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Prevalence, Timing, Locational Distribution, and Risk Factors for Heterotopic Ossification After Elbow Arthroscopy

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Background: Arthroscopic techniques aim to reduce complications and accelerate recovery of the elbow after treatments for posttraumatic stiffness, arthritis diseases, lateral epicondylitis, ligament reconstruction, and elbow trauma. However, data on the true prevalence and characteristics of heterotopic ossification (HO) formation after elbow arthroscopy are limited.

Purpose: To investigate the prevalence, timing, locational distribution, and risk factors of HO after elbow arthroscopy.

Study Design: Cohort study; Level of evidence, 4.

Methods: Data on 205 patients undergoing elbow arthroscopy by a single senior elbow surgeon at a single institution between May 2011 and January 2022 were retrospectively reviewed. The patients were evaluated at 2 weeks, 8 weeks, 6 months, and then annually after surgery or more frequently if HO developed, with a minimum of 1 year of postoperative follow-up. Postoperative anteroposterior and lateral elbow radiographs were taken at 2 weeks to rule out fracture and at 8 weeks to identify HO. The clinical outcomes were evaluated based on the pain visual analog scale; the shortened version of the Disabilities of the Arm, Shoulder and Hand score; Mayo Elbow Performance Score; and the Single Assessment Numeric Evaluation scores before and after surgery. Bivariate logistic regression analyses were used to determine factors affecting HO prevalence.

Results: Thirteen (12 male, 1 female) of 205 (6.3%) patients developed HO, with 10 (76.9%) with HO that formed on the medial compartment of the elbow. Ten (76.9%) patients were diagnosed at 8 weeks after arthroscopic surgery, 1 (7.7%) at 6 months after surgery, and 2 (15.4%) at 12 months after surgery. HO was not found at 2 weeks after surgery in any patient. The mean follow-up time was 3.5 years (range, 1.0-11.8 years). Eleven asymptomatic patients were treated nonoperatively, and 2 symptomatic patients underwent HO excision arthroscopically or had a combination of open surgery and arthroscopy. Age was a protective factor for HO formation (odds ratio [OR], 0.953; 95% CI, 0.910-0.999; $P = .047$). The risk factors for HO formation were tourniquet time (OR, 1.042; 95% CI, 1.019-1.065; $P < .001$) and surgical time (OR, 1.026; 95% CI, 1.011-1.041; $P < .001$).

Conclusion: Among 205 patients who underwent elbow arthroscopy, HO was a minor complication of elbow arthroscopy, with a prevalence rate of 6.3%, and was usually located on the medial compartment of the elbow. Although the presence of HO may not affect the clinical outcomes in most patients, it should be carefully monitored for a minimum of 8 weeks postoperatively. Younger age, longer tourniquet time, and longer surgical time contributed to HO formation after elbow arthroscopy.

Keywords: elbow; arthroscopy; heterotopic ossification; complication

Heterotopic ossification (HO) is the ossification of soft tissue that leads to the formation of histologically normal lamellar bone where bone normally does not exist.[54] The formation of HO is a well-described manifestation after trauma, surgical intervention, neurologic insults, diffuse idiopathic skeletal hyperostosis, and genetic conditions with abnormalities in bone morphogenetic protein metabolism.[4,43]

Arthroscopy has been applied to different kinds of elbow diseases, including posttraumatic stiffness,[8,42] stiff elbow,[50] rheumatoid arthritis,[41] primary osteoarthritis,[23,26,27] lateral epicondylitis,[6,24,35] lateral collateral ligament reconstruction,[5,25] and elbow trauma.[11,33] This technique is minimally invasive but relatively complex, with various complications compared with open surgery.[5,6,32]

HO is a known complication after open elbow surgery, including total elbow arthroplasty and treatment of elbow trauma, with prevalence rates of 10%[30] and 40%,[39] respectively. HO around the elbow impairs range of motion, and patients experience a loss of ability to work and difficulty with activities of daily living.[48]

HO formation after elbow arthroscopy is uncommon and rarely discussed as a complication.[12] Little is known about this complication because most of the reported investigations

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are case reports and involve patients who are asymptomatic.[10,15,46] Intravia et al[19] reported a prevalence of 2.5% for HO development in their analysis of 528 patients who underwent elbow arthroscopy. However, the duration of follow-up—in some cases as short as 2 days—may have resulted in an underestimation of the true prevalence, with later presentations going undetected.[19] In addition, the reported prevalence of HO was 25% after arthroscopic release for elbow arthritis and stiffness, which was postulated to be associated with the improper use of a radiofrequency device.[52]

Until now, there has been a lack of studies investigating the real prevalence of HO formation arising from different disease entities after elbow arthroscopy with enough follow-up time. Therefore, this study investigated the prevalence, timing, locational distribution, and risk factors of HO after elbow arthroscopy.

METHODS

After obtaining institutional review board approval (No. 2022-1226), we retrospectively reviewed 239 consecutive patients who underwent elbow arthroscopy between May 2011 and January 2022 performed by a single senior fellowship-trained elbow surgeon (I.-H.J.) at a single center. The requirement for written informed consent was waived due to the retrospective nature of the study. The inclusion criteria were (1) patients who underwent elbow arthroscopy with complete medical records, including preoperative, postoperative, and follow-up radiographs and operation records and (2) patients with clinical preoperative data and follow-up outcomes. The exclusion criteria were (1) <1 year of follow-up or (2) refused routine postoperative radiographs. A total of 34 patients were excluded: 30 with insufficient follow-up (<1 year) and 4 without postoperative imaging. Finally, this study recruited 205 patients. The leading indications for surgery were primary osteoarthritis (n = 85), lateral epicondylitis (n = 43), posttraumatic stiffness (n = 29), and elbow fracture-dislocation (n = 22). Other indications included posterolateral rotatory instability and osteoarthritis secondary to rheumatoid arthritis (n = 13 patients each). Posttraumatic elbow stiffness is defined as a reduction of functional motion arc of 30° to 130° of elbow flexion and 50° of pronation and supination (a total arc of 100°).[31]

General Surgical Technique

The patients underwent surgery in the lateral decubitus position under general anesthesia, with the tourniquet inflated to 250 mm Hg. The affected elbows were positioned at the arm holder, which allowed full assessment for postoperative flexion and extension. An arthroscopic shaver (4.5 mm Dyonic Incisor plus; Smith & Nephew) and a radiofrequency ablation system (Super Turbovac 90 RF Wand; ArthroCare) were used to clear soft tissue to allow visualization. Arthroscopy was performed using a 4-mm 30° arthroscope (IM4000, IM4120; ConMed Linvatec).

Postoperative Evaluation

The patients were evaluated at 2 weeks, 8 weeks, 6 months, and then annually after surgery or more frequently if HO developed. Postoperative anteroposterior and lateral elbow radiographs were routinely taken at 2 weeks to rule out fracture and at 8 weeks to identify HO.

HO was graded as per the Hasting & Graham (H&G) classification.[38] The indication for surgery, procedure performed, duration of surgery, and radiographic follow-up time were reviewed. Arthroscopic excision of HO was performed if a patient did not respond to nonoperative treatment, such as rehabilitation, physical therapy, and pain control using nonsteroidal drugs, for 6 months. The clinical outcomes were assessed using the pain visual analog scale (pVAS),[35] while the functional outcomes were evaluated using the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) score; the Mayo Elbow Performance Score (MEPS)[26,45]; and the Single Assessment Numeric Evaluation (SANE) before and after surgery.[36] The primary outcome of this study was the radiographic prevalence of HO formation, and the secondary outcomes were the time, the location of HO occurrence, and the effect of HO on clinical outcomes after elbow arthroscopy. Two fellowship-trained elbow orthopaedic surgeons (H.B. and H.A.) evaluated all radiographs to identify patients who developed HO and the HO location and severity through consensus.

Postoperative Protocol

Rehabilitation was required for all patients on postoperative day 1. Immediate motion was encouraged under the guidance of a physician. Patients with fracture-dislocations started active range of motion exercises after immobilization in a long-arm splint for 1 week. The patients increased their range of motion using the contralateral hand based on a protocol for active-assisted motion. Nighttime splinting was applied for the first 3 to 4 weeks for protection. Prophylactic medication of 200 mg celecoxib was prescribed for all patients once daily for 3 weeks after elbow arthroscopy.

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TABLE 1
Baseline Characteristics of Patients Undergoing Elbow Arthroscopy[a]

Characteristic	Total	HO	No HO	*P* Value
No.	205	13	192	
Sex, No.				.035
Male	132	12	120	
Female	73	1	72	
Age, y	51.1 ± 11.9	45.0 ± 15.9	51.6 ± 11.5	.169
Tourniquet time, min	72.4 ± 31.4	107.5 ± 19.8	70.0 ± 30.6	<.001
Surgical time, min	112.5 ± 39.8	153.0 ± 33.1	109.7 ± 38.7	<.001

[a]Data are presented as mean ± SD unless otherwise indicated. HO, heterotopic ossification; min, minutes.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 24.0 (SPSS, Inc). According to the results of the Shapiro-Wilk test for data normality distribution, an unpaired *t* test or a Mann-Whitney *U* test was used to compare characteristics between the HO and non-HO groups. Fisher exact test was used to compare the sex differences between the 2 groups. Bivariate logistic regression was used to determine factors affecting the prevalence of HO, including age, sex, tourniquet time, and surgical time. The results were reported as *P* values with 95% CIs. The statistical significance level was set as $P < .05$.

RESULTS

Patient Characteristics

Overall, this study included 205 patients. The mean age at the time of surgery was 51.1 years (range, 13-75 years). The mean follow-up time was 3.5 years (range, 1.0-11.8 years). According to Table 1, which details the characteristics of patients with and without HO, the 2 groups showed significant differences in sex distribution, tourniquet time, and surgical time (all $P < .05$). No patients showed infection or nerve injury after surgery.

Prevalence of HO

The overall prevalence rate of HO was 6.3%. Of the 205 elbows undergoing arthroscopic surgery, 13 patients (12 male, 1 female) developed postoperative HO. Table 2 shows details of these 13 patients.

Characteristic Findings of HO

Ten patients (76.9%) had HO form close to the medial compartment. Patient 11 (Table 2) had H&G grade 1 HO formation at 8 weeks, which had progressed to grade 2 on radiographs performed 6 months postoperatively. HO of the other 9 patients showed no progression. Furthermore, arthroscopic removal of HO was performed for 2 symptomatic patients (15.4%), including patient 8 at 12 months after HO formation and patient 11 at 6 months after HO formation (Table 2). Both patients developed recurrent HO at the same location. Among the 13 patients who developed HO, the leading diagnosis before arthroscopy was posttraumatic stiffness (8 patients: 7 male and 1 female), followed by elbow fracture/dislocation (3 male patients). Of the 3 (3/23; 13.0%) patients who developed HO, mostly on the medial side of the elbow, after arthroscopy for fracture-dislocations, 1 patient underwent repeated surgery for HO removal, while the other 2 experienced no clinical consequences. Two male patients with primary osteoarthritis showed HO development in the anterior part of the humerus after surgery (Figure 1). Eleven patients had H&G grade 1, and 2 patients had grade 2 (Table 2). For patients classified by different initial diagnoses, those with posttraumatic stiffness had the highest prevalence of HO formation (n = 8/29; 27.6%), followed by patients with trauma (n = 3/22; 13.6%).

Timing of HO Occurrence

Of the 13 patients with HO, 10 (76.9%) were diagnosed at 8 weeks after arthroscopic surgery, 1 (7.7%) at 6 months after, and 2 (15.4%) at 12 months after surgery. No HO was found at 2 weeks after surgery in any patient. As shown in Figure 2, a linear increase in HO development over the first 8 weeks after elbow arthroscopy was observed, indicating that most HO developed within 8 weeks after surgery.

Clinical and Functional Outcomes of Patients With HO Occurrence

For the nine patients treated nonoperatively with primary OA and posttraumatic stiffness, the mean MEPS, Quick-DASH, SANE, and pVAS scores improved from 73.9 (range, 35-95), 33.1 (range, 7-61), 40.0 (range, 20-60), and 1.6 (range, 0-4) to 93.9 (range, 85-100), 6.2 (range, 0-11), 79.3 (range, 50-99), and 0.4 (range, 0-2) (Table 3). Two patients (15.4%) experiencing posttraumatic stiffness or trochlear fracture both developed HO of H&G grade 2 after arthroscopic procedures and underwent repeated surgical removal (Table 2). The patient with trochlear fracture experienced HO recurrence 6 weeks after arthroscopic HO removal (Figure 3). In the other case with posttraumatic stiffness, HO was located in the anteromedial and posteromedial compartments after arthroscopic capsule release. HO was removed using a combination of arthroscopic and open

TABLE 2
Characteristics of Patients With Heterotopic Ossification[a]

Patient No.	Age, y	Sex	Initial Diagnosis	Initial Arthroscopy	H&G Grade	HO Location	Revision
1	71	Male	Primary OA	Osteocapsular arthroplasty, osteophytes/loose body removal	1	A	None
2	65	Male	Primary OA	Osteocapsular arthroplasty, osteophytes/loose body removal	1	A	None
3	22	Male	Posttraumatic stiffness	Capsule release, LCL repair	1	P, M	None
4	62	Male	Posttraumatic stiffness	Capsule release	1	P, M	None
5	43	Male	Posttraumatic stiffness	Capsule release	1	A, P, M	None
6	34	Female	Posttraumatic stiffness	Capsule release	1	A	None
7	34	Male	Posttraumatic stiffness	Capsule release, MCL release, triceps release	1	A, M	None
8	51	Male	Posttraumatic stiffness	Capsule release, posteromedial HO removal	2	A, P, M	HO removal
9	42	Male	Posttraumatic stiffness	Capsular release, ulnar nerve release, posteromedial HO removal	1	M	None
10	29	Male	Posttraumatic stiffness	Capsule release	1	M	None
11	40	Male	Coronoid/trochlear fracture, LCL tear	Coronoid/trochlear reduction and fixation, LCL repair	2	P, M	HO removal
12	29	Male	Coronoid fracture, LCL tear	Coronoid reduction and fixation, LCL repair	1	M	None
13	63	Male	Dislocation, LCL tear	LCL repair, loose body removal	1	A, M	None

[a]The H&G grades of HO of patients 8 and 11 were reported at the last review before HO removal. Those for the other patients were reported at the final review. A, anterior; H&G, Hasting & Graham; HO, heterotopic ossification; LCL, lateral collateral ligament; M, medial; MCL, medial collateral ligament; OA, osteoarthritis; P, posterior.

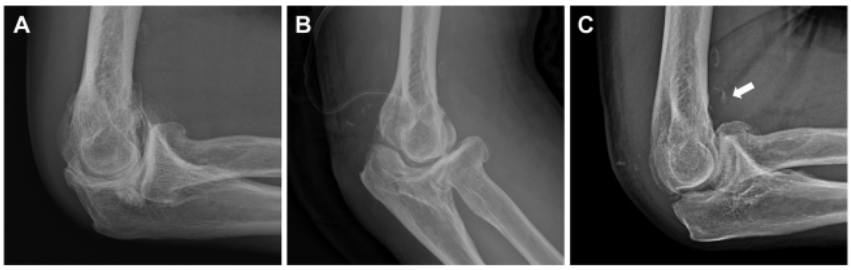

Figure 1. Development of heterotopic ossification (HO) in a 71-year-old male patient with primary elbow osteoarthritis. (A) Lateral radiograph before surgery showing primary osteoarthritis. (B) Lateral radiograph acquired immediately after arthroscopic osteocapsular arthroplasty showing no HO formation. (C) Lateral radiograph showing HO formation anterior to the humerus (white arrow) at the 4-week follow-up.

surgery because of its size. Both patients received repeat surgeries for recurrence, and the clinical scores of these two patients at the last follow-up were shown in Table 3.

Risk Factors for HO

Bivariate logistic regression was conducted to investigate the factors affecting HO prevalence. The regression variables included sex, age, tourniquet time, and surgical time. Age was a protective factor for HO formation (odds ratio [OR], 0.953; 95% CI, 0.910-0.999; $P = .047$), while tourniquet time (OR, 1.042; 95% CI, 1.019-1.065; $P < .001$) and surgical time (OR, 1.026; 95% CI, 1.011-1.041; $P < .001$) were risk factors for HO formation. Male sex appeared to be a contributing factor for HO formation (OR, 7.836; 95% CI, 0.980-62.663; $P = .052$).

DISCUSSION

The most important finding of this study was that the overall prevalence of HO after elbow arthroscopy was 6.3%

TABLE 3
Clinical and Surgical Outcomes for All Patients[a]

		MEPS		QuickDASH		SANE		pVAS	
Patient No.	Revision Surgery	Before Arthroscopy	Latest Follow-up	Before Arthroscopy	Latest Follow-up	Before Arthroscopy	Latest Follow-up	Before Arthroscopy	Latest Follow-up
1	None	80	85	23	10	50	70	3	0
2	None	95	100	7	2	50	90	0	0
3	None	80	100	34	0	50	99	0	0
4	None	80	95	27	9	60	60	2	0
5	None	80	80	23	11	20	50	2	2
6	None	85	100	39	2	60	90	2	0
7	None	70	100	34	0	20	95	0	0
8	HO removal	75	85	41	11	60	60	3	1
9	None	35	85	61	11	30	90	4	2
10	None	60	100	50	11	20	70	1	0
11	HO removal	—	85	—	5	—	80	—	1
12	None	—	100	—	0	—	95	—	0
13	None	—	100	—	2	—	95	—	0

[a]Values are presented as scores. Three patients lacked data on preoperative clinical outcomes because of elbow fracture-dislocation. HO, heterotopic ossification; MEPS, Mayo Elbow Performance Score; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; pVAS, pain visual analog scale; —, no preoperative scores because of traumatic diagnosis.

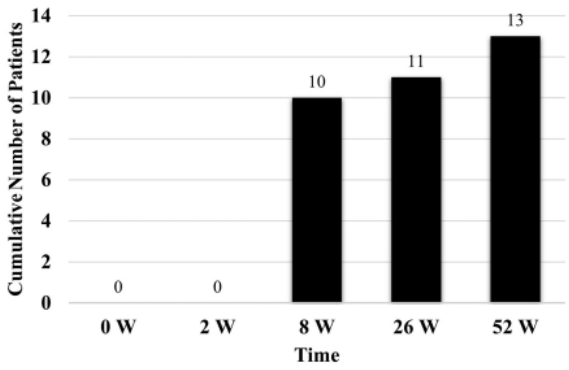

Figure 2. Cumulative numbers of patients with heterotopic ossification after elbow arthroscopy over time. W, week.

(13/205), which is considerably lower than that reported after open surgery.[12,44] Most HO (10/13; 76.9%) formed on the medial compartment of the elbow. The 10 cases were diagnosed at 8 weeks, and HO was not found at 2 weeks after surgery in any patient. Furthermore, only 2 patients (1.0%) who developed HO underwent repeated surgeries after elbow arthroscopy, and patients with primary OA and posttraumatic stiffness had improvements as per clinical outcomes.

Because the definition of HO varies across studies, the true prevalence of HO formation after elbow arthroscopy is not conclusive. In this study, HO was confirmed based on the definition described in Morrey's *the Elbow and Its Disorders*.[13] In addition, all the elbow arthroscopies were performed by the same experienced surgeon using routine protocols and the same equipment. Therefore, this study is believed to provide reliable actual data on the prevalence of HO formation after elbow arthroscopy.

Despite numerous studies on the prevalence of HO after hip and knee arthroscopy,[2,3,53] the prevalence of HO after elbow arthroscopy, especially with a large patient population, has been sparsely reported. Intravia et al[19] reported a prevalence of 2.5% for HO development in 528 patients who underwent elbow arthroscopy, which is lower than the prevalence of the current series (6.3%). However, the relatively short follow-up time (375.8 days; range, 2-2739 days) may not reflect the true prevalence of HO formation after elbow arthroscopy because 48 patients (9.1%) had follow-up durations of <2 weeks in their study.[19] The current study included patients with ≥1 year of follow-up, which strengthened the results of the HO prevalence. In addition, 3 case reports described HO formation after elbow arthroscopy for different diagnoses, including lateral epicondylitis,[10] loose body removal,[15] and posteromedial olecranon impingement.[46] Hughes and Hildebrand[18] reported HO recurrence after arthroscopic HO removal. However, some studies reported only the prevelance of HO formation after elbow arthroscopy but did not report recurrence after HO removal for elbow arthritis and stiffness, and they suggested the high prevalence rate related to improper application of the radiofrequency device.[52] In the current study, 10 (7.9%) of 127 patients developed HO after arthroscopic release for elbow arthritis and stiffness. The lower prevalence may result from the higher proportion of patients with elbow osteoarthritis in this series. No postoperative HO was found in patients with lateral epicondylitis, osteoarthritis secondary to rheumatoid arthritis, or posterolateral rotatory instability.

Because arthroscopy provides minimum insult to soft tissue, assessment and optimization of the anatomic

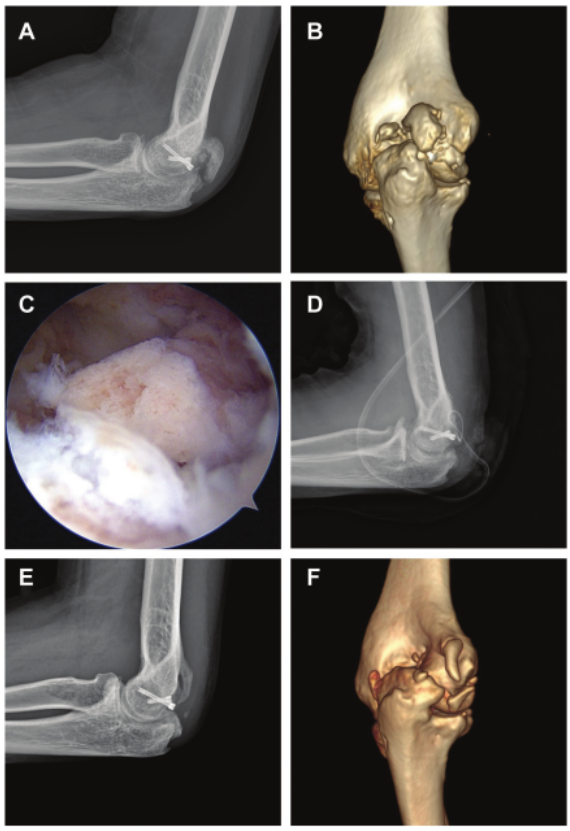

Figure 3. Heterotopic ossification (HO) of Hasting & Graham grade 2 that developed in a 40-year-old male patient after arthroscopic trochlear fracture fixation. (A, B) Lateral view radiograph and 3-dimensional computed tomography (3D CT) reconstruction acquired 8 weeks after arthroscopic trochlear fracture fixation showing HO in the posteromedial compartment. (C) The HO was removed under arthroscopy. (D) Lateral view radiograph immediately after arthroscopic removal revealed no HO in this area. (E, F) Lateral view radiograph and 3D CT reconstruction showed HO recurrence at the same location at the 1-year follow-up.

reduction of the articular surface, and evaluation of concomitant intra-articular injuries or pathology, it plays a prominent role in both diagnosis and treatment for trauma.[9,49] As one of the most intractable complications of elbow fracture-dislocations, HO occurs in 4.7% to 22.7% of cases undergoing open coronoid fixation for elbow fracture-dislocations.[34] Moreover, the additional dissection of soft tissue reportedly increases the risk of HO formation.[40] For this reason, Garofalo et al[14] considered the minimally invasive approach to be better for coronoid fractures to reduce the risk of HO and arthrofibrosis in patients undergoing arthroscopic treatment for coronoid fractures. Lee et al[29] and Hausman et al[17] observed no HO, while Adams et al[1] reported asymptomatic HO in 1 (1/7; 14.3%) patient. Colozza et al[7] identified HO on the medial side of the elbow in 2 (6.3%) of 32 patients but without clinical consequences. In the present study, of the 3 (3/23; 13.0%) patients who developed HO, mostly on the medial side of the elbow, after arthroscopy for fracture-dislocations, 1 patient underwent repeated surgery for HO removal, while the other 2 experienced no clinical consequences. Therefore, compared with open surgery, arthroscopy may be a more effective way to reduce postoperative HO formation for elbow fracture-dislocations.

In the current study, HO developed in patients with posttraumatic stiffness, fracture-dislocation, and primary osteoarthritis, where bony pathology was the dominant component. In contrast, patients with nonbony component pathology such as lateral epicondylitis and cubital tunnel syndrome did not develop HO after elbow arthroscopy. A previous study reported a relatively high HO prevalence after arthroscopic osteocapsular debridement, especially in patients with posttraumatic elbow stiffness.[52] However, patients with arthritis showed relatively low HO formation.[52] Yang et al[52] suggested that patients with a traumatic stiff elbow were more likely to have HO after surgery, which may be contributed to by nerve injury from the initial trauma. Mechanical injury of peripheral nerves triggered HO, possibly because of injury to axons and their myelin sheath after the nerves were transected and neuroinflammation was provoked by the injury.[16] The capsules showed abundant nerves,[20,21,28] and arthroscopic osteocapsular debridement reportedly damaged many mechanoreceptors.[22,28] This may explain the highest prevalence of HO in patients with posttraumatic stiffness, as more aggressive osteocapsular arthroplasty is performed to recover functional range of motion during surgery.

Furthermore, younger age, longer tourniquet time, and longer surgical time were risk factors for HO formation. Peterson et al[37] reported that aging affected the tendency to form ectopic bone after burn injury in mice. Xu et al[51] proposed that the hypoxic state of local tissues after trauma may also initiate HO. Spreadborough et al[47] found that tourniquet-induced ischemia leads to early endochondral bone formation, systemic inflammation, and hypoxia, resulting in increased HO formation in a rat model of blast-associated complex lower limb injury and traumatic amputation.

This study has several limitations. First, the number of patients for each indication varied largely, and the indications in this retrospective single-center study were not truly homogeneous; thus, we could not compare among different indications. Second, in some cases, HO formation is difficult to differentiate from other pathologies such as osteophytes. Thus, all radiographs were independently assessed by 2 orthopaedic surgeons; a consensus was then reached based on the definition of HO before the study. Third, the recommendation for patient monitoring for a minimum of 8 weeks was based on the prevalence rate from a radiographic examination at a specific serial time. Due to the surveillance schedule for routine follow-up, the methodology in the present study prevented the determination of the true linear time frame for HO development. This would require routine screening at regular

intervals. Fourth, this retrospective study has inherent limitations and potential biases. Fifth, all surgeries were performed by a single surgeon at a single institution; thus, issues with generalization may exist. Sixth, HO is uncommon in this population, and there were only 13 patients with (radiographic) HO, which limits the ability to perform multivariable analysis.

CONCLUSION

Our analysis of 205 patients who underwent elbow arthroscopy showed that HO is a minor complication of elbow arthroscopy, with a prevalence rate of 6.3%, and was usually located on the medial compartment of the elbow. Although the presence of HO may not affect the clinical outcomes in most patients, it should be carefully monitored for a minimum of 8 weeks postoperatively. Younger age, longer tourniquet time, and longer surgical time contributed to HO formation after elbow arthroscopy.

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