Clinical effectiveness of continuous passive motion (CPM) following femoroacetabular impingement surgery in adolescents

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Abstract

Purpose This study hypothesizes that the use of continuous passive motion (CPM) following open femoroacetabular impingement (FAI) surgery in the adolescent population improves clinical outcomes in terms of the modified Harris hip score (mHHS).

Methods Twenty-nine symptomatic adolescent FAI patients were postoperatively divided into one of three groups; no CPM, two days of inpatient CPM, and two weeks of CPM. mHHS was used preoperatively and postoperatively at six weeks, three months, six months, and nine months in all cases. Kruskal–Wallis (KW) analysis was performed to determine statistical differences in mHHS. mHHS was then re-evaluated using the Mann–Whitney test.

Results There were no statistically significant differences in hip scores between the three groups preoperatively ($p = 0.158$). There were statistically significant differences ($p < 0.001$) in mHHS between the three groups at all postoperative time periods. The group that received two weeks of CPM had the best outcome scores.

Conclusion The results of this study suggest that postoperative CPM use following open hip preservation surgery for symptomatic FAI in adolescents improves clinical outcomes. These benefits seem to be related to the duration of CPM.

Level of evidence Retrospective comparative study, Level III. Patients treated one way compared with patients treated another way at the same institution.

Keywords Continuous passive motion (CPM) · Adolescents · Hip · Femoroacetabular impingement

Introduction

Robert Salter's work on continuous passive motion (CPM) found that CPM leads to improvements in joint motion and function following injury or operative intervention in animal models [1–4]. The benefits of CPM during recovery from knee surgery in the adult population have been evaluated [5–9]. CPM following hip surgery in the adult population has been found to be beneficial [10–13]. However, the effectiveness of CPM use following hip preservation surgery in the adolescent population has not been thoroughly evaluated.

O'Driscoll presented four stages during the evolution of joint healing following trauma/surgery. These are: (1) bleeding, (2) edema, (3) granulation tissue, and (4) fibrosis [14]. During the bleeding stage there is hemarthrosis with capsular and synovial distension. This leads to secondary edema and inflammation, which limits joint motion and causes pain. The healing process continues with the formation of granulation tissue, which can often become a mechanical barrier to joint motion. The eventual transition of granulation tissue to fibrosis or scar tissue can lead to further restriction of joint motion.

Immediate/early postoperative use of CPM is postulated to interrupt this four-stage process by effectively eliminating or decreasing the early hemarthrosis [14–16]. This interrupts the subsequent cascade by decreasing synovitis

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and pain, eventually resulting in less granulation and minimal scar tissue [14].

The length of time CPM is used varies greatly. Laupattarakasem [17] indicated that three days of CPM usage is adequate, while other studies advise its use in some patients for up to 70 days [18]. Salter's original recommendations for CPM were that it should be used for a minimum of two weeks but no longer than four weeks, and in all cases should be used 24 h per day, stopping for bathroom breaks [19]. Salter emphasized that the first week was the most critical and that CPM should be introduced as early as possible following surgery [19].

Initial studies completed by Salter [1, 20–22] and O'Driscoll [15, 16] support the claim that CPM use improves clinical outcomes by preventing joint adhesions, stiffness, and the healing of articular tissues in animal models. However, other studies, including randomized controlled clinical trials, have not found a significant difference in outcomes between study patients that use CPM versus those that do not [6, 23, 24].

This study attempts to answer the following study question: does the use of CPM following open femoroacetabular impingement (FAI) surgery in the symptomatic adolescent population have a positive effect on clinical outcomes in terms of modified Harris hip score (mHHS)?

Methods

This study used a nonexperimental, retrospective design to compare three groups of patients that underwent open FAI surgery at our institution. The groups were determined based on their use of postoperative CPM. Duration of CPM was determined based on insurance coverage and ability to pay out of pocket for CPM rental if CPM rental was denied. The mHHS was determined by the attending physician using the method outlined by Byrd [25]. This modification of the Harris hip score is better adapted to younger patients, including young adults (although no specific hip scoring system has been proposed and validated for the high-functioning adolescent population). This mHHS included an assessment based on pain (44 points) and function (47 points). A multiplier of 1.1 provides a total possible score of 100. The elements of deformity (four points) and range of motion (five points) from the original Harris hip score were deleted by Byrd et al. in their modification. We chose to continue with that, as neither of these is a principal indication for surgery in adolescent FAI. Adolescent patients with idiopathic symptomatic FAI do not have specific deformity. Other than limitation of motion due to pain in flexion–adduction and internal rotation of the hip (the classic impingement position), they do not present with any limitation of motion.

Twenty-nine adolescent patients were divided into a control and two intervention groups. The control received no CPM and consisted of eight patients. The intervention groups were based on their duration of CPM use. One group used CPM for two days (2dayCPM) and the other group used CPM for two weeks (2weekCPM). The 2dayCPM group had six patients, and all six patients used CPM for two days. The 2weekCPM group had 15 patients. Of the 15 patients in the 2weekCPM group, one patient received CPM for ten days, one patient received CPM for 15 days, one patient received CPM for 20 days, and the remaining 12 patients received CPM for 14 days. The mean patient age was 15 years, 2 months (range = 11 years, 4 months to 18 years, 8 months). Sixty-two percent of the patients were male, while 38 % were female (Table 1).

Patient history, detailed physical examination, radiographs, and MR arthrogram were used to diagnose and assess the severity of involvement in FAI. Patients with underlying diseases of the hip joint, previous surgery, previous trauma, or fractures of the hip were excluded. All patients had hip pain of varying severity (mean duration of symptoms was 11 months (1 month to 10 years 3 months, with a mean pain scale of 7; range 4–9), and physical examination revealed a positive hip impingement test in all patients. An MR arthrogram was performed to help assess intra-articular involvement. mHHS was measured and recorded preoperatively and postoperatively at six weeks, three months, six months, and nine months in all cases. All complications were recorded.

Surgical method

All 29 adolescents underwent open surgical hip dislocation with trochanteric flip osteotomy for symptomatic FAI. All surgeries were carried out by the same surgeon (H.S.H). A 15–20 cm, straight-line skin incision was made with the patient in the lateral position. Along the anterior gluteus maximus and long axis of the femur, a fascia lata incision was performed to expose the greater trochanter. A “Z” osteotomy was performed, taking care to keep the gluteus medius, gluteus minimus, and vastus lateralis attached to the greater trochanteric fragment. A Z-shaped joint capsule incision was made with the fragment in anterior displacement and the hip in flexion, abduction, and external rotation. Anterosuperior dislocation of the femoral head was performed to assess the femoral head, acetabular rim, and labrum. Femoral head-neck osteochondroplasty, acetabular rim resection, and labral reattachment were performed as deemed necessary on a case-by-case basis. The hip was then reduced, and range and stability were tested and recorded. Closure of the articular capsule was performed, taking care not to apply excessive tension. The greater trochanteric fragment was fixed with two 3.5 fully threaded

Table 1 Population description

Pt. #	Age	Sex	Diagnosis	Pain scale preop	Duration of symptoms (in months)	Days of CPM
1	14 yrs 11 mos	M	FAI-Cam with labral tear	8	1.5	0
2	12 yrs 1 mos	M	Mixed FAI	9	7	0
3	13 yrs 2 mos	M	FAI-Cam with labral tear	9	2	14
4	15 yrs 6 mos	F	Mixed FAI	6	6	14
5	13 yrs 5 mos	F	FAI-Cam lesion	6	11	14
6	16 yrs 2mos	M	Mixed FAI	9	3	14
7	11 yrs 4 mos	F	FAI-Cam with labral tear	6	8	14
8	11 yrs 5 mos	M	FAI-Cam with labral tear	7	3	0
9	12 yrs 6 mos	F	Pincer FAI with labral tear	8	3	0
10	15 yrs 9 mos	M	FAI-Cam with labral tear	6	9	2
11	13 yrs 8 mos	M	FAI-Cam with labral tear	5	6	4
12	18 yrs 6 mos	M	Mixed FAI	7	3	2
13	15 yrs 0 mos	F	Pincer FAI with labral tear	6	4	14
14	15 yrs 3 mos	M	FAI-Cam with labral tear	7	8	2
15	17 yrs 5 mos	M	FAI-Cam with labral tear	8	6	0
16	15 yrs 5 mos	M	FAI-Cam with labral tear	8	4	2
17	18 yrs 8 mos	F	Mixed FAI with labral tear	6	10	14
18	12 yrs 11 mos	M	FAI-Cam with labral tear	8	1	0
19	13 yrs 1 mos	M	FAI-Cam with labral tear	8	4	2
20	15 yrs 1 mos	F	Pincer FAI with labral tear	6	9	14
21	18 yrs 10 mos	M	FAI-Cam with labral tear	8	3	0
22	15 yrs 4 mos	M	FAI-Cam with labral tear	9	3	2
23	16 yrs 4 mos	F	FAI mixed type	5	15	14
24	14 yrs 2 mos	F	FAI-Cam with labral tear	7	6	14
25	16 yrs 5 mos	F	FAI-Cam with labral tear	5	4	14
26	16 yrs 6 mos	M	Mixed FAI with labral tear	6	123	0
27	16 yrs 2 mos	M	FAI-CAM lesion	7	9	10
28	18 yrs 1 mos	F	FAI-Cam with labral tear	6	42	15
29	17 yrs 1 mos	M	Mixed FAI with labral tear	4	12	20

cortical screws. No regional or epidural blocks were used for any patient, and all patients were administered patient-controlled anesthesia.

CPM protocol

Our CPM protocol was instituted in the postanesthesia care unit (PACU) for all patients that could obtain the CPM machine. The CPM machine was set to vary hip flexion from 10° to 60°, but did not abduct or rotate the hip. Each day, an additional 10° of flexion was added to the range of motion until a maximum of 90° was reached. CPM was used for 12–16 h per day. A knee immobilizer and hip abduction pillow were used for two weeks when the patient was not in the CPM machine to prevent any flexion deformity from occurring at the knee and flexion-external rotation at the hip in the first two weeks as the tissues were healing. Weight bearing was restricted to toe-touch weight

bearing for six weeks on the operated side, followed by partial and then full weight-bearing over the next 2–3 weeks. PT for strength and ROM began at six weeks postsurgery, primarily because this was a group that had open surgical dislocation with trochanteric flip osteotomy, and we were waiting for the osteotomy to heal prior to active muscle strengthening and ROM exercises. Patients were assumed to have remained compliant with CPM use once discharged from the hospital (and this was confirmed via questioning during the postoperative visits), but no system was set up to monitor CPM usage at home, once discharged.

Statistical analysis

All analysis for this study was performed using SPSS (version 12.0.1, IBM, Armonk, NY, USA) and Excel (version 14.1.2, Microsoft, Redmond, WA, USA).

Descriptive analysis was performed to determine the demographic variation as well as the mean and median values for mHHS for each group.

Kruskal–Wallis (KW) analysis was performed to determine statistical differences in mHHS. These parameters were then re-evaluated using the Mann–Whitney test with the Bonferroni correction (p value acceptable at <0.067) to do a pairwise comparison of the control and 2dayCPM groups, the control and 2weekCPM groups, and the 2day-CPM and 2weekCPM groups. Both the KW test and the Mann–Whitney test are nonparametric tests that compare the mean ranks of each group.

Results

Effect of CPM on modified Harris hip score: all three groups

The data summarized below is expanded in Table 2.

Preop

We did not find a statistically significant difference in hip scores among the three groups preoperatively ($p = 0.158$).

Six weeks postop

We noted a statistically significant difference in hip scores among the three groups at six weeks postop ($p < 0.001$).

At six weeks postop we began to see that the two CPM groups were showing higher mHHSs.

Three months postop

We also found a statistically significant difference in hip scores among the three groups at three months postop ($p < 0.001$). At three months postop, both CPM groups were still doing better than the control, with the 2week-CPM group having a mean mHHS above 99.

Six months postop

The statistically significant difference in hip scores among the three groups continued at six months postop ($p < 0.001$). At six months postop, we noted that the control group had still not caught up to the two CPM groups in terms of mHHS.

Nine months postop

The statistically significant difference in hip scores remained among the three groups at nine months postop ($p < 0.001$). We continued to see an improvement in the hip scores among the three groups, but the control and 2dayCPM groups had not caught up to the 2weekCPM group. These results suggest that the use of CPM following open FAI surgery in the adolescent population improves clinical outcomes in terms of mHHS.

Table 2 Effect of CPM on modified Harris hip score—all three groups

Time period	Test	Control	2dayCPM	2weekCPM	Significance
Preop	KW rank	17.13	19.25	12.17	$p = 0.158$
	Mean	82.88 ± 6.36	84.33 ± 3.56	79.27 ± 6.27	
	Median	86	83.5	79	
6 weeks postop	KW rank	6.06	10.83	21.43	$p < 0.001$
	Mean	87.63 ± 4.47	91.17 ± 1.94	94.87 ± 2.00	
	Median	89	90.5	95	
3 months postop	KW rank	5.06	11.67	21.63	$p < 0.001$
	Mean	91.63 ± 2.45	96.83 ± 2.40	99.43 ± 1.33	
	Median	92	98	100	
6 months postop	KW rank	6.5	11.67	20.87	$p < 0.001$
	Mean	96.44 ± 1.94	97.90 ± 2.42	99.61 ± 0.85	
	Median	96.75	98.75	100	
9 months postop	KW rank	6.38	11	21.2	$p < 0.001$
	Mean	97.63 ± 1.19	98.67 ± 0.82	99.80 ± 0.56	
	Median	98	99	100	

Kruskal–Wallis (KW) results and descriptive analysis of mHHS among the three groups at each time period

Table 3 Effect of CPM on modified Harris hip score—pairwise comparison

	Preop	6 weeks	3 months	6 months	9 months
Control compared to 2dayCPM group					
Control	7.13	6.06	5.00	6.13	5.81
2dayCPM	8.00	9.42	10.83	9.33	9.75
Significance	$p = 0.755$	$p = 0.142$	$p = 0.008$	$p = 0.181$	$p = 0.081$
Control compared to 2weekCPM group					
Control	14.50	4.50	4.56	5.63	5.06
2weekCPM	10.67	16.00	15.97	15.40	15.70
Significance	$p = 0.213$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
2dayCPM compared to 2weekCPM group					
2dayCPM	14.75	4.92	4.33	5.33	4.75
2weekCPM	9.5	13.43	13.67	13.27	13.5
Significance	$p = 0.08$	$p = 0.002$	$p = 0.001$	$p = 0.018$	$p = 0.002$

Mann–Whitney test results comparing the mean rank of mHHS between all pairs of groups at each time period

Significant at $p = 0.0167$

Effect of CPM on modified Harris hip score: pairwise comparison

The data summarized below is expanded in Table 3.

Control compared to 2dayCPM

We found no statistically significant difference in hip scores between the control and 2dayCPM groups for any time period except the three-month postoperative time period ($p = 0.008$). At the three-month time period, the mHHS was higher for 2dayCPM than the control.

Control compared to 2weekCPM

We found a statistically significant difference in hip scores between the control and 2weekCPM groups for each time period except for the preoperative time period ($p = 0.213$). At the six-week ($p < 0.001$), three-month ($p < 0.001$), six-month ($p < 0.001$), and nine-month ($p < 0.001$) postoperative time periods, the mHHS for the 2weekCPM group was significantly higher than that for the control.

2dayCPM compared to 2weekCPM

We also found a statistically significant difference in hip scores between the 2dayCPM and 2weekCPM groups for each time period except for the preoperative time period ($p = 0.08$) and the six-month postoperative time period ($p = 0.018$). At the six-week ($p = 0.002$), three-month ($p = 0.001$), and nine-month ($p = 0.002$) time periods, the mHHS for the 2weekCPM group was significantly higher than that for the 2dayCPM group.

Discussion

Salter's basic animal research found that CPM leads to improvement in joint motion and function following injury or operative intervention. Since that time, CPM has gained clinical acceptance in many areas of orthopedic surgery. However, there are relatively few published studies that evaluate the effectiveness of postoperative CPM for the hip joint, particularly in an adolescent population following hip-preservation surgery for symptomatic FAI.

We became interested in the use of CPM following adolescent hip surgery when we began to perform hip-preservation procedures such as femoral head-neck osteochondroplasty and labral repair with or without acetabular surgery for symptomatic FAI [26–28]. Our clinical impression was that our patients benefited from the use of CPM; however, we soon found that many insurance plans did not cover the use of postoperative CPM. The families could afford to pay for the CPM machine rental from their personal funds in some cases, but this was not common. Accordingly, in the group of patients who could not afford that, we proceeded with hip preservation operations, even though postoperative CPM treatment would not be available.

The above circumstance explains our three treatment groups [i.e., no CPM, CPM usage when inpatient only (2dayCPM), and CPM usage for two weeks (2weekCPM)]. Although this method of treatment choice includes some economic disparity among the different groups, we felt that an analysis of data between the groups could still provide useful information.

In this study, we found that the use of postoperative CPM did seem to make a significant difference in clinical outcome. There was no statistically significant difference in

preoperative hip scores between the three groups in this study. At six weeks, three months, six months, and nine months, both of the CPM groups showed statistically significant increases in hip scores compared to the control group.

At the nine-month mark, all patients in the study had completed their physical therapy and were no longer receiving treatment for their hip condition. It is important to note that although there was a statistically significant difference in hip scores among the groups at nine months postop, this difference was probably not clinically significant.

There are several limitations to this study. The first is that this study was conducted based on a small sample of patients from a single surgeon at a single institution. To more clearly confirm the value of postoperative CPM, the method should be evaluated in a larger population of adolescent patients that undergo open FAI surgery. The second limitation is that this study was retrospective and therefore could not minimize the risk of sampling bias or confounding factors. This particular study could be subject to a higher than usual amount of selection bias because the study subjects self-selected into groups based on their ability to pay the additional out-of-pocket expenses associated with CPM rental. This may have had an impact on the results of the study.

The group that had the best clinical outcomes was the two-week group, which is also likely to be the group with the highest socioeconomic status (SES). SES is thought to impact healthcare outcomes. All three groups underwent physical therapy. Physical therapy has a direct impact on hip score because half of the hip score comes from function [25], which physical therapy works to improve. A major component of physical therapy is the “home exercise program,” which is a set of exercises that the therapist prescribes patients to do between visits. Higher-SES families may have more resources to put towards making sure that the child follows the home exercise program. It is reasonable to assume that additional focus on the home exercise program would make physical therapy more effective, therefore leading to an increase in hip score.

In addition to the confounding effects of SES, the way that patients were grouped may have also affected mHHS. mHHS is a patient-derived and subjective outcome measure. CPM was requested for all patients, and it is possible that the patients that did not get CPM perceived that they had a poorer outcome because CPM was not approved. The converse is also possible: patients that did get CPM may have perceived an additional benefit from the additional therapy.

Another important limitation related to mHHS is that although the mHHS is a widely accepted outcome measure [25, 29–31], it has not been validated in the adolescent population. It is worth noting that there are currently no

functional scoring systems that have been validated in the high-functioning/athletic adolescent population, and we therefore chose to use the one that would best fit our population (and has been published previously).

The results of this study suggest that immediate/early postoperative CPM use following open hip preservation surgery for symptomatic adolescent FAI patients improves clinical outcomes. Further research should be done with a larger randomized sample, preferably with an equal number of patients in each group. Despite these limitations, we continue to recommend the use of postoperative CPM when major hip preservation surgery is performed on adolescents and young adults.

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