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Loss of pronation-supination in patients with heterotopic ossification around the elbow

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Background: Heterotopic ossification (HO) is a well-recognized cause of limited flexion-extension, but it can also limit pronation-supination. There is a paucity of literature concerning restriction of pronation-supination due to HO.

Methods: We conducted a retrospective review of patients who had undergone elbow surgery for HO removal between January 1, 2003, and September 27, 2013. Computed tomography scans were reviewed to determine the presence of HO restricting forearm rotation and were rated independently by 4 observers. Each elbow was given 1 of 4 scores according to the likelihood that HO was restricting forearm rotation. Agreement was achieved when 3 or 4 observers thought that HO definitely or probably caused a loss of pronation-supination.

Results: Of 132 post-traumatic patients undergoing HO excision for restricted elbow motion, 61 (46%) also lacked a functional arc of pronation and supination (50° and 50°, respectively). Of these 61 patients, 32 (53%) were considered to have lost forearm rotation because of HO. The remaining 29 patients (47%) were thought to have restricted forearm rotation for reasons unrelated to HO.

Discussion: In this study, loss of pronation-supination affected almost half of the patients (61 of 132 [46%]) undergoing HO excision around the elbow. Of these 61 patients, 32 (52%) had HO extending into the proximal forearm and affecting rotation. From our data, one can expect that about one-quarter (24% of patients in this study, or 32 of 132) with post-traumatic HO of the elbow will have a significant functional loss of pronation-supination due to HO extending into the forearm.

Level of evidence: Level IV; Case Series; Prognosis Study

Keywords: Post-traumatic; heterotopic ossification; surgical excision; elbow; range of motion; forearm rotation contracture

On October 10, 2011, the Mayo Clinic Institutional Review Board met and approved the protocol for this study (11-002988, "General Radiologic Patterns of Elbow Injury").

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The elbow is one of the classic sites for heterotopic ossification (HO).[5] HO is one of the sequelae of elbow trauma, resulting in stiffness, loss of function, and disability.[1,7] There is a potential for HO at the elbow to limit not just flexion and extension but also pronation and supination.[6,9] However, we could find no published studies addressing the prevalence of motion loss in forearm pronation-supination due to HO formation about the elbow.

Most radiologic classifications of HO about the elbow are based on simple radiographs using the lateral profile,[6,7] and their main grading systems are related to the loss of motion in the sagittal plane (ie, flexion-extension).[7] Viola and Hastings[14] proposed a computed tomography (CT) classification of HO at or below the level of the proximal radioulnar joint.[6] Vince and Miller[13] and Jupiter and Ring[9] showed that significant limitation in pronation-supination can occur with HO, particularly after fractures in the proximal third of the forearm.

We hypothesized that limitation of forearm rotation is common in patients undergoing removal of HO around the elbow. The purpose of this study was to determine the prevalence of forearm rotation loss caused by—or at least affected by—HO in patients undergoing surgical excision of HO around the elbow.

Materials and methods

Inclusion and exclusion criteria

We performed a retrospective review of charts and radiographs of all patients who had undergone surgery for the restoration of elbow motion, including flexion-extension and/or pronation-supination, by the senior author (S.W.O.) between January 1, 2003, and September 27, 2013. To be included, each patient had to meet the following inclusion criteria: (1) radiologically detectable HO was present in the region of the elbow, (2) preoperative range-of-motion (ROM) data were available, and (3) preoperative CT scans were available for review. Patients who presented with any neuromuscular condition that could interfere with pronation or supination were excluded from the study.

Evaluation of HO and effect on pronation-supination

CT scans of the elbow were studied by 4 observers independently and blindly: an orthopedic surgeon with special interest in upper-extremity surgery, an orthopedic surgeon who recently completed residency, a physiatrist with clinical experience in HO prevention, and a research fellow who recently graduated from medical school. Each rated the CT scans as to the probability that HO in the region of the elbow or proximal forearm should have caused a loss of forearm rotation. The 4 possible categories were that HO definitively does not (0), possibly does (1), probably does (2), or definitively does (3) contribute to the limitation of pronation-supination. Agreement was achieved when 3 of 4 observers or all 4 observers thought that HO definitely or probably caused a loss of pronation-supination. If 2 observers thought HO did or probably did cause a loss of rotation and the other 2 thought that it did not or probably did not, a fifth person, the senior author (S.W.O., an experienced elbow surgeon), cast the deciding vote. The CT views that were routinely available included the 3-dimensional surface rendering as well as the 2-dimensional axial, sagittal, and coronal reconstructions. A standard protocol was followed when performing the CT scans, with 0.6-mm cuts typically captured.

Under normal circumstances, forearm rotation averages from about 75° of pronation to 85° of supination.[2] In our study, we considered functional ROM values for elbow motion in activities of daily living to be those published by Morrey et al[10] in their historical biomechanical study of normal elbow motion: 100° arc of elbow flexion (from 30° to 130°) and 100° of forearm rotation (50° of pronation and 50° of supination).

Statistical analysis

Intraclass correlation coefficients (ICCs) and 95% confidence intervals for the ICCs were used for the analysis of measurement reliability.[12] Interobserver reliability was determined based on the observers' rating of HO as definitively does not (0), possibly does (1), probably does (2), or definitively does (3) contribute to the limitation of pronation-supination. Statistical analyses were performed with SPSS software (version 22.0; IBM, Armonk, NY, USA). All ROM numerical summaries are reported as mean ± 1 standard deviation. Confidence intervals for proportions are asymptotic, and when appropriate, the Fisher exact test was used. A 2-sample *t* test with unequal variances was performed for comparison of mean values, and a nonparametric analysis of variance, as well as a fit robust to outliers, was conducted on the time since injury.

Results

A total of 160 patients (103 male and 57 female patients) met our inclusion criteria. We excluded 6 patients who had a functional ROM both in extension and flexion (30° and 130°, respectively) and in pronation and supination (50° and 50°, respectively) in whom surgery was performed either for pain or for restoration of terminal extension (such as is required by female gymnasts). This left 154 cases of HO excision in which the indication for surgery was a lack of functional ROM. The HO was post-traumatic in 132 (86%) and due to biceps tendon repair in 8 (5%), inflammatory arthritis in 8 (5%), degenerative arthritis in 2 (1%), prior surgery in 2 (1%), synovial chondromatosis in 1 (<1%), and septic arthritis in 1 (<1%).

Of the 132 post-traumatic patients, 71 (54%) lacked a functional range of extension-flexion only, 53 (40%) lacked functional ranges of both extension-flexion and pronation-supination, and 8 (6%) lacked a functional range of pronation-supination only (Figs. 1 and 2). In the latter 2 groups totaling 61 patients who lacked a functional range of pronation-supination, 32 were considered to have lost forearm rotation because of HO (Figs. 2 and 3). The remaining 29 patients (47%) were thought to have lost their forearm rotation owing to soft-tissue scarring or other reasons unrelated to HO (Fig. 4). Thus, HO caused loss of forearm rotation in 24% of the patients overall (32 of 132) who underwent post-traumatic HO removal (95% confidence interval, 17%-32%).

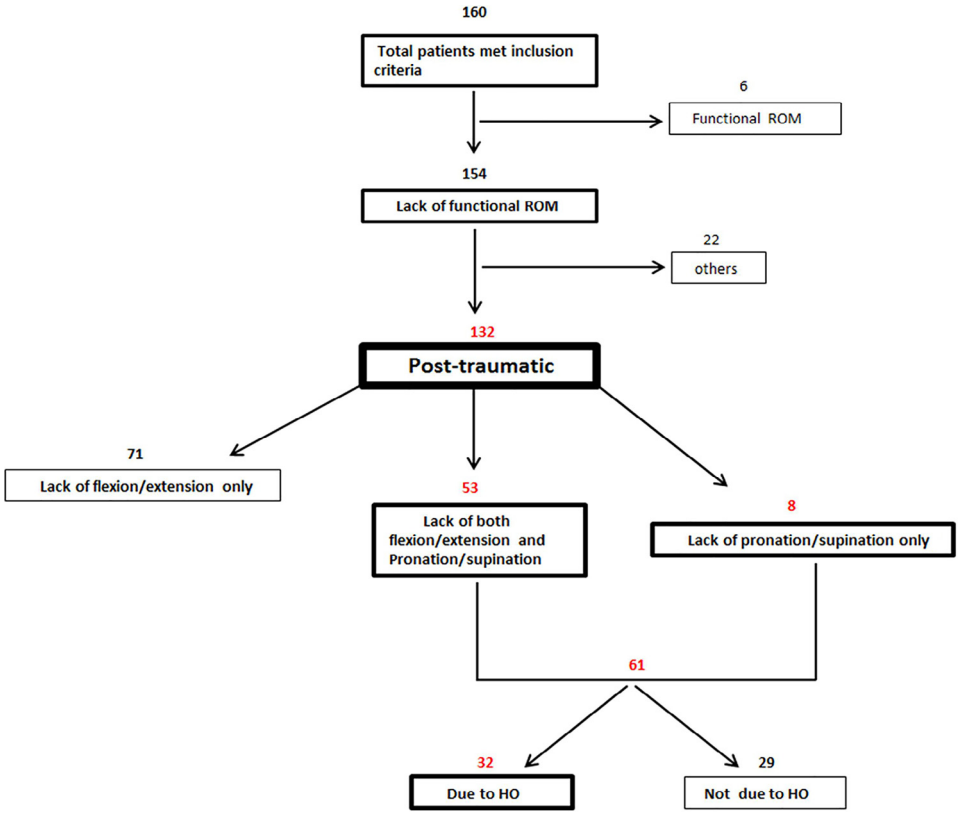

Figure 1 Etiologies of heterotopic ossification (*HO*) cohort. Of the 160 patients, 154 lacked a functional range of motion (*ROM*). Of these cases, 132 were post-traumatic. Among this latter group, 71 lacked only flexion-extension, 53 lacked both flexion-extension and pronation-supination, and 8 lacked only pronation-supination. In 32 of the 61 patients with a restriction in pronation-supination, this restriction was due to HO.

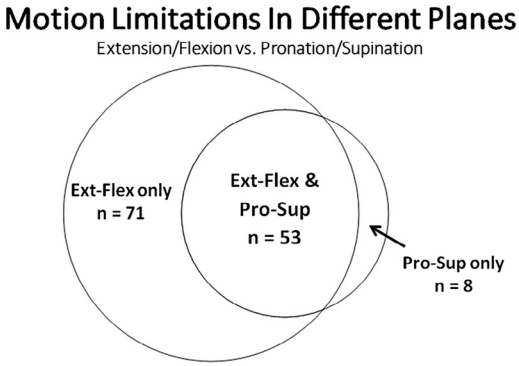

Figure 2 Venn diagram showing motion limitations in different planes. *Ext-Flex*, extension-flexion; *Pro-Sup*, pronation-supination.

Significant differences were found between the patients with loss of motion in rotation and those with loss of rotation and flexion-extension. Among the 8 patients lacking only pronation-supination, HO was considered the cause in all 8 (100%). In contrast, only 24 of the 53 patients (45%) lacking both extension-flexion and pronation-supination were considered to have lost forearm rotation owing to HO ($P < .0001$, Fisher exact test). The rotation loss in the remainder of these 53 patients was attributed to scarring.

No significant difference in pronation-supination was found in patients in whom HO affected only forearm rotation compared with those who lacked functional ROM in both flexion-extension and forearm rotation ($20° \pm 24°$ vs $33° \pm 31°$ for pronation [$P = .3$] and $4° \pm 13°$ vs $15° \pm 24°$ for supination [$P = .2$] for the group with blocked forearm rotation only vs the group with blocked forearm rotation with blocked flexion-extension). Loss of pronation-supination was not significantly different in the 8 cases after distal biceps repair versus the 8 post-traumatic cases that lacked only forearm rotation ($19° \pm 14°$ vs $20° \pm 24°$ for pronation [$P = .9$] and $8° \pm 16°$

Table I Ninety-five percent limits of agreement for interobserver reliability of 4 observers for rating of HO

	Observer 1	Observer 2	Observer 3	Observer 4
Observer 1	—	0.79	0.77	0.75
Observer 2	0.79	—	0.80	0.84
Observer 3	0.77	0.80	—	0.79
Observer 4	0.75	0.84	0.79	—

HO, heterotopic ossification.
HO was rated as definitively does not (0), possibly does (1), probably does (2), or definitively does (3) contribute to the limitation of pronation-supination.

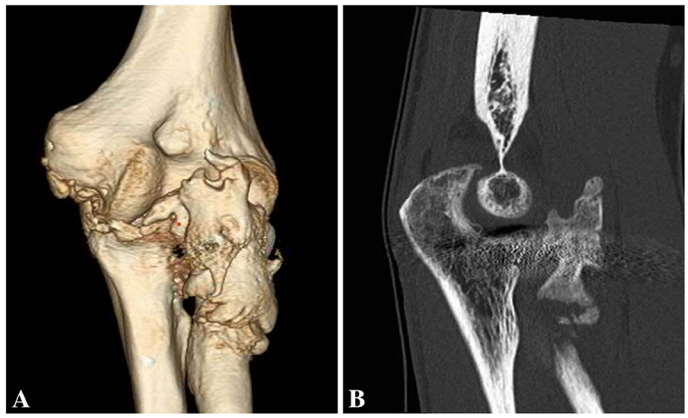

Figure 3 Heterotopic ossification limiting both extension-flexion and pronation-supination. A 3-dimensional computed tomography reconstruction image **(A)** and 2-dimensional sagittal reconstruction image **(B)** of the left elbow of a 29-year-old patient with post-traumatic elbow contracture show extensive heterotopic ossification in the anterior elbow around the radius up toward the humerus and almost bridging to the ulna, greatly reducing extension and flexion (25° and 90°, respectively), as well as pronation and supination (−10° and 10°, respectively).

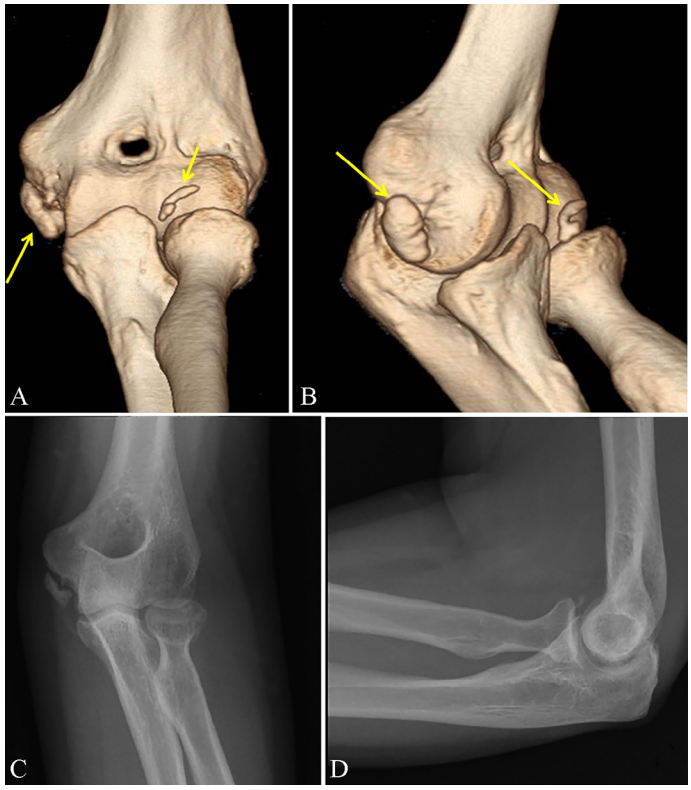

Figure 4 Heterotopic ossification that "does not contribute" to the limitation of pronation-supination. An anteroposterior view **(A)** and oblique view **(B)** of 3-dimensional computed tomography reconstruction images and an anteroposterior view **(C)** and lateral view **(D)** of radiographs of the right elbow of a 40-year-old male patient with post-traumatic contracture of the elbow show heterotopic ossification anterior to the radial head and close to the lateral epicondyle (*yellow arrows*) (extension and flexion of 60° and 135°, respectively, and pronation-supination of 50° and 40°, respectively).

vs 4° ± 13° for supination [$P = .6$] for the distal biceps repair cases vs the post-traumatic cases). Regardless of the type of ROM limitation, the relationship between pronation and supination was essentially the same.

Agreement among the observers was as follows: The observers agreed that in 32 of 61 cases (52%), HO definitely (score of 3) or probably (score of 2) caused a loss of forearm rotation. In all 8 cases (100%) lacking only pronation-supination, the observers agreed that HO definitely (score of 3) or probably (score of 2) caused a loss of forearm rotation. The observers also agreed that in 29 of 61 cases (48%), HO definitely did not cause (score of 0) or possibly caused (score of 1) a loss

of forearm rotation. Agreement as to the likelihood of a causal relationship between HO and restriction of forearm rotation was found in 46 of 61 cases overall (75%). In the remainder of cases with restricted forearm rotation, a high level of agreement was not reached. ICC and 95% confidence interval for each observer are shown in Table I. The 95% confidence interval was fully contained in the range of ICC values, indicating good to excellent reliability: 0.75 to 0.83.

Discussion

Most reports on surgery for HO of the elbow have addressed only the issue of flexion-extension.[3,4,7] However, our study shows that a loss of pronation-supination is common in these patients, affecting 61 of 132 patients (46%; ie, almost half). We found that the 32 of these 61 patients (52%) undergoing surgical excision of post-traumatic HO also lacked forearm rotation, mostly caused by HO extending into the proximal forearm. From our data, one can expect that about one-quarter (24% of patients in this study, or 32 of 132) with post-traumatic HO of the elbow will have a significant functional loss of pronation-supination due to HO extension into the forearm.

These data support our hypothesis that limitation of forearm rotation is common in patients with HO of the elbow. Some of the patients who lacked forearm rotation had no evidence to suggest HO as a direct cause; in these cases, it was due to post-traumatic scarring and/or soft-tissue contractures after immobilization.[4,8] Angular malunion of the radius or ulna can also impair forearm rotation[11] but was not present in this study.

Considering how prevalent loss of pronation-supination was in our patients, it is surprising that so little has been published concerning the restoration of forearm rotation in cases of HO around the elbow. Vince and Miller,[13] Jupiter and Ring,[9] Viola and Hastings,[14] and Hastings and Graham[6] have reported significant restrictions in pronation-supination with HO in the forearm. No classification has yet been agreed on, with authors principally describing HO according to its location in relation to structures in a proximal-to-distal direction. To our knowledge, the only CT-based classification of HO about the elbow is the one published by Viola and Hastings. It is based on axial CT images of the proximal forearm according to the proximal or distal location and subtyped according to the anterior or posterior location. Knowing the exact position of HO plays an important role in surgical planning. A useful classification system of HO about the elbow should take into consideration any potential effect of HO on pronation-supination.

Conclusion

Limitation of forearm rotation is common in patients undergoing removal of HO around the elbow. This study shows that about half of the patients with post-traumatic HO of the elbow have a loss of pronation-supination and this rotational loss of motion in approximately one-quarter of these patients is due to HO extending into the forearm.

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