms of general anesthesia with or without CPM, three trials [1,2,8] did not find better mobilization, nor, like another trial [9], a difference in pain level. CPM was not associated with more wound complications. One trial [10] found even more superficial infections among patients not having received CPM. Finally, one trial [8] found costs not significantly lower with CPM than with other modalities of treatment.
3.2.2. Advanced CPM (Table 2)

Four studies analyzed an advanced form of CPM, three involving treatment begun immediately at a high range of flexion [3,14,19,23], during 24–48 hours [14,19] or for a longer period, of 5 days [3], in comparing two protocols of CPM with a control group, or 6 days [23], in comparing two protocols of CPM without a control group. All trials but one [14] found a significant improvement of early flexion after advanced CPM, which was unconfirmed at longer follow-up (1 year). One trial [19] found greater extension lag at the end of treatment, but the difference disappeared at the final follow-up. The study also found more severe pain and more blood loss as compared [23] after advanced CPM, and thus did not recommend this type of CPM.

3.3. Level 2 studies

Some of the level 2 studies addressed particular techniques or subjects (Table 3).

One study [6] did not find CPM increasing the gain in flexion or shortening the length of hospital stay as compared to more traditional rehabilitation in a rehabilitation center among patients admitted at a mean of 8 days postoperatively with 5 hours of CPM per day, the device being set at 10° less than the maximum flexion.

Another study [11] compared two modalities of CPM, progressive and advanced (flexion set initially between 70° and 100°, with progressive extension obtained over 3 days in two successive series of 50 patients. The authors found a gain in

Table 2

High-power level 1 randomized controlled trials addressing advanced CPM

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Number of cases</th>
<th>FU</th>
<th>Control group(s)</th>
<th>Duration of CPM</th>
<th>Length of treatment</th>
<th>Prosthesis</th>
<th>Other points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bennett</td>
<td>2005</td>
<td>148*</td>
<td>1 year</td>
<td>PT/progressive CPM 3 h × 2</td>
<td>90°–40° 3 h × 2</td>
<td>5 days</td>
<td>Two different TKP, PCR ±, patella ±</td>
<td></td>
</tr>
<tr>
<td>Mac Donald</td>
<td>2000</td>
<td>120 (?)</td>
<td>1 year</td>
<td>PT/progressive CPM 18 and 24 h</td>
<td>70°–110° 24 h</td>
<td>24 h</td>
<td>Two different TKP</td>
<td></td>
</tr>
<tr>
<td>Pope</td>
<td>1997</td>
<td>70 (13)</td>
<td>1 year</td>
<td>PT/progressive CPM 20 h</td>
<td>0°–70° 20 h</td>
<td>48 h</td>
<td>Four different TKP</td>
<td></td>
</tr>
<tr>
<td>Yashar</td>
<td>1997</td>
<td>210 (95)</td>
<td>1 year</td>
<td>progressive CPM 20–24 h</td>
<td>70°–100° 20–24 h</td>
<td>6 days</td>
<td>TKP</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author</th>
<th>Early flexion</th>
<th>Final flexion</th>
<th>Early extension lag</th>
<th>Late extension lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bennett</td>
<td>64.9/69.4/78.7</td>
<td>102.9/102.2/105.5</td>
<td>6.5/6.2/7.7</td>
<td>4.1/3.5/3.4 NSD</td>
</tr>
<tr>
<td>Mac Donald</td>
<td>140/101/101 6 weeks</td>
<td>112/113/112</td>
<td>NSD</td>
<td>2/2/2 NSD</td>
</tr>
<tr>
<td>Pope</td>
<td>56.8/70.3/78.3</td>
<td>100/103.8/102</td>
<td>6.2/11.3/8.2</td>
<td>7.1/6.9/5.3 NSD</td>
</tr>
<tr>
<td>Yashar</td>
<td>84.3/89.1 D7</td>
<td>110/115/113</td>
<td>8.1/9.1</td>
<td>1.8/0.5 NSD</td>
</tr>
</tbody>
</table>

NSD: nonsignificant difference; SD: significant difference; P < 0.05; FU: follow-up. | a () = excluded from the final analysis. | b …/… = first control group/second control group if exists. | c PT = physiotherapy. | d CPM range on the first day. | e TKP = total knee prosthesis, PCR+/− = posterior cruciate retaining or not, patella ± = patellar resurfacing or not. | f In degrees, control group/second control group if exists/CPM.
flexion after advanced CPM that was maintained at 1 year follow-up (120° vs. 111°) and significantly shorter length of hospital stay (7.6 vs. 9.7 days, with precise discharge criteria), and therefore noticeably reduced global costs (2877 $ vs. 3647 $). The authors did not find cutaneous problems with the therapy.

In a randomized series of 83 TKA, another trial [12] proposed, as an alternative to CPM, the technique of “drop and dangle”: the knee is closed in flexion and immobilized on a splint at 90° of flexion. The patient is mobilized on the following day and asked to do auto-mobilization exercises sessions of 20 min twice a day, in a seated position, with the support of the foot on the ground. This technique provided the same results on range of motion as an advanced protocol of CPM (starting with 90° flexion, 20 hours/day). The results on extension were even (paradoxically) better (extension lag 0.7° vs. 3.5°). This technique goes together with proper management of pain with epidural catheter and morphine pump. It allowed for a significantly reduced length of stay (5.5 vs. 7.1 days, with precise discharge criteria). This paper is the only one among the 21 selected that described a possible correlation between function, radiological results, and the type of implants used at surgery.

A phlebographic study of thromboembolic complications [13] did not reveal significant differences between control and CPM treatment. Phlebographic anomalies were about 40%, more frequent among patients having had cemented arthroplasty, for whom preventive treatment was recommended.

The six other series (Table 4), more classical, were low-powered trials [7,16,17] and controlled clinical trials [15,21,22]. They compared the results of progressive CPM with those of classical rehabilitation. Two found quickly increased flexion with CPM but all found no significant differences at long-term follow-up. Only one [21] found late extension lag problems among patients receiving CPM. In three of four series, the results on length of stay favored CPM. The results were less clear concerning pain (which does not seem to be increased by the use of CPM), cutaneous complications and thromboembolism problems.

### Table 3
Level 2 studies addressing particular techniques or subjects

<table>
<thead>
<tr>
<th>Author</th>
<th>Years</th>
<th>Type</th>
<th>Number of cases</th>
<th>FU</th>
<th>Control group</th>
<th>CPM</th>
<th>Prosthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen</td>
<td>2000</td>
<td>RCT in RC</td>
<td>51</td>
<td>Until discharge (8.4d)</td>
<td>PT</td>
<td>CPM max flexion –10°</td>
<td>TKP</td>
</tr>
<tr>
<td>Jordan</td>
<td>1995</td>
<td>CCT</td>
<td>100</td>
<td>1 year</td>
<td>CPM 40°</td>
<td>CPM 70°–100°</td>
<td>TKP (one kind)</td>
</tr>
<tr>
<td>Kumar</td>
<td>1996</td>
<td>RCT</td>
<td>83</td>
<td>6 months</td>
<td>“Drop and dangle”</td>
<td>CPM 0–90° 10 h × 2</td>
<td>TKP (two kinds)</td>
</tr>
<tr>
<td>Lynch</td>
<td>1988</td>
<td>RCT phlebography J7</td>
<td>150</td>
<td>Until discharge</td>
<td>D3</td>
<td>CPM 0–30° 10–18 h</td>
<td>TKP (four kinds)</td>
</tr>
</tbody>
</table>

**a** RCT = randomized clinical trial, CCT = controlled clinical trial, RC = rehabilitation center.

**b** PT = physiotherapy.

**c** Range of CPM on the first day.

**d** TKP = total knee prosthesis.

### Table 4
Low-power randomized trials and controlled clinical trials

<table>
<thead>
<tr>
<th>Author</th>
<th>Years</th>
<th>Type</th>
<th>Number of cases</th>
<th>FU</th>
<th>Control groups</th>
<th>CPM</th>
<th>Duration of treatment</th>
<th>Prostheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colwell</td>
<td>1992</td>
<td>RCT</td>
<td>22 (5)</td>
<td>1 year</td>
<td>D3</td>
<td>24 h, 40°</td>
<td>?</td>
<td>TKP</td>
</tr>
<tr>
<td>Montgomery</td>
<td>1996</td>
<td>RCT</td>
<td>68 (8)</td>
<td>?</td>
<td>D1</td>
<td>3 h × 3, as tolerated</td>
<td>Until discharge</td>
<td>43 Uni 25 TKP</td>
</tr>
<tr>
<td>Nielsen</td>
<td>1988</td>
<td>RCT</td>
<td>54 (4)</td>
<td>14 days</td>
<td>D2</td>
<td>2 h × 2, 25°</td>
<td>12 days</td>
<td>TKP</td>
</tr>
<tr>
<td>Maloney</td>
<td>1990</td>
<td>CCT (two successive groups)</td>
<td>174 (28)</td>
<td>2 years</td>
<td>D4</td>
<td>24 h, 30°</td>
<td>Until discharge (7.9 days)</td>
<td>TKP</td>
</tr>
<tr>
<td>Ritter</td>
<td>1989</td>
<td>CCT (bilateral TKA)</td>
<td>50 patients (?)</td>
<td>1 year</td>
<td>D1</td>
<td>20–24 h, progressive?</td>
<td>5 days</td>
<td>TKP</td>
</tr>
<tr>
<td>Wasilewski</td>
<td>1990</td>
<td>CCT (three successive groups)</td>
<td>91 (?)</td>
<td>1 year</td>
<td>D4</td>
<td>24 h, 0–60°</td>
<td>Until 90°</td>
<td>TKP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author</th>
<th>Early flexion</th>
<th>Final flexion</th>
<th>Early extension lag</th>
<th>Final extension lag</th>
<th>Conclusions CPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colwell</td>
<td>45/48 NSD</td>
<td>107/108 NSD</td>
<td>6/12 NSD</td>
<td>3/3 NSD</td>
<td>Less pain, costs NSD</td>
</tr>
<tr>
<td>Montgomery</td>
<td>67/76 NSD</td>
<td>107/108 NSD</td>
<td>6/12 NSD</td>
<td>3/3 NSD</td>
<td>LOS and pain NSD, quicker flexion, less swelling</td>
</tr>
<tr>
<td>Nielsen</td>
<td>71/71 NSD</td>
<td>107/108 NSD</td>
<td>6/12 NSD</td>
<td>3/3 NSD</td>
<td>Pain NSD</td>
</tr>
<tr>
<td>Maloney</td>
<td>78/80 NSD</td>
<td>104/101 NSD</td>
<td>6/6 NSD</td>
<td>3/3 NSD</td>
<td>Shortens LOS, more cutaneous problems, less pulmonary embolism</td>
</tr>
<tr>
<td>Ritter</td>
<td>72/78 NSD</td>
<td>99/99 NSD</td>
<td>2.9/2.8 NSD</td>
<td>3/3 NSD</td>
<td>Initial extension lag, less swelling</td>
</tr>
<tr>
<td>Wasilewski</td>
<td>81/91 SD</td>
<td>109/109 NSD</td>
<td>10/10 NSD</td>
<td>10/10 NSD</td>
<td>Less pain, quicker flexion, better final score</td>
</tr>
</tbody>
</table>

NSD: nonsignificant difference; SD: significant difference P< 0.05; LOS: length of hospital stay.

**a** RCT = randomized clinical trial, CCT = controlled clinical trial.

**b** () = excluded from the final analysis, at various follow-ups.

**c** Start of the mobilization in the control group (in days).

**d** Range of CPM on the first day.

**e** TKP = total knee prosthesis, Uni = unicompartmental prosthesis.

**f** In degrees, control group/CPM.
3.4. Professional practice

CPM is used in France both by surgeons and PMR physicians but under conditions that may vary greatly according to the organization of care structures. The PMR physicians less often use CPM systematically (71%), more often reserving the therapy for patients “at risk of stiffness” (27%), as compared with orthopedic surgeons (80% and 15% use, respectively). These slight differences correspond to different timing: surgeons usually prescribe rehabilitation for the immediate postoperative period, and PMR physicians prescribe it later, usually in rehabilitation centers.

4. Discussion

O’Driscoll and Giori [18] explained the discrepancy in results among publications describing the clinical application of CPM rehabilitation after TKA by the fact that most protocols do not respect the principles revealed by experimental results. CPM can only be clinically and biologically efficient if it involves a huge range of motion, necessary to generate a pump effect and to have an influence on collagenous healing.

In our use of the SOFMER methodology to develop clinical practice guidelines on the use of CPM in rehabilitation after TKA, a review of the literature led us the same conclusions. The rare positive results of CPM were found in series in which CPM was set at high levels from the beginning of therapy, but even in these cases, long-term effectiveness was rarely demonstrated.

Most of the series contained methodological biases that complicated their results: variable inclusion criteria (various diagnoses frequently mixed), use of different types of prostheses, mix of types of arthroplasties (uni- or tricompartmental), with or without cement, with or without patellar resurfacing, variable use of tourniquets during surgery, lack of data concerning the management of pain, and little analysis of the correlation between functional results and positioning of the implants. Some of these factors could have a determining influence on patients recovering mobility after TKA, which is more important than the postoperative rehabilitation regimen itself.

5. Conclusion

An analysis of publications for this study of clinical practice guidelines for CPM used in rehabilitation after TKA, investigated by use of the SOFMER methodology, reveal mediocre methodological quality of studies, particularly for the older studies. Their analyses are impaired by the evolution of the comparator with time and the recent introduction of new mobilization protocols. However, at short-term follow-up, the use of “classical” CPM after TKA could have, according to several authors, a beneficial influence on the speed of recovery of motion, early flexion, postoperative pain, knee swelling and length of hospital stay after surgery. It could have a negative effect on early recovery of active and passive extension but no deleterious effect on wound healing and no influence on thromboembolism complications. CPM, in its currently most-often used method of application (progressive increase of flexion from extension), whatever its duration, has no positive effect over intermittent early mobilization, at short- and chiefly, long-term follow-up.

Some parameters probably play a more important role in the early recovery of motion than the modality of rehabilitation. The management of pain is one example: control of pain is the necessary condition for the application of an intensive early mobilization protocol, whatever its type. In this situation, advanced CPM can perhaps provide better results than classical progressive CPM. Nevertheless, except for rare studies (e.g. when the comparator is splint immobilization for several days), our review of the literature showed no long-term confirmation of the early benefit of CPM.

6. Clinical practice guidelines

There is no sufficient evidence to recommend for clinical practice substituting CPM with other rehabilitation techniques aimed at early mobilization after TKA, but the procedure could be an adjunctive option to accelerate short-term results.

The technique, however, remains largely integrated in the French rehabilitation practice after TKA, both in orthopedic surgery units and in PMR units.

Data on preoperative ranges of motion should be systematically collected to improve the postoperative management and follow-up.

There is a need for good methodological quality studies to evaluate the different modalities of CPM and the alternative techniques of intermittent mobilization, particularly the starting flexion.

References


