Distal humeral hemiarthroplasty: indications, results, and complications. A systematic review

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Abstract

Background Distal humeral hemiarthroplasty (DHH) is a treatment option for unreconstructable intra-articular distal humerus fractures. DHH may also be used in the setting of rheumatoid arthritis, orthopaedic tumor with significant bone loss, malunion, or osteomyelitis. DHH has specific advantages over other, more common, treatment modalities: total elbow arthroplasty (TEA) and open reduction internal fixation (ORIF). DHH is especially a reasonable option in younger patients to preserve bone stock, avoid significant weight restrictions, and limit loosening.

Methods The literature was reviewed for all cases of DHH for fracture and non-fracture indications between 1947 and 2014. Two hundred thirty-six papers were identified; 4 studies including 17 patients met criteria for non-fracture indications and 13 studies including 116 patients were identified for fracture indications. A systematic review was generated; patient indications, outcomes, and complications were recorded. **Results** For non-fracture indications, good to excellent results were achieved in 76.5 % of patients with a mean arc of motion of 62° at mean follow up of 46.3 months. Half of the patients experienced a complication, most commonly stiffness. Loosening of the prosthesis was not noted in any patient. For fractures, good to excellent results were achieved in 67.4 % of patients with a mean arc of motion of 98.3° at a mean follow up of 42.2 months. One third of the patients

experienced a complication but only 1.7 % experienced loosening of the prosthesis.

Conclusion Here, we present the first review of the indications for DHH. DHH is a reasonable treatment option for older patients with unreconstructable intra-articular fractures of the distal humerus as well as younger patients with rheumatoid arthritis, orthopaedic tumor with significant bone loss, malunion, or osteomyelitis.

Keywords Elbow arthroplasty · Distal humerus fracture · Rheumatoid arthritis

Introduction

In 1947, Mellen and Phalen [23] created custom acrylic implants for young active duty soldiers with complex intra-articular fractures of the distal humerus at a US Army Hospital. Since then, distal humeral hemiarthroplasty (DHH) has most frequently been described for treatment of unreconstructable fractures of the distal humerus [1, 5, 13, 19, 29] (Fig. 1a, b). However, indications have expanded to include painful rheumatoid elbow [30, 31], ankylosis [30], osteomyelitis [3, 26], and tumor [26].

The most commonly utilized surgical treatment options in these settings include total elbow arthroplasty (TEA) [8, 11, 24] and open reduction internal fixation (ORIF) [15, 32]. While TEA offers the advantage of complete removal of diseased articular surface, DHH has specific advantages over TEA. DHH may afford a lower surgical time [5], does not introduce polyethylene particulate debris [9], is less subject to component loosening [6, 11], and may be more suitable for a younger patient that may not tolerate the weight restrictions [2, 12, 14, 17, 25]. TEA also has the disadvantage of significantly limited weight restriction and has a high rate of loosening [6, 11]. In addition, an unacceptably high rate of

Informed consent is not necessary in this study, as it is a review of previously published literature.

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Fig. 1 **a** Postoperative AP X-ray of distal humeral hemiarthroplasty in a 74-year-old woman who sustained a comminuted intra-articular fracture of the distal humerus. DHH was the index procedure in this case. **b** Postoperative lateral X-ray of distal humeral hemiarthroplasty in the same patient

unsatisfactory outcomes in the treatment of intra-articular distal humerus fractures has been reported in ORIF [15].

While DHH use in fractures is well described [1, 5, 13, 19, 29], other indications are not well-studied and consist primarily of case reports and short series. In this systematic review, we will highlight the indications, results, and complications for both the fracture and non-fracture indications for DHH. This investigation is the largest analysis of DHH patients in the literature.

Materials and Methods

Literature Search

A systematic review of the literature was performed. We used PubMed to search all years through May 2014 with combinations of search terms: distal humerus/ humeral hemiarthroplasty/ arthroplasty/ replacement, elbow hemiarthroplasty/ arthroplasty/ replacement. Two independent reviewers assessed methodology and quality of each study. We extracted homogenous data from studies which met the inclusion/exclusion criteria and generated frequency-weighted means. A meta-analysis was performed when data was sufficiently homogenous.

Inclusion/Exclusion Criteria

The inclusion criteria for the studies were as follows: (1) published in English, (2) involving distal humeral hemiarthroplasty, not including radiocapitellar or total elbow arthroplasties, (3) reported at least one of the primary outcomes of interest including MAYO score, disability of the arm

shoulder and hand score (DASH), American shoulder and elbow score (ASES), or ROM. The exclusion criteria were as follows: (1) any review or technique article, or biomechanical study, and (2) if two studies involved the same patient cohort but one at a later time point with more patients, the later study would be used and the earlier excluded. If a study involved a mixed cohort of patients who received DHH for both fractures as well as other indication, the individual data for the patients of interest was extracted. Two authors independently performed electronic searches. Abstracts with clearly or potentially relevant titles were browsed for relevance to DHH and included as appropriate. If a title was clearly irrelevant, it was excluded. If an abstract met inclusion/exclusion criteria, the authors reviewed the entire text to verify qualification. Additionally, the authors manually reviewed all references from all studies that met the inclusion/exclusion criteria to generate a list of qualifying studies not identified on the electronic searches. Both authors met and conferred at this point. There was no discrepancy between their findings.

Data Extraction

We extracted and analyzed study design, demographic variables, indications for surgery, outcomes, and complications. The two authors independently extracted the data, then conferred and compiled the data, correcting any discrepancies.

Statistical Analysis

The weighted averages were calculated for the demographic and outcome data. Categorical data such as complications were pooled from the studies and used to determine the overall complication rate. For each variable, the calculations were

performed out of the total number of patients or elbow which reported that variable. The authors assessed each aforementioned data set for homogeneity. Heterogenous data was excluded from meta-analysis. If the data was homogenous, we performed a chi-squared statistic.

Results

Study Retrieval and Characteristics

Our searches generated 236 different articles. Two hundred fifteen articles were excluded based on the clear irrelevance of the title. From these remaining 21, 10 more were excluded after abstract review based on being review articles (5) or biomechanical studies (2), or written in a language other than English (3). We retained one article which included DHH performed for 5 patients with fractures as well as 5 for other indications. We also extracted 7 additional articles during the manual reference check (2 case reports and 5 case series) that were not found during the primary search. The full text of these remaining 15 articles was reviewed and all met the inclusion/exclusion criteria but 2, one which involved the same patient cohort at a later follow-up and one which involved total elbow arthroplasty instead of DHH.

Our systematic review produced 4 primary articles with 17 patients for analysis for non-fracture indications and 13 primary articles with 116 patients for fractures. None of the articles were of the same author. Study characteristics are shown. Two studies were more recent, published between 2001 and 2014. The remaining two studies were published between 1970 and 2000. All studies were level IV evidence, consisting of case series with no control or comparative groups.

Patient Demographics

Fractures

We extracted data on 116 patients with 116 elbows from the 13 primary studies. The patients demographics were pooled (Table 1). Complete patient demographics with regard to age, sex, and mechanism were provided by almost all the studies. The average age was 62.2 years and the majority was female. Fracture patients were statistically older as compared to other indications ($p < 0.0005$) and more likely to be female ($p = 0.048$) (Table 1).

Of the 116 elbows which represented 87.2 % of the literature, 63.7 % were intra-articular, 90.2 % were comminuted, and 5.1 % were open. Falls represent 79.3 % of the fracture cases (Table 1), motor vehicle collisions (11.3 %), blast

Table 1 Patient demographics

Characteristic	N	%	Studies reporting	P value
Total fracture (Fx) elbows	116	87.2	13	
Total other (Ot) elbows	17	12.8	4	
Fx follow up (mean, mo)	42.2	–	13	
Ot follow up (mean, mo)	46.3	–	4	
Age (mean, year) Fx	62.2	–	13	<0.0005
Age (mean, year) Ot	31.8	–	4	
Gender (F) Fx	56	72.7	11	0.048
Gender (F)	8	42.9	4	
Fx mechanism: fall	42	79.3	13	
Fx type: intra-articular	72	63.7	13	
Fx type: comminuted	102	90.2	13	
Fx type: open	6	5.1	13	
Ot indication: RA	10	58.8	4	
Ot indication: Sarcoma	3	17.7	4	
Ot indication: ankylosis	2	11.8	4	
Ot indication: OM	2	11.8	4	

injuries (3.8 %), crush injuries (3.8 %), and gunshot wounds (1.9 %) represented the other fracture mechanisms.

Olecranon osteotomy was performed in 72.1 % of elbows and ulnar nerve transposition in 76.7 % of fracture cases. All studies included the type of prosthesis. Half (50.0 %) utilized the Latitude prosthesis, followed by 29.3 % with the Sorbie–Questor prosthesis, and 6.9 % with the Kudo prosthesis. Various older units were utilized in the earlier studies, including the acrylic (3.5 %), nylon (3.5 %), Vitallium (2.6 %), stainless steel (2.6 %), and titanium (1.7 %) custom designs.

Non-Fractures

We extracted data on 14 patients and 17 elbows from the 4 primary studies. The patients demographics were pooled (Table 1). Complete patient demographics with regard to age, sex, side, and mechanism were provided by almost all the studies. The average age was 31.8 years and mostly men.

Of the 17 elbows which represented 12.8 % of the literature, 58.8 % underwent DHH for rheumatoid arthritis, 17.7 % for sarcoma, 11.8 % for hemophilia, and 11.8 % for osteomyelitis (Table 1).

All studies included type of prosthesis. The majority of patients received the Sorbie–Questor prosthesis (41.2 %) (Wright Medical Technology, Arlington, TN). Various older units were utilized in the earlier studies, including the titanium (23.5 %) and stainless steel (5.9 %) custom designs.

Outcomes

Fractures

The mean follow-up was 42.2 months. Most studies reported good or excellent outcomes (12), flexion-extension range of motion (13), and prono-supination range of motion (9) (Table 2). Overall, 67.4 % of patients experienced good to excellent outcomes at final follow-up. This was not statistically different than the non-fracture cohort ($p=0.581$). The weighted average flexion-extension and prono-supination arcs were 98.3 and 160°, respectively. Fewer studies, mostly more recent studies, reported standardized objective outcomes including the Mayo elbow performance score (MEPS) (6), American shoulder and elbow score (ASES) (6), and disability of the arm shoulder and hand (DASH) score (4). Of those that did, the weighted averages were found to be 83.4 for the MEPS, 66.2 for the ASES, and 22.8 for the DASH score. Roughly, half (6) of the studies reported a structured postoperative rehabilitation program for all patients.

Non-Fracture Indications

The mean follow-up was 46.3 months. Most studies reported good or excellent outcomes (4), and flexion-extension range of motion (3), and prono-supination range of motion (1) (Table 2). Overall, 76.5 % of cases experienced good to excellent outcomes at final follow-up. The weighted average flexion-extension and prono-supination arcs were 61.8 and 116.5° for all studies including each of those variables. Arc of motion was superior in the fracture cohort in terms of both flexion-extension ($p<0.0005$) and prono-supination ($p<0.0005$) (Table 2). Only one study addressed standard postoperative rehabilitation (1) and only for 2 of the patients. Standardized objective outcome scores were not well recorded in this cohort.

Complications

Fracture

A total of 37 patients (31.9 %) underwent a total of 38 reoperations (32.8 %) for various intra- and postoperative complications. Overall, 27.6 % of patients experienced at least 1 complication. Overall there were 85 complications among the 116 patients. The most common complication was hardware irritation (34.1 %), followed by neuropathy (16.5 %), and laxity (16.5 %). Other less common complications included fracture (either intra- or postoperative) (9.4 %), pain (7.1 %), stiffness (5.9 %), infection (2.4 %), heterotopic ossification (2.4 %), osteoarthritis (2.4 %), loosening (1.7 %) and to an even lesser extent weakness (1.2 %), posterolateral rotatory instability (1.2 %), and wound breakdown (1.2 %).

Table 2 Results and complications

Characteristic	N	%	P value
Fx good-excellent	58	67.4	0.581
Ot good-excellent	13	76.5	
Fx FE ROM (mean, arc°)	98.3	—	<0.0005
Ot FE ROM (mean, arc°)	61.8	—	
Fx PS ROM (mean, arc°)	160	—	<0.0005
Ot PS ROM (mean, arc°)	116.5	—	
Fx complications	37	27.6	0.264
Ot complications	7	50	
Fx reoperations	38	32.8	0.268
Ot reoperations	3	17.6	

Neither the rate of complications ($p=0.264$) nor the rate of reoperations ($p=0.268$) was statistically significant between the two groups (Table 2).

Non-Fracture Indications

A total of 3 patients (17.7 %) underwent a total of 3 reoperations (17.7 %) for various intra- and postoperative complications. Overall, 50.0 % (7) of the patients experienced at least 1 complication. Overall there were 11 complications among the 14 patients. The most common complication was stiffness (54.6 %), followed to a much lesser extent by neuropathy (9.1 %), infection (9.1 %), heterotopic ossification (9.1 %), wound breakdown (9.1 %), and hardware failure (9.1 %). No cases of loosening were reported.

Discussion

This review highlights both the fracture and non-fracture indications of DHH; the latter of which include rheumatoid arthritis, tumor, osteomyelitis, and malunion. By investigating the results of 133 cases of reported DHH in the English language literature, this work represents the most complete analysis of DHH.

Patients undergoing DHH for fractures were more likely to be female ($p=0.048$) and were nearly twice as old as compared to the non-fracture patient ($p<0.0005$). Rheumatoid arthritis (RA) accounted for 59 % of cases of non-fracture use of DHH. Swoboda et al. [31] published a series of seven DHH for primarily young patients with RA. All patients were females with an average age of 33 years. While one patient underwent explant following metastatic disease, the patients uniformly achieved excellent pain relief but achieved only an average arc of motion of 74°. Despite the poor range of motion, the authors proposed the benefit of DHH was the preservation of bone stock. The authors affirmed the most suitable patients for DHH are younger patients with smaller

bone. Street et al. reported on ten cases of DHH, three of which were patients with RA [30]. The average age of these three patients was 31. Similar to the findings Swoboda et al. [31], excellent pain relief was achieved yet the arc of motion was only 23°. Auto-fusion was encountered in two of the three patients. Complete lack of follow-up and physical therapy are likely factors in the poor range of motion in this series. In addition, the authors used DHH in the treatment of two elbows in one patient elbow ankylosis secondary to hemophilia. Despite regimented physical therapy, postoperatively, the patient developed significant heterotrophic ossification and was limited to an arc of motion of 20° bilaterally.

In addition to RA, DHH has also been used in the treatment and reconstruction of orthopaedic tumors. Scaglioni et al. [26] published a series of four patients in which DHH was used for reconstruction with vascular pedicles and free fibula head flaps. The series included two patients with Ewing sarcoma. Postoperatively, a 15-year-old boy had a 90 % functional rating according to the American Musculoskeletal Tumor Society (AMTS) score. One 4-year-old boy with Ewing sarcoma was also treated with DHH and had a postoperative AMTS score of 83. The series also contained two cases of osteosarcoma.

The series also contained two cases of osteomyelitis. DHH represents a reasonable treatment option in the young and active patient with bony destruction of the distal humerus secondary to tumor. One 53-year-old patient achieved an AMTS score of 90 at 18-month follow-up with no signs of infection, while a 27-year-old male had a postoperative score of 76 [26]. Barnea et al. [3] reported the third case of distal humerus reconstruction for osteomyelitis in a 53-year-old man which had been unsuccessfully treated with repeated irrigation, debridement, and long-term antibiotics. The patient underwent resection of the distal two thirds of the humerus and humeral spacer insertion in the first stage. The second stage included fibular shaft graft in which the fibular head was used to articulate with the olecranon process. At 18-months follow-up, the patient had a functional elbow without signs of infection. Although this case report does not use the DHH prosthesis, it does represent a novel means of distal humeral reconstruction.

While most patients undergoing DHH for non-fracture indications have tolerable functional results, most of the patients do not gain functional range of motion. Patients averaged 62° of flexion-extension and 117° pronosupination. Both of these were significantly less than the fracture cohort ($p < 0.005$). Inability to complete physical therapy because of secondary medical comorbidities may contribute to this finding. Also preoperative range of motion may have been less in the non-fracture group, as some patients were being treated for elbow ankylosis, although this data was not recorded.

Older females contributed a significant portion of cases to the fracture cohort. In fact, nearly 80 % of the fracture cases in

the literature occurred via fall. Burkhart et al. [5] published a series of DHH for 10 female patients with an average age of 75 years. Of these, 8 were for comminuted, osteoporotic distal humerus fractures, while 2 were for revisions of failed open reduction internal fixation. At 12 months, patients had an average of 124° arc of motion, a DASH score of 11.5, and a MEPS score of 91.3. Despite the complex fractures and poor bone quality in these elderly female patients, there was no evidence of loosening, radiographic lucency, bone resorption, or progressive radio-ulnar osteoarthritis at follow up. The authors conclude that the reduced operative time afforded by a hemi-prosthesis should make DHH a consideration for the treatment of elderly comorbid patients with complex distal humeral fractures. Adolfsson et al. [1] treated 8 elderly females with an average age of 80 years with DHH, using a triceps splitting approach with radial head excision, who achieved a MEPS of 90.6 and an arc of 95°.

The second most frequently reported population in the fracture cohort were young, high demand patients with complex fractures of the distal humerus. The vast majority of fracture cases in this analysis were both intra-articular and comminuted. Hohman et al. [13] treated 8 patients with comminuted, unreconstructable intra-articular distal humerus fractures. At a mean 36-months follow up, of the 5 patients who had an acute operation, the average MEPS and DASH scores were 80 and 31, respectively; and the arc of motion was 96°. Smith et al. [29] published the largest reported cohort of DHH for distal humerus fractures including 26 patients with an average age of 60 years. At 80 months, the average MEPS and DASH scores were 90 and 19, respectively; and arc of motion was 116°. The authors noted unique complications to use of hemiarthroplasty in young patients. Ulnar wear and spur formation occurred in over half of the patients in the study; however, it was not noted if these radiographic findings were clinically significant.

There was a higher complication rate in the non-fracture cohort (50 vs. 27.6 %); these values were not statistically different ($p = 0.264$). In addition, there was a trend toward a higher reoperation rate in the fracture cohort (32.8 vs. 17.6 %). Although the external validity of these findings is limited by the small sample size collected over 67 years, it is possible that they are still clinically relevant. In the non-fracture cohort, 2 of the 17 elbows had preoperative ankylosis which significantly increased the reported postoperative stiffness (6 of 17), which was reported as a complication. In the future, a regimented physical therapy program may limit stiffness. Other reported complications in younger patients included screw breakage [4], transient neurapraxia [5], and were generally less severe than those seen in older patients. Older patients experienced wound infections [5], periprosthetic fracture, [1], and conversion to TEA. [29] However, the functional results from DHH in younger patients have not been quite as favorable [28], especially in older series [4, 5, 32]. Younger patients have

more functional demands than older, more sedentary patients and thus may experience more discomfort and functional limitations with DHH. However, the functional restrictions of the DHH are significantly fewer than the TEA option [20]. Also, earlier papers tended to be the younger cohorts which generally had irregular follow up, limited physical therapy, and inconsistent outcome measurements.

While in the present analysis, only 2 of the 134 cases resulted in loosening; loosening is an especially worrisome and frequent complication of TEA. In a systematic review of total elbow arthroplasty, accounting for 3618 reported TEAs, Little et al. [20] reported the average loosening rate of 9 % and radiolucency rate of 14 %. In 23 TEAs at 48-month follow up, Schneidberger et al. [27] reported a loosening rate of 17 %. The authors elicited specific risk factors, namely poor cementing technique and anterior ulnar impingement. Equal rates of loosening occurred between the humeral and ulnar components in this study, which has been reported elsewhere as well [16, 21, 22]. However, isolated ulnar component loosening is a well-described complication of TEA and has been the cause of revision surgery [10, 18]. In a series of ten semiconstrained TEA, Cheung [7] proposed that prosthesis pullout was perpetuated by pistoning of the ulnar component in the cement mantle. Limiting potential bony impingement in elbow hyperflexion and precise placement of the ulnar component must be ensured to minimize loosening. While it is likely that loosening occurs equally between humeral and ulnar components, DHH does not appear to loosen at the same rate as TEA [16, 21, 22, 27]. In addition, ulnar bone stock is preserved making DHH a more suitable choice in younger patients with unreconstructable distal humerus fractures.

The lack of standardized outcome measurements and consistent follow up are limitations to our analysis. The DHH literature is limited, therefore our analysis lacks power. The case series that do exist are short, often times with limited or irregular follow up, and thus afford non-statistically significant odds ratios. We are unable to utilize certain statistical analyses such as the correlation test, as the power of the test depends on the number of studies included. In meta-analyses with fewer than 25 studies, the correlation test will be nonsignificant and will not rule out bias in the literature search [8]. In addition, there is limited data on more contemporary RA patients treated with DHH. In 1999, Swoboda et al. [31] reported on 7 patients with RA. While disease modifying antirheumatic drugs have changed the course of disease progression in the upper extremity, it is possible that the cases of DHH in this patient demographic may be limited in the future. However, it is worth anecdotally noting that in 2013–2014, the senior author has used DHH twice in elderly patients with RA.

DHH is most typically used for intra-articular fractures of the distal humerus in older patients as well as younger patients with RA or tumor. DHH offers preservation of bone stock without the postoperative restrictions required by TEA.

Although this report highlights the poor range of motion many patients experienced, pain relief is reliable. Future research may be directed at prosthesis design. Currently, there is only one prosthesis available to surgeons in the USA (Tornier; Saint-Ismier Cedex, France). While this prosthesis is both anatomic and modular, it lacks soft tissue attachments and it does not have elongated stem or press-fit options. In addition to product design, prospective analysis should be directed at forming regimented physical therapy protocol and outcome measures should be more carefully recorded.

Conflict of Interest John Dunn declares that he has no conflict of interest.

Nicholas Kusnezov declares that he has no conflict of interest.

Miguel Pirela-Cruz declares that he has no conflict of interest.

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