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HIP

Learning curve of basic hip arthroscopy technique: CUSUM analysis

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Abstract

Purpose Hip arthroscopy is known to have a steep learning curve by measuring operation times or complication rates. However, these measures are arbitrary and are based on the number of procedures performed rather than clinical outcomes. Recently, Cumulative sum (CUSUM) analysis has been used to monitor the performance of a single surgeon by evaluating clinical outcomes. Our purpose was to determine the learning curve for basic hip arthroscopy technique using CUSUM technique.

Methods Forty consecutive patients who underwent hip arthroscopy were evaluated. Modified Harris Hip Score less than 80 at 6 months postoperatively was considered as treatment failure. Patients were chronologically stratified in two groups (the early group—cases 1–20, and the late group—cases 21–40), and age, gender, body mass index, and operation time were compared in both group. CUSUM analysis was then used to plot the learning curve.

Results Eight patients (20 %) experienced treatment failure. Although there was no significant difference of treatment failure rate between the early and late groups (30 vs. 10 %, n.s.), the operation time was shorter in the late group ($p = 0.014$). In addition, CUSUM analysis showed that failure rates diminished rapidly after 21 cases and reached an acceptable rate after 30 cases.

Conclusions Surgeon's experience is an important predictor of failure after hip arthroscopy, and CUSUM analysis revealed that a learning period is required to become proficient at this procedure, and that experience of approximately 20 cases is required to achieve satisfactory outcomes in terms of clinical outcomes. Surgeon can use the present learning curve for self-monitoring and continuous quality improvement in hip arthroscopy.

Level of evidence Retrospective case series, Level IV.

Keywords Hip · Arthroscopy · Learning curve · CUSUM analysis

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Introduction

Hip arthroscopy is useful for treating several pathologies, such as femoroacetabular impingement, acetabular labral tear, snapping hip, septic arthritis of the hip, and loose body [11, 12, 22]. But it is known to have a steep learning curve, because the surgical field is deeply located and the working space is confined [13, 19].

Evaluations of the learning curves of surgical procedures have been conventionally performed by measuring operation times, hospital stays or procedure-related complication rates [2, 8, 14]. However, these measures are not based on patient-oriented outcomes, but are based on surgeon-oriented variables.

Cumulative sum (CUSUM) analysis, which is widely used for quality control purpose in industry, is a robust and objective method of detecting trends with respect to an agreed standard over a consecutive series of measurements [24]. CUSUM analysis allows researchers to inspect and review the performance of procedures even without prior sample size calculation. However, CUSUM analysis has not been previously applied to evaluate hip arthroscopy, although it has been applied to other endoscopic procedures [6, 15].

The purpose of this study was to determine the learning curve for basic technique of hip arthroscopy, using CUSUM analysis.

Materials and methods

The design and protocol of this retrospective study were approved by our institutional review board, who waived informed consent. First 40 consecutive hip arthroscopies were performed by a single surgeon between 2009 and 2011. The surgeon had previously undergone a 1-year hip surgery fellowship at a tertiary teaching hospital. During fellowship, although he did not perform hip arthroscopy, he assisted 117 hip arthroscopies of his senior professor. During the study period, indication of hip arthroscopy was a patient who had an intraarticular pathology and intractable pain even after non-operative management for 6 months. Patients with arthritic change (Tonnis grade ≥II) radiographically were excluded [4].

During the study period, 22 partial labral resections, including three femoroplasties, were performed for a labral tear, and 18 debridements or loose body removal for eight septic arthritis, five loose bodies, three inflammatory arthritis, and two synovitis (Table 2).

All hip arthroscopies were performed using a standard basic hip arthroscopy technique under general anaesthesia. Briefly, with a patient placed supine on a fracture table with the affected limb in traction and the opposite limb abducted, gentle and sufficient traction was applied to the affected limb to distract the joint by 10–12 mm under an image intensifier. During traction, the hip was placed in approximately 5° of abduction and 20° of internal rotation such that the femoral neck was parallel to the ground. All hip arthroscopies were performed by one surgeon via anterior, anterolateral, and posterolateral portals using 30° and 70° angled 5.5-mm arthroscopes. For initial inspection of the hip joint, a 70° angled 5.5-mm arthroscope was inserted through the anterolateral portal, where was created 1 cm distal and 2 cm anterior to the tip of the greater trochanter. The posterolateral portal was placed 1 cm distal and 2 cm posterior to the tip of the greater trochanter. The anterior portal was placed at the intersection of a sagittal line drawn distally from the anterior superior iliac spine and a transverse line from the tip of the greater trochanter. A banana knife or electrocautery was used to enlarge each portal to facilitate manoeuvering of the instruments. After establishing the three portals, each portal kept the arthroscopic sheath for rapid interchanging of the arthroscope, various arthroscopic instruments, and an inflow cannula between portals. A limited capsulotomy was made between anterior and anterolateral portals to assess the labrum, ligamentum teres, cartilage, and capsule. Torn labrum was resected and debrided using a 4.2-mm motorized shaver and by electrocautery. After surgery, tolerable range of motion (ROM) of the hip and weight bearing were permitted postoperatively.

Routine objective follow-ups were performed at 6 weeks and 3 and 6 months after discharge. All patients were assessed using a modified Harris hip score (HHS). This modified score excluded items of deformity (four points) and range of motion (five points) from the original Harris hip score, because neither of these is a principle indication for hip arthroscopy. Therefore, modified Harris hip score included only the pain (44 points) and function (47 points) portion of the original Harris hip score and was adapted to evaluate outcomes of hip arthroscopy, as described elsewhere [1, 17, 20]. A multiplier of 1.1 provides a total possible score of 100.

Treatment failure was defined as a modified HHS less than 80 at 6 months after operation [5]. Operation time was also scrutinized.

CUSUM analysis

To perform CUSUM analysis, four parameters must be defined: acceptable failure rate ($p0$), unacceptable failure rate ($p1$), type I error rate (α), and type II error rate (β). On the basis of literature review [20, 23], we considered an acceptable failure rate of 20 %, and an unacceptable failure rate of 40 %. The probabilities of type I and type II (α and β) errors were set at 0.05 and 0.20, respectively. From these, two decision limits ($h0$ and $h1$) and the variable s were calculated using the formulas shown in Table 1 [24].

In the CUSUM curve, each case was plotted in sequence along the x-axis. When a failure occurs, the constant '$1-s$' was added to the CUSUM. When a success occurred (no failure), the variable 's' was subtracted from the cumulative score. Thus, a positive trend in the CUSUM line indicates failure, whereas a negative trend indicates success. If the line crosses the upper decision limit ($h1$) from below, this indicates that the actual failure rate is equal to the unacceptable failure rate with a type I error probability of 0.05. If the line crosses the lower decision limit ($h0$)

Table 1 Cumulative sum equations and the variables used to perform CUSUM analysis

Pre-setted variables	Definition	Value
$p0$	Acceptable failure rate	0.2
$p1$	Unacceptable failure rate	0.4
α	Probability of type I error	0.05
β	Probability of type II error	0.20
Calculated variables	Formulae	
P	$\ln(p1/p0)$	0.69
Q	$\ln[(1-p0)/(1-p1)]$	0.29
s	$Q/(P+Q)$	0.29
a	$\ln[(1-\beta)/\alpha]$	2.77
b	$\ln[(1-\alpha)/\beta]$	1.56
$h0$	$-b/(P+Q)$	−1.59
$h1$	$a/(P+Q)$	2.83

from above, this indicates that the actual failure rate does not differ from the acceptable failure rate with a type II error probability of 0.20. When the line is between $h1$ and $h0$, no statistical inference can be made.

Statistical analyses

Data are reported as means (standard deviations). Patients were allocated to an early group (cases 1–20) or late group (cases 21–40) to determine whether level of experience affected failure rate. We examined differences between the two groups using Fisher's exact test for categorical variables and the Mann–Whitney *U* test for continuous variables. A p value <0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 16.0 (SPSS, Chicago, IL, USA).

Results

Forty hip arthroscopies were performed by single surgeon during the study period. The first 20 hip arthroscopies were performed for 12 months, and the last 20 for 10 months. Thirty-eight of the study subjects visited our outpatient clinic for follow-up evaluation at 6 months after operation, and the other two patients were contacted and asked to complete the questionnaire by telephone. Thus, a modified HHS was obtained at 6 months for all patients. Treatment failure occurred in eight patients (20 %). Although failure rates in the early and late groups were not significantly different (6/20, 30 % vs. 2/20, 10 %, respectively, n.s.), mean operation time of the late group was significant shorter than that of the early group ($p = 0.012$) (Table 2). In early group, two patients experienced transient perineal paraesthesia, and one patient had numbness at lateral aspect of thigh due to lateral femoral cutaneous nerve injury, while one patient had a transient perineal paraesthesia in late group.

The CUSUM learning curve is shown in Fig. 1. Point A (case 21) on the learning curve corresponds to the main inflection point at which the failure rate begins to improve consistently. At point B (case 30), the line crosses the

Table 2 Patients characteristics

	Early cases ($n = 20$)	Late cases ($n = 20$)	p value
Age (years)	40.9 ± 17.1	42.0 ± 15.3	n.s.
Gender (men/female)	12:8	8:12	n.s.
BMI (kg/m^2)	23.0 ± 2.7	23.4 ± 2.9	
Diagnosis			n.s.
Labral tear	6	15	
Septic arthritis	5	2	
Loose bodies	4	2	
Inflammatory arthritis	3	0	
Synovitis	2	1	
MHHS			
Preoperative	46.1 ± 22.4	49.1 ± 18.6	
At 6 months	81.5 ± 8.5	85.7 ± 9.4	n.s.
Treatment failure	6	2	n.s.
Operation time (min)	135.0 ± 68.4	90.8 ± 35.1	0.012

BMI body mass index, *MHHS* modified Harris Hip Score; *NS* no significant difference

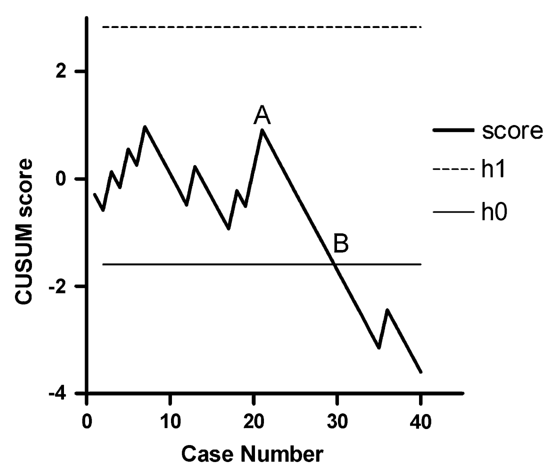

Fig. 1 Cumulative sum chart for hip basic hip arthroscopy technique. Point A (case 21) represents the inflection point where the failure rate begins to improve. When the line crosses the lower decision limit ($h0$) at point B (case 30), the failure rate is not significantly different that the acceptable recurrence rate. At no point does the line cross the upper decision limit ($h1$)

lower decision limit and the failure rate is equal to the defined acceptable failure rate (20 %) with type II error probability of 0.20. The failure rate did not reach the unacceptable threshold at any time.

Discussion

The present study showed that a learning curve for basic technique hip arthroscopy, an experience of at least 20 cases, is required to achieve a satisfactory outcome.

Previous studies on learning curve of hip arthroscopy have demonstrated that operation times decrease with experience [8, 21]. Although operation time is objective, it is not a measure of real patients' clinical outcome. To the best of our knowledge, this study is the first to demonstrate that poor clinical outcome after hip arthroscopy reduce with experience. Based on the results obtained by a single surgeon, we estimate a learning curve of approximately 20 cases, in terms of patient-reported outcome.

Cumulative sum analysis is a useful tool that allows researchers to monitor any type of surgical performance using a binary outcome measure. Furthermore, the graphic displays obtained can be easily understood. An upward trend indicates unacceptable performance, and when this occurs, a careful review is required with the aim of modifying the procedure used. In addition, CUSUM analysis could be used to provide feedback to trainees engaged in technical demanding procedures like hip arthroscopy [11, 13].

Several limitations of this study should be born in mind. First, a learning curve of a single surgeon was presented for a relatively small sample size. Only having a single surgeon, the results could be biased if the surgeon was extremely talented or, on the other hand, not very talented. However, CUSUM analysis provides a sensitive means of addressing unknown and increasing sample sizes. Second, only basic techniques such as debridement, lavage, and removal of loose bodies were included in this study. Difficult procedures such as labral repair were not performed during the study period. The learning curve of labral repair or femoroplasties is likely to be extended. Third, to defined a failure of procedure, we used modified HHS that has ceiling effect with difficulty separating individuals with a high level of function [9]. To overcome this limitation, a cut-off value of 80 was used. This should be considered before generalization. Fourth, other factors, such as age [17] and chondral lesion [10, 16] might have influenced the clinical outcome. Although the mean age of our subjects (40.9 and 42.0 years) was higher than those of other studies on adolescent [3, 7, 18], patients with arthritic change (Tonnis grade ≥II) were excluded. In addition, surgeon's experience on arthroscopy of other joints and the volume and frequency of the procedure might also have influenced the performance.

Arthroscopists can use the present learning curve for self-monitoring and continuous quality improvement in hip arthroscopy.

Conclusions

This study has demonstrated that a substantial learning curve period must be overcome before proficiency is achieved at hip arthroscopy, and that the CUSUM analysis can be used for self-monitoring and continuous quality improvement in terms of basic hip arthroscopy.

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