Original Article

The clinical implications of heterotopic ossification in patients treated with radial head replacement for trauma: A case series and review of the literature

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ABSTRACT

Radial head arthroplasty (RHA) is an acceptable treatment for comminuted radial head fractures (RHF). Fourteen patients with no postop HO prophylaxis were treated with RHA for comminuted RHF. A 50% incidence in HO was seen following RHA with a statistically increased risk ($p \leq 0.05$) of reoperation compared to those without HO. Decreased ROM was seen on the affected side ($p \leq 0.05$); patients without HO showed no statistical difference ($p \geq 0.05$) in ROM or grip strength. HO following RHA increases patient risk for reoperation and decreases ROM. We recommend HO prophylaxis with NSAIDs and/or radiotherapy if no direct patient contraindications are found.

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1. Introduction

Radial head fractures account for one-third of all elbow fractures.¹ Radial head arthroplasty (RHA) has long been the treatment of choice for radiocapitellar arthritis. Following numerous modular design changes, adjustable-length spacer designs are more prevalent in the market. Along with the changes in design, the indications for use have also evolved. It has more recently become the treatment of choice for comminuted Mason Type-III and Mason–Johnson Type-IV radial head fractures.² Patients with comminuted radial head fractures are typically considered to have complex unstable injuries where the radial head fracture is only one part.⁷ Historically, in comminuted radial head fractures, the radial head was either excised or it underwent open reduction internal fixation.^{8,9} The reported complications with these treatments include proximal radial migration, valgus instability, posterolateral rotatory instability, hardware complications, and nonunions (Fig. 1).^{10–13}

Reports of heterotopic ossification (HO) are frequent in the literature following elbow injury, elbow arthroscopy, open reduction internal fixation of fractures, and radial head replacement.^{3,4,14–18} Many authors routinely use prophylaxis against HO with NSAIDs and/or radiation following elbow injury or surgery.^{5,6,8,17,19–22} However, some authors note that the evidence for this is weak.⁸ Despite previous reports of HO following elbow injury and radial head replacement, no studies, to our knowledge, delineate the clinical implications and results of HO following radial head replacement (Fig. 2).

Radiotherapy and NSAID use are both associated with complications.^{23–27} There have been multiple reports of successful improvement in a range of motion following capsular release with and without prophylaxis for HO.^{28–33} Those patients with HO have been approached more cautiously.^{34,35} Lindenhovius et al. noted, however, no significant difference in ultimate range of motion following contracture release for elbows with and without HO for patients with elbow stiffness.¹⁵ To our knowledge, this is the first report of the clinical results of patients with and without HO who have undergone radial head arthroplasty.

This project was approved by the Institutional Review Board of the Medical University of South Carolina (Pro00009207).

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Fig. 1. Preop injury films showing severely comminuted radial head fracture.

Fig. 2. Postop films showing significant HO post RHA.

2. Materials and methods

Between May 2007 and April 2010, 14 radial head replacements were performed for Mason Type-III or Mason–Johnson Type-IV radial head fractures by one single surgeon (GJS) with the Acumed Anatomic Radial Head System (Acumed Medical; Hillsboro, Oregon). After approval by the IRB, patients who had been treated with a radial head replacement for trauma were identified. Medical records were reviewed to identify demographic data, comorbidities, concomitant injuries, and revision surgery data. Prospectively, these patients returned to the hand therapy clinic for evaluation of bilateral elbow range of motion and grip strength studies performed by a licensed, independent occupational therapist. Radiographs were independently reviewed by the attending hand surgeon, attending musculoskeletal radiologist, and two orthopedic surgery chief residents for evidence of HO.

2.1. Radial head prosthesis

The Acumed Anatomic Radial Head system (Accumed Medical; Hillsboro, Oregon) is a modular radial head implant. The stem is composed of titanium alloy, grit blasted and fluted. The head and collar are polished cobalt chrome with varying collar heights. The prosthesis attempts to restore the normal ellipsoidal shape of the radial head.

2.2. Perioperative management

Under general anesthesia utilizing a tourniquet, a Kocher approach was utilized for 10 of the fractures and a posterior approach was used for the remaining four. The attending surgeon based the approach on a case-by-case basis for each patient depending on his or her scope of injury. Once the fracture was deemed unreconstructable, the radial head fracture fragments were removed. The radial neck was delivered and an oscillating saw was used to make a level cut. The canal was opened and reamed sequentially until a snug fit was obtained. The proximal cortex was reamed with the collar reamer. The collar height was determined. Trial implants were assembled and trialed to assure the proper size. Once the proper size was determined, the final implants were assembled and implanted. Following implantation

of the radial head, the lateral ulnar collateral ligament was reconstructed in 4 patients. Two patients underwent a concomitant open reduction, internal fixation of a proximal ulna fracture. All patients were placed into a posterior slab plaster splint for 3–5 days. The postoperative rehab protocol was individualized according to the concomitant injuries. All patients were removed from the splint within the first week and were started with gentle range of motion under the supervision of a licensed occupational therapist within a “safe” arc of motion dictated by their associated soft tissue injuries. None of the patients received prophylaxis for HO.

2.3. Statistics

Data analysis was conducted with IBM SPSS Statistics Version 20 for Windows (SPSS, Chicago, IL). Dichotomous variables were compared with chi-square. Continuous variable analysis, even with a small *n*, was conducted with either one-way ANOVA or independent *t*-tests due to the robustness of these tests.

3. Results

There were a total of 14 patients included in the study, 8 males and 6 females. The average age was 53 years (range 35–79). There were five radial head replacements on right upper extremities and eight on left upper extremities. Six of the injuries were isolated radial head fractures, three were “terrible triad” injuries, two were Monteggia fracture variants, and the remaining three were radial head fractures with lateral ulnar collateral ligament disruption. Final range of motion and grip strength measurements were performed at an average of 3 years postoperatively.

Seven total cases of HO (50%) were observed and eight revision surgeries were performed. Of the 4 posterior approaches, 2 developed HO and 2 did not. Both Monteggia variants developed postoperative HO. None of the “terrible triad” injuries developed HO. In all cases where HO was identified, it was felt to be restricting range of motion. All surgeries that were performed in the setting of HO were completed with a primary goal of HO removal to increase range of motion. Only one surgery was performed for capsular contracture alone. There were no significant differences ($p \geq 0.05$) in the demographic data or comorbidities in those patients with HO compared to those without HO (Table 1). There were also no significant differences ($p \geq 0.05$) in ROM based on demographics or comorbidities.

Patients were evaluated for range of motion and grip strength measurements by an independent licensed occupational therapist. Twelve of fourteen (86%) patients were available for measurements. These measurements included elbow flexion, extension, supination, pronation performed with a goniometer, and grip strength measurements performed with a dynamometer of both operative and nonoperative extremities. Of the two that did not follow-up, one had no radiographic evidence of HO at last follow-up and no revision surgery, and one had radiographic evidence of HO that required revision surgery.

When all patients were considered collectively in a single group, we noted significant differences ($p \leq 0.05$) in affected and

Table 1
Comparison of demographic data and comorbidities in patients with HO vs without HO.

Chi-square comparison	<i>p</i> value
HO and race	0.577
HO and sex	0.280
HO and ASA	1.000
HO and age	0.109

Table 2

Objective physical outcome measures – all patients.

	Affected arm	Unaffected arm	p value
Elbow flexion	129.1 ± 11.7°	140.2 ± 8.1°	<0.014
Elbow extension	22.4 ± 18.9°	0.8 ± 1.9°	<0.002
Elbow supination	63.3 ± 24°	79.2 ± 9.5°	<0.050
Elbow pronation	69.3 ± 12.7°	80.8 ± 7.3°	<0.014
Grip strength	32.1 ± 31 N/m ²	36.2 ± 29 N/m ²	0.751

Table 3

Objective physical outcome measures – patients with HO.

	Affected arm	Unaffected arm	p value
Elbow flexion	125 ± 13°	139 ± 10.9°	<0.034
Elbow extension	33.2 ± 18.7°	0.8 ± 2.0°	<0.01
Elbow supination	45 ± 21.4°	77.5 ± 11.7°	<0.039
Elbow pronation	60 ± 8.4°	80 ± 8.4°	<0.004
Grip strength	26.3 ± 20.1 N/m ²	32.2 ± 23.4 N/m ²	0.078

Table 4

Objective physical outcome measures – patients without HO.

	Affected arm	Unaffected arm	p value
Elbow flexion	133.2 ± 9.5°	140.8 ± 4.9°	0.058
Elbow extension	11.7 ± 12.9°	0.8 ± 2°	0.115
Elbow supination	81.5 ± 2.3°	80.8 ± 7.4°	0.793
Elbow pronation	78.5 ± 9°	81.7 ± 6.8°	0.363
Grip strength	37.9 ± 41.1 N/m ²	40.2 ± 36.7 N/m ²	0.367

unaffected sides in flexion (129 vs 140.1), extension (22.4 vs 0.8), supination (63.3 vs 79.2), and pronation (69.3 vs 80.8), with no significant difference ($p \geq 0.05$) noted in grip strength (Table 2). When considered independently, patients with HO had significant differences ($p \leq 0.05$) in extension, flexion, supination, and pronation in their affected elbow compared to their unaffected elbow (Table 3). However, injured elbows with no evidence of HO had no significant differences ($p \geq 0.05$) in their range of motion values or their grip strength when they were compared to their contralateral, uninjured elbows (Table 4).

4. Discussion

HO is known to occur at variable rates following elbow injury or surgery. Incidence varies from 3% to 49%.^{16,36,37} Risk factors for HO include genetic predisposition, soft tissue injury, neurologic factors, and systemic factors. The results for radial head replacement for fracture can be found in Table 5. It is now accepted that replacement of the radial head for a comminuted proximal radius fracture is a valid treatment option and provides reproducible long-term results. One study by Harrington et al. described follow-up of a mean of 12 years and 20 patients with 16 good to excellent results and no implant-related problems.³⁸ A recent, randomized controlled trial comparing radial head replacement with open reduction and internal fixation for comminuted radial head fractures showed a statistically decreased risk of complications and higher patient satisfaction scores in the radial head replacement group.³ There were no reported cases of HO in their radial head replacement group, yet they failed to note whether or not these patients received NSAIDs and/or radiation treatment. Moro et al. showed significant loss of elbow flexion, extension, and supination in the affected extremity when compared with the unaffected extremity in his group of 27 patients that underwent radial head replacement for fracture.²² HO occurred in eight of the 25 (32%) patients evaluated. They gave 20 of the 27 patients HO prophylaxis; however, they failed to note whether or not the

patients who developed HO were those that received prophylaxis. Doornberg et al. noted 13 cases of HO (48%) following radial head arthroplasty for comminuted fractures. His group had an average flexion contracture of 20° in his series of 27 patients.⁴ Four of these patients required reoperation to release their contracture. Grewal et al. prospectively followed 28 patients who had radial head replacement with a modular, smooth stem prosthesis for unreconstructable fracture.⁵ Seventeen of twenty-eight patients received prophylaxis for HO for 3 weeks or oral indomethacin. Mild yet significant differences in operative and nonoperative side range of motion and power were observed. These results are similar to the findings in the present investigation, although there was no loss of grip strength in the current study. They had six cases of HO and offered two surgical revisions for stiffness. Unfortunately, they did not delineate whether or not HO affected the ultimate range of motion nor did they note whether the indomethacin was protective against HO development.

Efficacy of radiation therapy for high-risk patients following hip fracture or total hip arthroplasty is well documented in the literature.^{39–44} The role of radiation therapy in the elbow is less clear. McAuliffe et al. showed good results with early excision of HO when completed in conjunction with postoperative radiation therapy.⁴⁵ Heyd et al. showed an improvement in the Morrey score from 33.3 to 84.5 points following surgical HO resection and postoperative low-dose radiation therapy with no recurrences of HO.⁴⁶ Used in a preventative manner, Egol et al., on the other hand, noted a 27% incidence of HO in those proximal radius fractures treated with ORIF and postoperative low-dose radiation. There were, however, no functional limitations in 10 of 11 patients. Radiation therapy has several advantages: it is delivered locally with no systemic effects, which limit the effects on distant fractures; it is not dependent on gastric absorption, which can vary from patient to patient; and it is not dependent on patient compliance. There are reported cases of sarcoma following HO prophylaxis dosing radiation, albeit exceedingly rare.⁹

There have been multiple randomized controlled trials suggesting that indomethacin and radiation are both effective in decreasing the rates of HO following total hip or acetabular fracture. NSAIDs are not free from side effects.^{25,47–51} NSAIDs have varying degrees of ulcerogenic potential and can also have nephrotoxic, cardiotoxic, and neurotoxic effects. The results of NSAID therapy for radial head replacement, however, are somewhat confusing. Some note they reserve NSAID therapy for those who are medically acceptable candidates.^{5,22} Viola and Hanel showed a significant increase in flexion/extension arc as well as pronation/supination arc at 2 years following simple release with 5 days of indomethacin and sucralfate.³³ They did not routinely check radiographs postoperatively, so the recurrence rate of HO is unknown. Moro et al. prescribed 20 of 27 patients who underwent radial head replacement with six weeks of indomethacin and misoprostal, yet 8/25 (32%) patients developed HO.²² It was not clearly defined what percentage of these patients had received prophylaxis. Grewal et al. prophylaxed 17/28 patients who underwent radial head replacement for fracture with 3 weeks of indomethacin.⁵ They had 6 cases of HO and noted more significant HO in two patients who were not administered indomethacin; but with regard to the remainder of patients who developed HO, it is not clear if they were in the group that received chemical prophylaxis or not. It is impossible to know from either of these studies if the prophylaxis had any impact on the HO rates.

We noted a 50% incidence in HO in our patients, none of whom received any prophylaxis. This is higher than most reports in the literature; however, some studies report up to a 32% HO rate even with prophylaxis. Some studies note a significant increase in those whose surgery is delayed more than 72 h. We had no significant difference in HO formation in those patients whose surgery was

Table 5

Studies of acute RHA for comminuted or unreconstructable radial head fractures.

Study Author and year	Number of patients	Results	HO prophylaxis?	HO	Incidence of reoperation
Chen et al., 2011 ³	22	20/22 good to excellent results with arthroplasty. Significantly fewer complications vs ORIF. 2 patients with a motion deficit >30°	Unknown	No HO noted in radial head replacement group	None
Lim et al., 2008 ⁵²	6	Avg flexion contracture 20°. Avg loss of flexion 25°. Avg pronation 40°, average supination 50°	Unknown	1 of 6	Unknown
Doornberg et al., 2007 ⁴	27	Avg flexion contracture 20°. Avg flexion 131°. Avg pronation 73°, avg supination 57°	Unknown	13 of 27	26% were reoperated on. 5 total surgeries for stiffness
Zhao et al., 2007 ⁶	10	Avg flexion contracture 10°, avg loss of extension 13°. Avg pronation and supination losses were 9.3 and 11.1°, respectively	Unknown	0 of 10	None
Grewal et al., 2006 ⁵	28	Significant losses in elbow flexion, extension, supination, and grip strength	Indomethacin 25 mg po tid × 3 weeks in 17/28 pts	6 of 26	2 patients offered surgical release for stiffness
Ashwood et al., 2004 ²	16	Significant loss of flexion in all 4 ranges. Mean flexion contracture 15°, avg loss of flexion 10°, avg loss of pronation and supination 12°	Indomethacin × 6 weeks	0 of 16	Unknown
Moro et al., 2001 ²²	24	Significant loss of elbow flexion, extension, and supination. Significant loss of strength in affected extremity	Indomethacin and misoprostal × 6 weeks	8 of 25	Unknown
Judet et al., 1996 ⁵³	12	Mean flexion contracture 12.5°, mean total flexion 115°, mean supination 68°, mean pronation 74°	"NSAIDs are prescribed"	Unknown	Unknown
Knight et al., 1993 ⁵⁴	31	Mean flexion contracture was 20°, loss of flexion 10°, loss of pronation and supination was 10°	Unknown	At least 1	At least 3
Harrington et al., 2001 ⁵⁵	22	Mean loss of flexion and extension strength was 10% and 13%, respectively Mean loss of pronation and supination strength 13% and 19%, respectively. Mean loss of grip strength 13%	Unknown	8 of 22 (presence of HO did not correlate to functional scores)	4 patients for removal of implants
Popovic et al., 2007 ⁵⁶	51	Mean flexion averaged 130°; extension, 14°; supination, 71°; and pronation, 68°. The mean functional arc of motion was 116° (range 50–135°). Mean grip strength significantly reduced	Unknown	21 of 51	Unknown

delayed more than 72 h. This could be a result of our small sample size. Some consider HO incidence to increase with increasing soft tissue damage. Notably, of the three patients with "terrible triad" injuries in our cohort, none developed HO or needed revision surgery. Numerous studies suggest a decreased range of motion following radial head replacement for fracture; none of these studies have correlated their results with the presence or absence of HO. Our results suggest that the patients who develop HO have a statistically significant increased risk of reoperation. They also have statistically significant postoperative range of motion deficits. When the cohorts are grouped (as in all previous studies), the total cohort also shows these differences. The same is not true of the patients who failed to develop HO when we considered them independently. They had no difference in range of motion or grip strength on affected and unaffected sides.

The results of radiotherapy and NSAID therapy are outlined above. There are conflicting results as to the efficacy of both following elbow injury. Given that most radial head replacements no longer rely on bony in-growth, the results of the study from

Hamid et al. are of less concern in this instance.²⁶ The prosthesis used in this study is designed for bony ongrowth; however, we do not believe this to be the scope or focus of this paper. Our results suggest that control of HO following radial head arthroplasty may directly impact final range of motion. There are data to suggest that poor elbow range of motion leads to lower patient-oriented outcome scores,⁵² although these data were not collected during this investigation. The literature does not clearly support either NSAIDs or radiation therapy for elbow HO; however, both have been shown to be effective in total hip arthroplasty and acetabular fracture. We believe it is reasonable to employ these methods following radial head arthroplasty if there are no patient-specific contraindications to their use.

There are several limitations in our study. Patients were identified retrospectively; yet with prospective data gathering, we were able to use each patient as their own control. There were two patients that were not available to be included in the measurements. One of these patients required revision surgery to treat HO, and the other had neither. Additionally, the small number of

patients who have an injury that is amenable to radial head arthroplasty (Mason Type-III or Mason–Johnson Type-IV) limits our sample size. We also failed to collect patient-oriented outcome scores for our patients. These could have been useful in defining their disability with limitations in range of motion, although this is clearly documented in the literature.⁵⁷

Additional studies, including prospective, randomized studies, would be useful in determining the clinical significance of HO following radial head replacement. It would also be useful to know the efficacy of radiation therapy and/or NSAIDs in preventing HO following radial head arthroplasty.

5. Conclusion

Formation of HO following radial head arthroplasty predicts significantly lower postoperative range of motion and increases the risk of reoperation. The currently available literature does not support or refute the use of NSAIDs or radiotherapy following radial head arthroplasty. We recommend prophylaxis against HO with NSAIDs or radiotherapy if there are no direct patient contraindications, given the negative effect of HO following radial head arthroplasty. More studies are needed to clearly define each of their roles in this setting.

Conflicts of interest

The authors have none to declare.

References

- Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg*. 1954;42(September (172)):123–132.
- Ashwood N, Bain GI, Unni R. Management of Mason type-III radial head fractures with a titanium prosthesis, ligament repair, and early mobilization. *J Bone Jt Surg Am*. 2004;86-A(February (2)):274–280.
- Chen X, Wang SC, Cao LH, Yang GQ, Li M, Su JC. Comparison between radial head replacement and open reduction and internal fixation in clinical treatment of unstable, multi-fragmented radial head fractures. *Int Orthop*. 2011;35(July (7)):1071–1076.
- Doornberg JN, Parisien R, van Duijn PJ, Ring D. Radial head arthroplasty with a modular metal spacer to treat acute traumatic elbow instability. *J Bone Jt Surg Am*. 2007;89(May (5)):1075–1080.
- Grewal R, MacDermid JC, Faber KJ, Drosdowech DS, King GJ. Comminuted radial head fractures treated with a modular metallic radial head arthroplasty. Study of outcomes. *J Bone Jt Surg Am*. 2006;88(October (10)):2192–2200.
- Zhao J, Yang S, Hu Y. The early outcomes with titanium radial head implants in the treatment of radial head comminuted fractures. *J Huazhong Univ Sci Technol Med Sci*. 2007;27(December (6)):681–683.
- Ring D. Displaced, unstable fractures of the radial head: fixation vs. replacement – what is the evidence? *Injury*. 2008;39(December (12)):1329–1337.
- Pike JM, Athwal GS, Faber KJ, King GJ. Radial head fractures – an update. *J Hand Surg Am*. 2009;34(March (3)):557–565.
- Farris MK, Chowdhry VK, Lemke S, Kilpatrick M, Lacombe M. Osteosarcoma following single fraction radiation prophylaxis for heterotopic ossification. *Radiat Oncol*. 2012;7:140.
- Herbertsson P, Josefsson PO, Hasselius R, Besjakov J, Nyqvist F, Karlsson MK. Fractures of the radial head and neck treated with radial head excision. *J Bone Jt Surg Am*. 2004;86-A(September (9)):1925–1930.
- Ikeda M, Oka Y. Function after early radial head resection for fracture: a retrospective evaluation of 15 patients followed for 3–18 years. *Acta Orthop Scand*. 2000;71(April (2)):191–194.
- Morrey BF, Tanaka S, An KN. Valgus stability of the elbow. A definition of primary and secondary constraints. *Clin Orthop Relat Res*. 1991;(April (265)):187–195.
- Lindenhovius AL, Felsch Q, Doornberg JN, Ring D, Kloen P. Open reduction and internal fixation compared with excision for unstable displaced fractures of the radial head. *J Hand Surg Am*. 2007;32(May–June (5)):630–636.
- Ring D, Adey L, Zurakowski D, Jupiter JB. Elbow capsulectomy for posttraumatic elbow stiffness. *J Hand Surg Am*. 2006;31(October (8)):1264–1271.
- Lindenhovius AL, Linzel DS, Doornberg JN, Ring DC, Jupiter JB. Comparison of elbow contracture release in elbows with and without heterotopic ossification restricting motion. *J Shoulder Elbow Surg*. 2007;16(September–October (5)):621–625.
- Ilahi OA, Strausser DW, Gabel GT. Post-traumatic heterotopic ossification about the elbow. *Orthopedics*. 1998;21(March (3)):265–268.
- Hastings 2nd H, Graham TJ. The classification and treatment of heterotopic ossification about the elbow and forearm. *Hand Clin*. 1994;10(August (3)):417–437.
- Bimmel R, van Riet RP, Sys J. Heterotopic ossification causing proximal radioulnar synostosis after insertion of a radial head prosthesis. *J Hand Surg Br*. 2006;31(August (4)):383–384.
- Garland DE. Early excision of heterotopic ossification about the elbow followed by radiation therapy. *J Bone Jt Surg Am*. 1998;80(March (3)):453–454.
- Abrams RA, Simmons BP, Brown RA, Botte MJ. Treatment of posttraumatic radioulnar synostosis with excision and low-dose radiation. *J Hand Surg Am*. 1993;18(July (4)):703–707.
- Rubenstein JH, Salenius SA, Blitzer PH, Katin MJ, Dosoretz DE. Prevention of heterotopic bone formation with low dose radiation therapy. *J Fla Med Assoc*. 1992;79(December (12)):828–832.
- Moro JK, Werier J, MacDermid JC, Patterson SD, King GJ. Arthroplasty with a metal radial head for unreconstructible fractures of the radial head. *J Bone Jt Surg Am*. 2001;83-A(August (8)):1201–1211.
- Tielemans MM, Eikendal T, Jansen JB, van Oijen MG. Identification of NSAID users at risk for gastrointestinal complications: a systematic review of current guidelines and consensus agreements. *Drug Saf*. 2010;33(June (6)):443–453.
- Beehrle DM, Evans D. A review of NSAID complications: gastrointestinal and more. *Lippincotts Prim Care Pract*. 1999;3(May–June (3)):305–315.
- Bjorkman DJ. Current status of nonsteroidal anti-inflammatory drug (NSAID) use in the United States: risk factors and frequency of complications. *Am J Med*. 1999;107(December (6A)):35–8S. discussion 85–10S.
- Hamid N, Ashraf N, Bosse MJ, et al. Radiation therapy for heterotopic ossification prophylaxis acutely after elbow trauma: a prospective randomized study. *J Bone Jt Surg Am*. 2010;92(September (11)):2032–2038.
- Stein DA, Patel R, Egol KA, Kaplan FT, Tejwani NC, Koval KJ. Prevention of heterotopic ossification at the elbow following trauma using radiation therapy. *Bull Hosp Jt Dis*. 2003;61(3–4):151–154.
- Aldridge 3rd JM, Atkins TA, Gunneson EE, Urbaniak JR. Anterior release of the elbow for extension loss. *J Bone Jt Surg Am*. 2004;86-A(September (9)):1955–1960.
- Cohen MS, Hastings 2nd H. Operative release for elbow contracture: the lateral collateral ligament sparing technique. *Orthop Clin N Am*. 1999;30(January (1)):133–139.
- Cohen MS, Hastings 2nd H. Post-traumatic contracture of the elbow. Operative release using a lateral collateral ligament sparing approach. *J Bone Joint Surg Br*. 1998;80(September (5)):805–812.
- Mansat P, Morrey BF. The column procedure: a limited lateral approach for extrinsic contracture of the elbow. *J Bone Jt Surg Am*. 1998;80(November (11)):1603–1615.
- Marti RK, Kerkhoffs GM, Maas M, Blankevoort L. Progressive surgical release of a posttraumatic stiff elbow. Technique and outcome after 2–18 years in 46 patients. *Acta Orthop Scand*. 2002;73(April (2)):144–150.
- Viola RW, Hanel DP. Early “simple” release of posttraumatic elbow contracture associated with heterotopic ossification. *J Hand Surg Am*. 1999;24(March (2)):370–380.
- Ring D, Jupiter JB. Operative release of ankylosis of the elbow due to heterotopic ossification. Surgical technique. *J Bone Jt Surg Am*. 2004;86-A(March (suppl 1)):2–10.
- Jupiter J. Heterotopic ossification about the elbow. *Instr Course Lect*. 1991;1991(40):41–44.
- Thompson 3rd HC, Garcia A. Myositis ossificans: aftermath of elbow injuries. *Clin Orthop Relat Res*. 1967;50(January–February):129–134.
- Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. *J Bone Jt Surg Am*. 1986;68(June (5)):669–674.
- Harrington JJ, Sekyi-Otu A, Barrington TW, Evans DC, Tuli V. The functional outcome with metallic radial head implants in the treatment of unstable elbow fractures: a long-term review. *J Trauma*. 2001;50(January (1)):46–52.
- Ayers DC, Everts CM, Parkinson JR. The prevention of heterotopic ossification in high-risk patients by low-dose radiation therapy after total hip arthroplasty. *J Bone Jt Surg Am*. 1986;68(December (9)):1423–1430.
- Ghalambor N, Matta JM, Bernstein L. Heterotopic ossification following operative treatment of acetabular fracture. An analysis of risk factors. *Clin Orthop Relat Res*. 1994;(August (305)):96–105.
- Hedley AK, Mead LP, Hendren DH. The prevention of heterotopic bone formation following total hip arthroplasty using 600 rad in a single dose. *J Arthroplasty*. 1989;4(December (4)):319–325.
- Kolb O, Knelles D, Barthel T, Kraus U, Flentje M, Eulert J. Randomized trial comparing early postoperative irradiation vs. the use of nonsteroidal antiinflammatory drugs for prevention of heterotopic ossification following prosthetic total hip replacement. *Int J Radiat Oncol Biol Phys*. 1997;39(December (5)):961–966.
- Knelles D, Barthel T, Karrer A, Kraus U, Eulert J, Kolb O. Prevention of heterotopic ossification after total hip replacement. A prospective, randomised study using acetylsalicylic acid, indomethacin and fractional or single-dose irradiation. *J Bone Joint Surg Br*. 1997;79(July (4)):596–602.
- Burd TA, Lowry KJ, Anglen JO. Indomethacin compared with localized irradiation for the prevention of heterotopic ossification following surgical treatment of acetabular fractures. *J Bone Jt Surg Am*. 2001;83-A(December (12)):1783–1788.
- McAuliffe JA, Wolfson AH. Early excision of heterotopic ossification about the elbow followed by radiation therapy. *J Bone Jt Surg Am*. 1997;79(May (5)):749–755.
- Heyd R, Strassmann G, Schopohl B, Zamboglou N. Radiation therapy for the prevention of heterotopic ossification at the elbow. *J Bone Joint Surg Br*. 2001;83(April (3)):332–334.
- Aly A. NSAID-induced ulcer and its complications. *Nord Med*. 1997;112(June (6)):195–197.
- Berthelot JM, Maugars Y. Complications of NSAID gastropathy and use of gastric cytoprotection: experience at a tertiary care health center. *J Rheumatol*. 2000;27(May (5)):1322.

49. Frech EJ, Go MF. Treatment and chemoprevention of NSAID-associated gastrointestinal complications. *Ther Clin Risk Manag.* 2009;5(February (1)):65–73.
50. Graham DY, Smith JL. Gastroduodenal complications of chronic NSAID therapy. *Am J Gastroenterol.* 1988;83(October (10)):1081–1084.
51. Hansen JM, Hallas J, Lauritsen JM, Bytzer P. NSAID and ulcer complications. An analysis of risk factors. *Ugeskr Laeger.* 1997;159(June (24)):3787–3791.
52. Lim YJ, Chan BK. Short-term to medium-term outcomes of cemented Vitallium radial head prostheses after early excision for radial head fractures. *J Shoulder Elbow Surg.* 2008;17:307–312.
53. Judet T, Garreau de Loubresse C, Piriou P, Charnley G. A floating prosthesis for radial-head fractures. *J Bone Jt Surg Br.* 1996;78:244–249.
54. Knight DJ, Rymaszewski LA, Amis AA, Miller JH. Primary replacement of the fractured radial head with a metal prosthesis. *J Bone Jt Surg Br.* 1993;75:572–576.
55. Harrington IJ, Sekyi-Otu A, Barrington TW, Evans DC, Tuli V. The functional outcome with metallic radial head implants in the treatment of unstable elbow fractures: a long-term review. *J Trauma.* 2001;50:46–52.
56. Popovic N, Lemaire R, Georis P, Gillet P. Midterm results with a bipolar radial head prosthesis: radiographic evidence of loosening at the bone-cement interface. *J Bone Jt Surg Am.* 2007;89:2469–2476.
57. Lindenhovius AL, Buijze GA, Kloen P, Ring DC. Correspondence between perceived disability and objective physical impairment after elbow trauma. *J Bone Jt Surg Am.* 2008;90(October (10)):2090–2097.