Heterotopic Ossification Resection After Open Periarticular Combat-Related Elbow Fractures

Kevin W. Wilson, MD; Jonathan F. Dickens, MD; Reed Heckert, MD; Scott M. Tintle, MD; John J. Keeling, MD; Romney C. Andersen, MD; and Benjamin K. Potter, MD

A retrospective review was performed to evaluate the outcomes and complications following heterotopic ossification (HO) resection and lysis of adhesion procedures for posttraumatic contracture, after combat-related open elbow fractures. From 2004 to 2011, HO resection was performed on 30 blast-injured elbows at a mean 10 months after injury. Injuries included 8 (27%) Gustilo-Anderson type II fractures, 8 (27%) type III-A, 10 (33%) III-B, and 4 (13%) III-C. Mean preoperative flexion–extension range of motion (ROM) was 36.4°, compared with mean postoperative ROM of 83.6°. Mean gain of motion was 47.2°. Traumatic brain injury, need for flap, and nerve injury did not appear to have a significant effect on preoperative or postoperative ROM. Complications included one fracture, six recurrent contractures, and one nerve injury. The results and complications of HO resection for elbow contracture following high-energy, open injuries from blast trauma are generally comparable to those reported for HO resection following lower energy, closed injuries. (Journal of Surgical Orthopaedic Advances 22(1):30–35, 2013)

Key words: combat-related injury, elbow, elbow contracture, heterotopic ossification, trauma

The goal of treatment of fractures about the elbow should be to restore articular congruity while preserving a functional range of motion (ROM). Morrey et al. (1) described a functional flexion–extension ROM of 100° in 1981, with most activities of daily living requiring an arc from 30° to 130°. More recently, Sardelli et al. (2) described a need for a greater functional arc of flexion–extension, to accomplish more contemporary activities such as the use of keyboards and cellular phones.

The elbow is notorious for its propensity to develop heterotopic ossification (HO). HO is the deposition of mature lamellar bone in soft tissues, presumably by inappropriate differentiation of pluripotent mesenchymal cells into bone-forming osteoblastic cells in the periarticular soft tissues (3). Through contracture of the extra-articular soft tissues, HO can have devastating effects on achieving a successful outcome, resulting in prolonged rehabilitation and subsequent procedures to improve ROM lost to bone impingement and arthrofibrosis (4).

The ability to prevent HO development after trauma is limited. Although successful in combatting HO about the hip, nonsteroidal anti-inflammatory medications have not been clearly shown to prevent HO following surgical treatment of elbow trauma (5). Radiotherapy has been shown to be effective against HO development; however, its use in the setting of trauma presents many difficulties. The recommendation for radiotherapy delivery within 48 hours and the risk associated with open wounds, polytrauma, and fracture healing often precludes radiotherapy in elbow trauma (6). A recent prospective randomized study of radiation therapy for HO in elbow trauma was terminated before completion because of an unacceptably high number of adverse events, particularly nonunion (7).

While dynamic splinting, prolonged therapy, and activity modification remain tenets of posttraumatic elbow contracture management, surgical excision of HO to improve functional elbow ROM has been shown to be safe and effective (8, 9). The majority of the injuries in these series result from closed, civilian trauma. The outcomes of HO resections after high-energy periarticular elbow trauma, as seen in recent military conflicts, remain unknown.

From Department of Orthopaedics and Rehabilitation, Walter Reed National Military Medical Center, Bethesda, Maryland. Address correspondence to: Kevin Wilson, MD, WRNMMC Bethesda, Department of Orthopaedics and Rehabilitation, 8901 Wisconsin Avenue, Bethesda, MD 20889; e-mail: kevinwilsonmd@gmail.com.

Received for publication October 4, 2012; revision received November 16, 2012; accepted for publication November 19, 2012.

For information on prices and availability of reprints, e-mail reprints @datatrace.com or call 410-494-4994, x232.

1548-825X/13/2201-0030$22.00/0

DOI: 10.3113/JSOA.2013.0030

The association of HO with combat-related trauma is well documented (10). Given that combat-related injuries are characterized by high-energy blast and ballistic mechanisms, wide zones of injury, soft tissue loss, systemic inflammation for concomitant injuries, and high incidence of traumatic brain injury, it can be expected that combat-related periarticular elbow injuries may represent the worst-case scenario for HO development and elbow injury outcomes. Surgical treatment of elbow contracture secondary to HO in these blast-injured elbows has not yet been evaluated in the literature, to our knowledge.

The objective of this analysis is to review the outcomes of HO resection to improve ROM in combat-related periarticular elbow fractures complicated by heterotopic ossification. Risk factors for poor outcomes, derived from injury characteristics, were also evaluated. Our hypothesis was that surgical intervention can remain a potentially successful treatment option to improve and restore functional motion, even in these severely injured and contracted elbows.

Methods

A retrospective review of open periarticular combat-related elbow fractures treated at the National Naval Medical Center at Bethesda and Walter Reed Army Medical Center (now Walter Reed National Military Medical Center at Bethesda) was approved by the respective institutional review boards. Open, periarticular elbow injuries were defined as open fracture within 5 cm of the radiocapitellar or ulnohumeral joints. Patients treated with upper extremity amputation within the first 24 hours of injury were excluded. A review of our institution's electronic surgical scheduling system revealed surgical treatment of 132 consecutive periarticular injuries to the elbow in 128 combat-injured male patients treated at our facility between 2004 and 2011. Heterotopic ossification was defined as ectopic bone formation within the zone of injury after initial definitive management. Ninety-two (69%) elbows developed HO on radiographic follow-up. Inclusion criteria were patients who underwent primary elbow HO excision surgery with concurrent capsulectomy or lysis of adhesions to improve flexion–extension arc of motion. Of the 43 elbows on which HO excision was performed, 13 elbows were excluded from review: seven had inadequate pre- and postoperative ROM documentation, two had proximal forearm amputations requiring HO excision for pain or prosthetic fitting, and three had procedures primarily to improve pronation–supination motion.

Abstracted data were collected from inpatient and outpatient electronic medical records and included patient demographic, mechanism of injury, concomitant injuries, Gustilo and Anderson fracture classification, interval and definitive treatment procedures, and adjunctive procedures (rotational or free tissue transfer, skin graft, and neurovascular procedures). Operation reports and inpatient records documented indications for procedures, preoperative ROM values, intraoperative complications, and HO prophylaxis utilization. Radiographs demonstrating the most severe HO were used to determine Hastings classification for each elbow (11). Outcomes were derived from electronic medical record capture of follow-up orthopaedic clinic and occupational therapy encounters, which routinely include ROM and complication details. Clinical photographs taken on arrival at our institution were available for the majority of injuries. All digital radiographs of the upper extremity performed at our institution were reviewed on the local Picture Archiving and Communication System (PACS). Serial radiographs of a case example are displayed in Figure 1.

Surgical Details and Rehabilitation

A full discussion of surgical techniques and rehabilitation principles is beyond the scope of this report. Multiple surgeons over the 7-year review period were involved in the procedures. After review of operative reports, the approach utilized was dictated by the anatomic location of the focus of heterotopic bone. Also, flap location and hardware removal influenced approaches. In a majority of cases, combined medial and lateral approaches were needed, with conventional skin incisions generally not available because of prior incisions, traumatic wounds, and/or flap positions. Postoperatively, the use of an indwelling regional anesthesia catheter for 2 to 3 days was common to facilitate initiation of ROM and occupational therapy. HO prophylaxis regimens varied throughout the collection period. Two of the more recent patients were treated with Celebrex, 10 were prescribed Indocin, and eight patients received radiotherapy within 72 hours after surgery. All patients received inpatient therapy and were followed closely in the outpatient occupational therapy clinic. In addition to therapy, routine orthopaedic follow-ups with exam occurred generally at 2 weeks, 6 weeks, 12 weeks, 6 months, and annually until loss of follow-up. Most active follow-up was discontinued after separation from the active duty military to the Veterans Affairs system.

The ROM at final follow-up, including cases of failed and repeat procedures, was used for outcome calculations, as per the intent-to-treat principle. Statistical analysis of the data included basic summary calculations for demographic variables and testing of the preoperative and postoperative ROM between groups with independent samples *t* tests, equal variances not assumed.

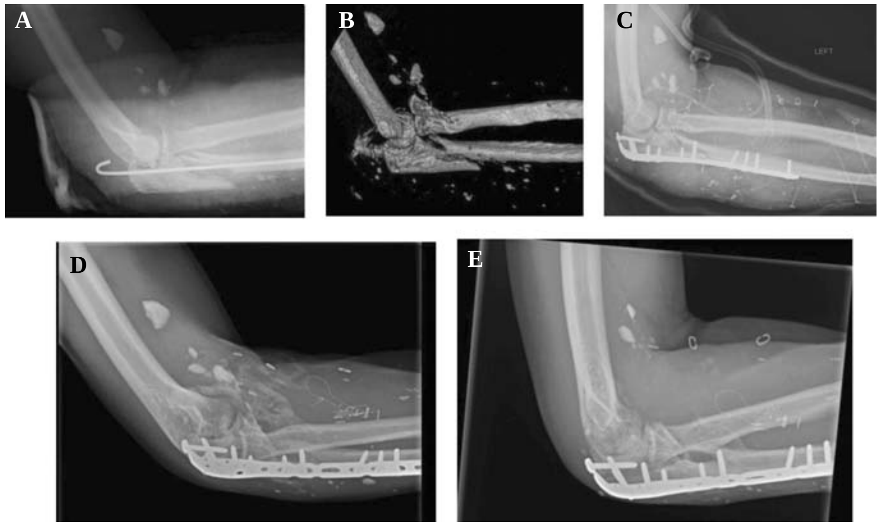

FIGURE 1 Serial radiographs of treatment course. A 27-year-old active duty male sustained an improvised explosive device blast injury to the left upper extremity while serving in Afghanistan as an explosive ordinance disposal team leader, resulting in a Gustilo-Anderson type 3B open proximal ulna and radial head fracture-dislocation. He was treated for traumatic brain injury. He underwent irrigation and debridement and provisional stabilization before arrival at our facility. Radiograph (**A**) and computed tomography three-dimensional reconstruction (**B**) are shown. He underwent serial irrigation and debridement. After anterolateral thigh free tissue transfer, open reduction and internal fixation (**C**) was performed 11 days after injury. After 3 postoperative months, he returned with elbow HO and contracture (**D**) that was refractory to therapy and splinting. His arc of motion was 25° to 65° of flexion. HO resection was performed 6 months after definitive fixation, followed by intensive occupational therapy. Postresection radiographs (2 weeks postoperatively) are displayed (**E**). At the 2-year follow-up, his arc of motion was 30° to 115° of flexion.

Results

The complex injuries of patients in this study involved concomitant arm and forearm fractures, including 20 distal humerus (present in 67% of the injuries), 23 proximal ulna (77%), and 7 proximal radius (23%) fractures (see Table 1). Thirteen of 30 injuries (43%) involved two or more primary fractures about the elbow. The affected limb had undergone between one and five procedures (mean 2.7) along the medical evacuation route, before arrival at our facility. There was an average of 5.2 procedures for debridement and soft tissue management before the initial definitive fixation of fractures. The mean age was 25 (range, 19–42) years, and mean follow-up was 35 (range, 12–51) months. The mean time from initial definitive management until HO resection was 10 (range, 3–18) months (see Table 1).

The mechanism of injury was most commonly explosive blasts (90%, 27/30) from improvised explosive devices, grenades, or mortars. The remaining three patients sustained gunshot wounds. Eight injuries (27%) were classified as Gustilo-Anderson type II. The remaining 22 injuries were all Gustilo-Anderson type III injuries. Ten elbows (33%) were IIIB, requiring pedicled or free tissue transfer for definitive wound closure. Four elbows (13%) were IIIC, associated with vascular injury requiring repair or revascularization procedure at time of injury. Seventeen elbows (57%) had associated nerve injuries. Radiographic and clinical evaluation revealed that no patients were Hastings class I (HO without functional limitation), 10 were class IIa (limited

TABLE 1 Demographics and injury characteristics

Age	25	(range, 19–42) years
Follow-up	35	(range, 12–51) months
Mechanism	27	(90%) Blasts
	3	(10%) gunshot wounds
TBI	16	(53%) of patients
Time to HO resection	10	(range, 3–18) months
Fracture		
Humerus	20	67%
Ulna	23	77%
Radius	7	23%
Combined	13	43%
Prior Procedures (mean)		
Downrange	2.7	procedures
Debridements	5.2	procedures
Gustilo-Anderson		
I	0	0%
II	8	27%
IIIa	8	27%
IIIb	10	50%
IIIc	4	20%
HO Classification		
I	0	0%
IIa	10	33%
IIb	5	17%
IIc	14	47%
III	1	3%

TABLE 2 Degrees of motion before and after HO resection

Variable	No.	Before	After	Gain	*p* Value
All elbows	30	36.4	83.6	47.2	<.001
TBI	16	38.3	78.1	39.8	<.001
No TBI	14	34.2	89.9	55.7	<.001
Flap	10	37.9	79.6	41.7	.003
No flap	20	35.6	85.6	50.0	<.001
Nerve injury	17	39.2	78.4	39.2	<.001
No nerve injury	13	32.6	90.4	57.8	<.001

Note: The mean degrees of motion preoperative, postoperative, and total gain measurements are displayed for the entire cohort (all elbows), and for elbows associated with and without each of TBI, need for flap coverage, and presence of nerve injury. Analysis of all subsets across the cohort demonstrated a significant gain in motion.

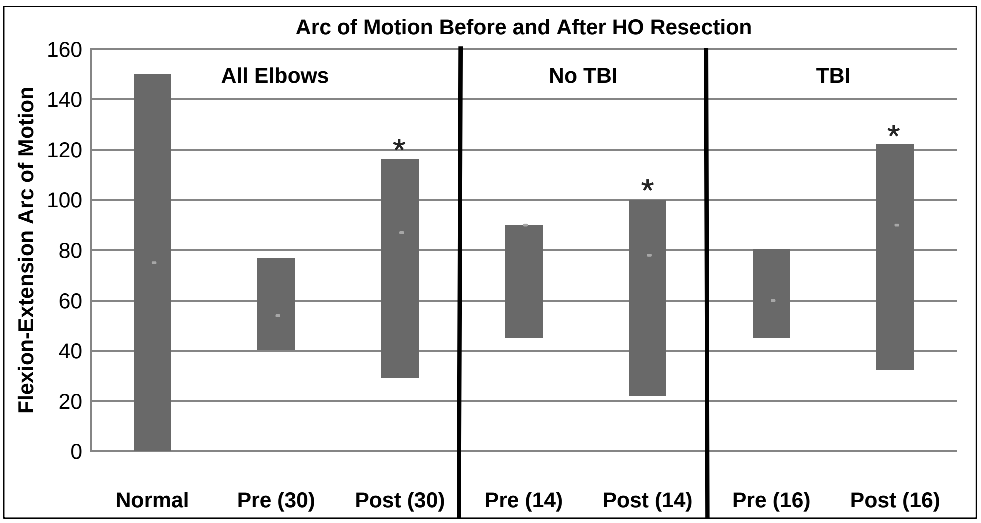

FIGURE 2 Arc of motion before and after HO resection. Arc of motion is displayed for normal elbows, preoperative elbows, postoperative elbows for entire cohort, for elbows without concomitant TBI, and for elbows in individuals with TBI diagnosis. *denotes a significant difference between preoperative and postoperative ROM values.

flexion–extension), 5 were class IIb (limited pronation–supination), 14 were class IIc (limited both pronation–supination and flexion–extension arcs), and 1 was class III (ankylosis). Fifty-three percent of patients (16/30) were diagnosed with traumatic brain injury (TBI) after known head injury or after mandatory TBI screening upon arrival to the United States.

Analysis of Heterotopic Ossification Resection Outcomes

The mean preoperative flexion–extension arc of motion was 36.4°, compared with mean postoperative arc of motion of 83.6°. A mean sustained gain of 47.2° of flexion–extension ROM (range, −15° to 110°, Table 2) was seen across the sample. The arc of motion preoperatively and postoperatively for the injured elbows in this series is significantly narrowed from the normal range of motion (0°–140°) for uninjured elbows (Fig. 2). No significant difference was observed in the ROM gains between elbows with and without TBI diagnosis ($p = .102$), a well-established risk factor for heterotopic ossification.

We noted significant mean gains in ROM from preoperative measurements to final postoperative measurements across the sample, including subsets with and without potential confounding factors (Table 2). Subanalysis of only elbows with concomitant TBI, need for flap, and nerve injury continued to demonstrate a significant gain in ROM in each subset, with and without the potential complicating variable. We found no significant difference in the preoperative and postoperative motion for elbows with or without each of the potential complicating variables (Table 3). Although there appeared to be a trend for elbows without TBI (55.6° vs. 39.9°), flaps (50.0° vs. 41.7°), or nerve injuries (57.8° vs. 39.2°) to achieve a greater gain in range of motion, no statistically significant difference was found.

TABLE 3 Comparison of pre- and postoperative motion by potential risk factors

Variable	Before	*p* Value	After	*p* Value	Gain	*p* Value
TBI	38.3		78.1	.115	39.9	.102
No TBI	34.2		89.9		55.6	
Flap	37.9	.419	79.6	.300	41.7	.274
No flap	35.6		85.6		50.0	
Nerve injury	39.2	.538	78.4	.203	39.2	.136
No nerve injury	32.6		90.4		57.8	

Note: A Student *t* test of means was performed for the preoperative, postoperative, and total gain measurements for elbows with and without each of concomitant TBI, need for flap coverage, and presence of nerve injury. No statistically significant differences were found among the mean preoperative, postoperative, or gain measurements among elbows with any of the potential risk factors for stiffness.

Complications

Heterotopic ossification resections were complicated by one intraoperative distal humerus fracture, six episodes of recurrent arthrofibrosis (less than 15° improvement), and one reinjury of a previously injured posterior interosseous nerve (PIN). The medial condyle humerus fracture fixation was revised with the HO resection procedure, and the postoperative motion plan was continued. Three of the six recurrent arthrofibrosis cases were treated with postoperative radiotherapy. Four of the six recurrent arthrofibrosis cases went on to repeat lysis of adhesion and manipulation under anesthesia procedures, with no significant lasting improvement. The PIN palsy improved with observation.

Discussion

We reviewed the results of HO excision for severe, open, combat-related periarticular elbow fractures. With regard to soft tissue management and concomitant injury, blast-injured elbows present unique challenges during initial management and subsequent attempts to improve function. Based on our observations, however, the HO excision procedures remain a reasonable treatment option in such injuries.

Resection of HO to improve functional elbow ROM has been shown to be successful in multiple settings (8, 9, 12–14). Moritomo et al. (15) reported an increase from 37.3° to 112.8° after "early" HO resection at mean 7.7 months in nine consecutive patients after closed elbow trauma. Gaur et al. (16) reported a mean sustained gain of 57° after HO excision at an average of 17.3 months after severe burns in seven children at a pediatric burn center. Park et al. (17) reported consistent improvements in motion (mean total arc improvement of 60°), as well as in Mayo Elbow Performance Indices (mean increase of 21 points), among 42 patients with contracture caused by closed trauma who underwent surgical release and HO excision at a median of 10 months after injury.

More recently, Baldwin et al. (9) concluded that excision of HO resulting from multiple etiologies can reliably increase functional ROM. In a cohort of patients with TBI, direct elbow trauma, and combined etiologies, Baldwin et al. presented an average increase from 57° to 106°, resulting in a mean gain in arc of motion of 49°. Our mean increase in flexion–extension arc of motion of 47.2° is comparable, considering the complexity of these types of patients. Similarly, Baldwin et al. evaluated for potential risk factors for reduced final arc of motion. Timing of resection and neurologic characteristics had no effect; however, motion limitation in pronation–supination and flexion–extension was found to be a significant variable in the final arc of flexion–extension motion after HO resection (9). We could not evaluate for pronation–supination because of inadequate documentation and inclusion of two patients with below-elbow amputations.

Addressing contracture in elbows with a severely compromised soft tissue envelope has precedence. Successful operative release of complete ankylosis in 20 elbows among 15 severe trauma and burn patients was reported by Ring and Jupiter (18). Their series included three burn injuries requiring free tissue transfer at the time of HO excision and five type 2 Gustilo-Anderson open wounds. Despite the increased severity of the etiology and additional procedures required for initial management, the mean sustained arc of motion was 81° for the burn cohort and 94° for the trauma cohort. None of these patients had concurrent TBI (18).

The current study may represent the largest series of HO resections involving peripheral nerve injuries, open fractures, or wounds requiring flap coverage. It can be implied that nerve injury and soft tissue deficits represent more serious insults to the periarticular soft tissues that are involved in the elbow contractures. It is also reasonable to conclude that open fracture or fracture-dislocation about the elbow from blast trauma would represent a more severe injury compared to closed trauma related to civilian injuries. Nerve injury and need for flap coverage, however, were not found to play a role in the ROM outcomes of surgical resection of HO. The results of the present series demonstrate generally comparable results to HO resection following lower energy, closed injuries, with slightly decreased ROM gains and similar complication rates.

We encountered a moderate rate of complications from HO excision in our series (26.7%), with six elbows experiencing a recurrence or persistence of substantial contracture. No permanent neurovascular injuries were encountered in this series. Our rate of complications, including recurrence, is similar to the rates reported in other series (14–18). Ring and Jupiter reported clinically significant recurrent HO in one-third of their trauma cohort (18). A means for identifying those limbs at risk for complication or recurrence has not been established. Given the unremarkable influence of potential risk factors for HO and contracture in this and other series, potential etiologies for recurrent contracture remain unclear.

The shortcomings of this analysis are related to its retrospective nature and multiple treatment regimens carried out by multiple surgeons. Surgical approaches varied based on the location of the ossification, prior procedures, and the status of the surrounding soft tissue envelope. No consistent regimen of chemotherapy or radiotherapy HO prophylaxis was used; however, recommendations for safe prophylaxis regimens after elbow injury or surgery have not yet been established in other patient populations. Most importantly, the cohort may be unique because of the spectrum of concomitant injury and wide zone of injury to the elbow seen in combat-related trauma. This may limit one's ability to extrapolate our findings to the general community.

Based on our observations, HO resections in combat-related blast injuries to the elbow can produce reliable gains in the arc of elbow motion. Blast injuries are not commonly encountered in the orthopaedic community; nevertheless, it may be noteworthy that the utility of HO resections with concurrent lysis of adhesions is maintained following these complex injuries, even in what may be the worst-case scenario for posttraumatic elbow HO. Elbow contractures associated with open fracture, soft tissue loss, and nerve injury should not preclude attempts at improving ROM with surgical excision of HO.

References

1. Morrey, B. F., Askew, L. J., Chao, E. Y. A biomechanical study of normal functional elbow motion. J. Bone Joint Surg. Am. 63:872–877, 1981.
2. Sardelli, M., Tashjian, R. Z., MacWilliams, B. A. Functional elbow range of motion for contemporary tasks. J. Bone Joint Surg. Am. 93:471–477, 2011.
3. Kaplan, F. .S, Glaser, D. L., Hebela, N., et al. Heterotopic ossification. J. Am. Acad. Orthop. Surg. 12:116–125, 2004.
4. Summerfield, S. L., DiGiovanni, C., Weiss, A. C. Heterotopic ossification of the elbow. J. Shoulder Elbow Surg. 6(3):321–332, 1997.
5. Lindenhovius, A. L. C., Jupiter, J. B. The posttraumatic stiff elbow: a review of the literature. J. Hand Surg. Am. 32(10):1605–1622, 2007.
6. Alfieri, K. A., Forsberg, J. A., Potter, B. K. Blast injuries and heterotopic ossification. Bone Joint Res. 1:174–179, 2012.
7. Hamid, N., Ashraf, N., Bosse, M. J., et al. Radiation therapy for heterotopic ossification prophylaxis acutely after elbow trauma. J. Bone Joint Surg. Am. 92:2032–2038, 2010.
8. Viola, R. W., Hastings, H. Treatment of ectopic ossification about the elbow. Clin. Orthop. Relat. Res. 370:65–86, 2000.
9. Baldwin, K., Hosalker, H. S., Donegan, D. J., et al. Surgical resection of heterotopic bone about the elbow: an institutional experience with traumatic and neurologic etiologies. J. Hand Surg. Am. 36:798–803, 2011.
10. Forsberg, J. A., Pepek, J. M., Wagner, S., et al. Heterotopic ossification in high-energy wartime extremity injuries: prevalence and risk factors. J. Bone Joint Surg. Am. 91(5):1084–1091, 2009.
11. Hastings, H., II, Graham, T. J. The classification and treatment of heterotopic ossification about the elbow and forearm. Hand Clin. 10(3):417–437, 1994.
12. McAuliffe, J. A., Wolfson, A. H. Early excision of heterotopic ossification about the elbow followed by radiation therapy. J. Bone Joint Surg. Am. 79(5):749–754, 1997.
13. Evans, P. J., Nandi, S., Maschke, S., et al. Prevention and treatment of elbow stiffness. J. Hand Surg. Am. 34:769–778, 2009.
14. Maender, C., Shajpal, D., Wright, T. W. Treatment of heterotopic ossification of the elbow following burn injury: recommendations for surgical excision and perioperative prophylaxis using radiation therapy. J. Shoulder Elbow Surg. 19:1269–1275, 2010.
15. Moritomo, H., Tada, K., Yoshida, T. Early, wide excision of heterotopic ossification in the medial elbow. J. Shoulder Elbow Surg. 10(2):164–168, 2001.
16. Gaur, A., Sinclair, M., Caruso, E., et al. Heterotopic ossification around the elbow following burns in children: results after excision. J. Bone Joint Surg. Am. 85(8):1538–1543, 2003.
17. Park, M. J., Chang, M. J., Lee, Y. B., et al. Surgical release for posttraumatic loss of elbow flexion. J. Bone Joint Surg. Am. 92:2692–2699, 2010.
18. Ring, D., Jupiter, J. B. Operative release of compete ankylosis of the elbow due to heterotopic bone in patients without severe injury of the central nervous system. J. Bone Joint Surg. Am. 85(5):849–857, 2003.