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ELBOW

Arthroscopic treatment for limitation of motion of the elbow: the learning curve

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Abstracts
Purpose The aim of this study was to demonstrate our learning curve in arthroscopic treatment for limitation of motion of the elbow.
Methods To verify the surrogates for learning curve, operative time in 120 consecutive elbows were plotted by case number and the learning curve was illustrated by the best-fit curve. The study population was divided into eight consecutive blocks (15 patients per block) by observing a notable change in the learning from the curve. Mean operative time and mean improvement in motion and clinical score in each block were compared.
Results Mean operative time decreased significantly from the first block to the second block (133–98). No further significant change was noted thereafter. Contrarily, no significant increase in motion improvement or clinical score improvement was identified but a significant decrease was found between the fourth and fifth block (47–36 and 30–24, respectively). Operative time was negatively correlated with preoperative range of motion ($P = 0.003$). Clinical score improvement was also negatively correlated with preoperative range of motion ($P < 0.001$). Motion improvement was more strongly correlated with preoperative range of motion ($P < 0.001$).
Conclusions This study demonstrated a learning curve in which a significant decrease in operative time was shown after an initial 15 patients. Motion and clinical score improvement were not satisfactory surrogate for learning curve and found to be closely related to preoperative range of motion. Qualification of the learning curve for arthroscopic treatment for limitation of motion of the elbow provides a guide for surgeons assuming the expected time line to become proficient in this technique.

Keywords Learning curve · Limitation of motion · Elbow · Arthroscopy

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Introduction

Limitation of motion (LOM) of the elbow is common and open release has been successfully employed to treat fixed elbow contractures [5, 16, 19]. Recently, there have been advances in elbow arthroscopy to treat LOM of the elbow [2, 3, 9, 11, 13, 18, 21, 22, 24, 26–28]. Arthroscopic release has many advantages including limited soft tissue dissection, improved joint visualization, and accelerated rehabilitation, and is a reasonable alternative to open release [4, 25, 29].

However, the close proximity of neurovascular structures and restricted working space makes arthroscopic release technically demanding [7, 15, 17]. In addition, extensive scar and noncompliant tissue further complicates arthroscopic treatment [7]. We introduced the transarticular approach to facilitate the initial entry of the arthroscope in the stiff elbow [10]. Finally, because this procedure is performed less frequently than knee or shoulder arthroscopy, it is difficult to become proficient. Morrey [20] emphasized that the learning curve has limited the application of elbow arthroscopy. Despite the recognized need for establishing the learning curve in this procedure, little objective data are currently available, although we previously reported on the clinical outcomes of using the arthroscopic procedure in the early and middle period of our experience [11, 12].

The purpose of this study was to describe our consecutive experience in arthroscopic treatment for LOM of the elbow to demonstrate our learning curve. It was hypothesized that as learning progresses, operative time (OPTIME) decreases or the improvement in range of motion (ROM) increases or the improvement in clinical score increases.

Materials and methods

After institutional review board approval (4-2007-0502, Yonsei University College of Medicine), the records of the patients who underwent arthroscopic treatment by a single surgeon for LOM of the elbow between 1990 and 2006 at a single institution were reviewed retrospectively. Indications for surgery were posttraumatic or degenerative LOM of the elbow in patients who failed nonsurgical treatment for at least 3 months and interference with daily activities. Both flexion and extension contracture were indicated for surgery with preoperative ROM ranging from 10 to 110. Patients with distorted anatomy were not indicated for the arthroscopic procedure. Twenty-four patients with infectious arthritis or inflammatory disease, such as rheumatoid arthritis, pigmented villonodular synovitis, and gouty arthritis, were excluded. Three patients combined with simultaneous hardware removal and 4 patients with mini-open procedures in the posterior compartment were excluded from the series. Seventeen patients with a follow-up of less than 2 years were also excluded. In all, 120 consecutive patients were available for evaluation. There were 99 male and 21 female patients with a mean age of 35 (±13) years. The study population was not involved with worker's compensation issue. Radiographic evaluation using plain radiograph with or without 3-dimensional computed tomography was used to assess joint congruency, status of articular cartilage, osteophytes, and loose bodies. OPTIME was defined from the operation record as the number of minutes from when arthroscopic examination was initiated until the portal was closed. The final evaluation was done at the fixed follow-up period of 2 years to assess the outcome at the same time interval from the surgery. Improvement in motion (IMPROVE ROM) was defined as the difference between the ROM at 2 years after surgery and the preoperative ROM (preROM). Clinical score was assessed using the Mayo Clinic Elbow Performance Index (MEPI), and improvement in MEPI (IMPROVE MEPI) was defined as the difference between the MEPI at 2 years after surgery and the preoperative MEPI. To investigate the factors affecting the study variables, information was collected on the sequential case number, patient sex, age, duration from the onset of symptoms to the arthroscopic treatment, the etiology of LOM (traumatic or degenerative), preROM, preoperative MEPI, the number of loose bodies, and whether or not the anterior capsular release was performed. All arthroscopic findings and procedures were recorded in the elbow arthroscopy protocol and collected prospectively. Patients were followed up postoperatively at 1 or 2 weeks, 3 months, 6 months, 1 year, and yearly thereafter. The ROM of the elbow was measured with standard goniometry [1].

Surgical technique

Patients were placed in a prone position under general anesthesia. Reaching the maximum tourniquet time (120 min), the tourniquet was deflated and the remaining procedures were progressed without it. When there was a need for re-inflation of the tourniquet, we waited at least 20 min.

Arthroscopic procedures were performed with a small-joint arthroscope (2.7 mm diameter, 30° angulation). The anterolateral portal was established for initial entry of the arthroscope after joint distension. After case number 90, the initial entry of arthroscope was modified by the transarticular approach. The entry point for the transarticular approach is at the intersection of a horizontal line drawn from the radiocapitellar joint to the olecranon, with a sagittal line drawn just lateral to the olecranon [10]. By inspecting the anterior chamber with the arthroscope through the transarticular approach, the anteromedial portal site can be identified by palpation and confirmed by inserting a needle into the joint (Fig. 1). The posterolateral portal was used as the entry portal for inspection of the posterior compartment of the joint. An additional straight

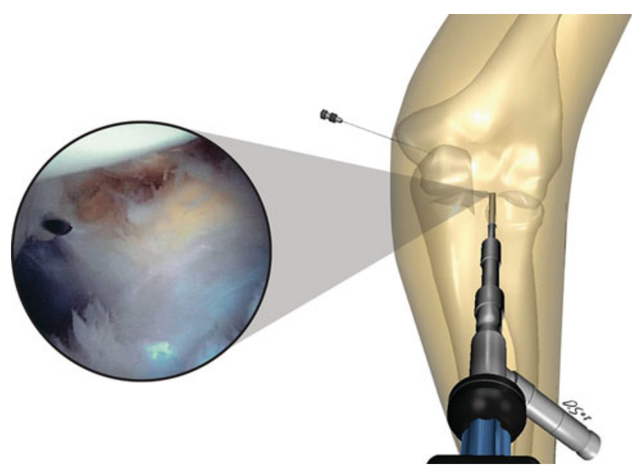

Fig. 1 The arthroscope is inserted through the transarticular approach, and the anterior chamber is inspected. The anteromedial portal site can be identified by palpation and confirmed by inserting a needle into the joint

posterior portal (2 cm medial to the posterolateral portal) through the triceps tendon was used for instrument access. The surgical procedures depended on the intra-articular findings. In the anterior chamber, extensive scarring and hypertrophic synovium was debrided using a full radius resector. Loose bodies were removed, and the bony impingement by osteophytes of the coronoid process or distal humerus was relieved using an osteotome or motorized burr. A contracted anterior capsule was divided at the proximal one-third level of the capsule from the medial to lateral side until the posterior fibers of the brachialis muscles were identified proximally.

In the posterior compartment, scar tissue around the olecranon fossa and posterior capsule was removed through the posterior portal. The bony impingement by osteophytes of the olecranon tip or the posterior olecranon fossa was relieved using a motorized burr. Active and gentle passive ROM exercise was begun as soon as pain and swelling had subsided after surgery. In patients with a marked LOM before surgery, continuous passive motion exercise was used during postoperative physiotherapy for a week.

Statistical analysis

The SPSS version 12 (SPSS, Chicago, IL) was used to analyze the data. P value less than 0.05 was considered significant. The paired 2-sample t test was used to detect changes in the ROM and the MEPI before and 2 years after surgery. Using Excel (Microsoft, Redmond, WA), the OPTIME was plotted by case number and the relationship between the variables was illustrated by the best-fit curve. The study group was divided into eight consecutive blocks (15 patients per block) by observing a notable change in the learning from the curve. To further validate the 15-patient demarcation, mean OPTIME, IMPROVE ROM, and IMPROVE MEPI in each block were compared using 2-sample t tests. Pearson's correlation analysis or 2-sample t tests were performed to identify any significant factors that may affect OPTIME or IMPROVE ROM or IMPROVE MEPI.

Results

Clinical data are listed in Table 1. Mean ROM significantly improved from 77° (±24) to 117° (±13) ($P < 0.001$). Mean MEPI significantly improved from 60(±10) to 87(±5) ($P < 0.001$). Mean OPTIME was 104 min (±38).

OPTIME by case number is shown in Fig. 2. A notable change in the learning was suggested after case 15. Mean OPTIME decreased significantly from the first block to the second block and there were no significant changes thereafter (Fig. 3). Contrarily, as for the mean IMPROVE ROM and IMPROVE MEPI, no significant increase was identified but a significant decrease was found between the fourth and fifth block. Accordingly, OPTIME was determined to allow the analysis of learning effect. Correlation analyses revealed that OPTIME ($r = -0.269$, $P = 0.003$),

Table 1 Clinical data

	Traumatic ($n = 62$)	Degenerative ($n = 58$)	Overall ($N = 120$)
Age (years)	30 (13)	40 (12)*	35 (13)
Gender (M:F)	48:14	51:7	99:21
Duration of symptoms (months)	39 (74)	36 (46)	37 (62)
Loose bodies in a joint	0.8 (1.1)	2.8 (4.7)*	1.8 (3.4)
Anterior capsular release			
Performed:Not performed	37:25	22:36†	59:61
Preoperative			
Mean flexion	102 (17)	107 (14)	104 (16)
Mean extension	31 (15)	23 (10)*	27 (14)
Mean ROM	71 (25)	84 (20)*	77 (24)
Mean MEPI	57 (11)	63 (9)*	60 (10)
2 years after surgery			
Mean flexion	126 (10)	128 (9)	127 (10)
Mean extension	10 (7)	10 (7)	10 (7)
Mean ROM	116 (13)	118 (12)	117 (13)
Mean MEPI	87 (4)	88 (4)	87 (5)
Mean IMPROVE ROM	45 (21)	34 (13)*	40 (18)
Mean IMPROVE MEPI	30 (10)	25* (8)	27 (9)
Mean OPTIME	101 (38)	107 (39)	104 (38)

Standard deviations are given in the parenthesis

Significantly different when compared with traumatic etiology * by 2 sample t test, †by chi square test

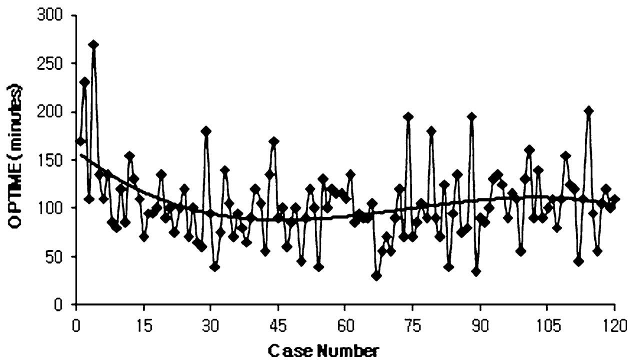

Fig. 2 OPTIME by case number

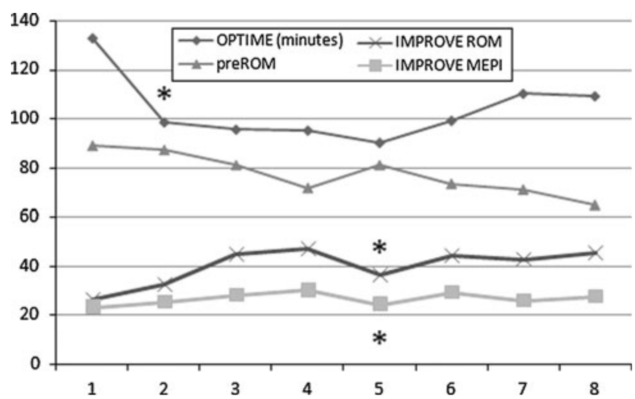

Fig. 3 Mean values for OPTIME, IMPROVE ROM, IMPROVE MEPI, and preROM with consecutive blocks of 15 patients. *Significantly different from previous block

IMPROVE MEPI ($r = -0.594$, $P < 0.001$), and IMPROVE ROM ($r = -0.843$, $P < 0.001$) were negatively correlated with preROM. The etiology of LOM, anterior capsular release, and patient sex had significant effects on IMPROVE ROM and IMPROVE MEPI but not on OPTIME. We experienced two transient median nerve palsies, two ulnar nerve irritations, and one reflex sympathetic dystrophy, which recovered with conservative treatment. Those were not eligible for evaluating the learning curve because of the small sample size and its sporadic occurrence.

Discussion

The most important finding of the present study was that operative time in arthroscopic treatment for LOM of the elbow significantly decreased after an initial 15 patients, whereas improvement in motion or clinical score was not related to the surgeon's experience but closely related to preoperative range of motion. The determination of minimal requirements with respect to procedural number appears to be somewhat arbitrary in various studies [8, 14]. There is also considerable disagreement among surgeons as to the minimum number of repetitions required for most common procedures [23]. Guttsman et al. [8] proposed that 10 patients were sufficient to become proficient in performing arthroscopic rotator cuff repair while we suggested a minimum of 15 patients in this procedure. Fifteen-patient demarcation was preferred because a notable change was suggested by inspection in OPTIME curve after 15 patients, and the mean OPTIME did not significantly differ between the block 1 and 2 with 10-patient demarcation.

In our previous reports in 1995 and 2000, IMPROVE ROM measured 24 and 42°, respectively. We speculated that the increase in IMPROVE ROM was a result of gaining more experience, which led to the hypothesis of the current study. However, IMPROVE ROM and IMPROVE MEPI had much stronger correlation with preROM than OPTIME did. Those are thought to closely depend on preROM rather than surgeon's experience as illustrated in Fig. 3. This suggests that one cannot determine the proficiency of arthroscopic treatment of LOM of the elbow entirely based on how much arc of motion is gained or how much the patient's symptom improved. Evidences in support of the fact are found in various reports (Table 2) [2, 3, 11–13, 18, 21, 24, 26–28]. A strong negative correlation between preROM and IMPROVE ROM is uniformly found across the studies regardless of some etiological and procedural differences ($r = -0.963$, $P < 0.001$) (Fig. 4).

Generally, a learning curve has an expert level where the surgeon's performance stabilizes. However, an increasing trend in OPTIME in latter period (Figs. 2, 3) shows the surgical time gets longer after it reaches an expert level. These findings should be interpreted in conjunction with the decreasing trend in preROM. This phenomenon results from the influence of "case mix" on the learning curve [6]. In case mix, the patients a surgeon treats tend to become

Table 2 PreROM and IMPROVE in published studies

Authors	Year of study	preROM	IMPROVE
Byrd [3]	1994	83°	44°
Timmerman and Andrews [28]	1994	94°	29°
Kim et al. [11]	1995	92°	24°
Phillips and Strasburger [24]	1998	87°	41°
Savoie et al. [27]	1999	50°	81°
Kim and Shin [12]	2000	79°	42°
Menth-Chiari et al. [18]	2001	88°	39°
Ball et al. [2]	2002	82°	50°
Lapner et al. [13]	2005	108°	18°
Salini et al. [26]	2006	50°	74°
Nguyen et al. [21]	2006	84°	38°
Current study	2009	77°	40°

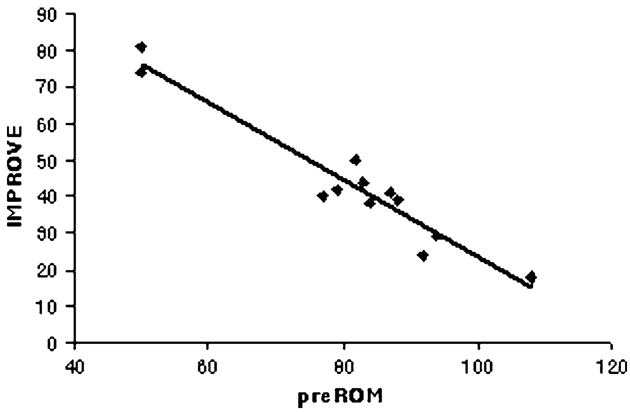

Fig. 4 A strong negative correlation between preROM and IMPROVE ROM in published studies

more difficult as he becomes more experienced and the learning curve should be interpreted in consideration of its effect. It can be assumed that the degree of LOM (preROM) of the elbow reflects the difficulty of cases attempted, given that the volume of a normal elbow joint is 14 ± 2 ml, whereas that of a stiff elbow is 6 ± 3 ml [7]. Furthermore, the capsular compliance of the stiff elbow is only 15% of normal compliance, so adequate capsular distension of the stiff elbow might not be possible [7]. Arthroscopic procedures can be complicated by decreased volume and compliance of the elbow, and this is consistent with the inverse relationship of the OPTIME and preROM in the result. Therefore, the case mix in this study represents that severer contractures are included in the latter period of the series. It can be proved by the significant difference in mean preROM between the first and last three blocks (86° vs. 72°).

This study has some limitations. First, the transarticular approach was introduced at the seventh block. This approach can allow the safe creation of the initial portal in those severely contractured elbows; however, we do not think that it is a fundamental modification of the procedure because the subsequent procedures followed the usual manners. Furthermore, no changes in outcome measures occurred after using the approach. Second, "case mix" could have been be avoided by excluding the patients with severe contracture of the elbow; however, the consecutiveness of the series will be considerably biased and the measure of learning would be seriously impaired. Third, the arthroscopic procedures were not identical and varied according to the intra-operative findings. Various statistical analyses were employed to evaluate the effect of the procedural differences and we attempted to incorporate them into investigating the learning effect. Fourth, it is known that not only is the number of procedures important to learning but also the frequency with which they are performed [14]. The current series ranges over 17 years, and the span between procedures was sometimes longer than a month. It could be argued that an accumulation of experience in this situation is diminished. However, this series was consecutive and performed by a single surgeon. Fifth, the learning curve in this study reflects one surgeon's experience, and the lessons learned from the non-LOM cases could have an impact on the learning curve. Therefore, it can be one of the comparable guidelines for other surgeons to assume the expected timeline, but cannot be applied uniformly. Despite these limitations, we believe the present study adds a detail on the learning curve in this procedure that has not been addressed in the literature.

Conclusions

This study demonstrated a learning curve in which a significant decrease in operative time was shown after an initial 15 patients. Improvement in motion or clinical score was not a satisfactory surrogate for learning curve and found to be closely related to preoperative range of motion.

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