SCIENTIFIC ARTICLE

Epidemiology and Treatment of Radial Head Fractures: A Database Analysis of Over 70,000 Inpatient Cases

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Purpose We aimed to study the epidemiology of radial head fractures within a single national registry database while analyzing trends in available treatments.

Methods A retrospective analysis of data from 2007 to 2016 provided by a national inpatient database registry was performed using the International Classification of Diseases code for radial head fractures and associated German Procedure Classification (OPS) codes. All surgical interventions were evaluated according to fracture type, patient sex and age, and distribution differences over the last decade to detect changes in the treatment trends. The number of major revision procedures was identified and the revision burden for each procedure calculated.

Results Overall, 70,118 radial head fractures were included, with the annual number rising over 20% during this period. Women were significantly older than men (peak incidence, 55−64 years vs 30−39 years) and more frequently injured (women-to-men, 1.3:1). Surgical interventions increased during the study period, with locking plate fixation of comminuted fractures and radial head arthroplasty (RHA) becoming increasingly performed while radial head resections decreased. The revision burden differed significantly between the fixation techniques, with an increased occurrence of RHA revision procedures more recently.

Conclusions The data show a higher number and incidence of surgical procedures, especially for comminuted radial head fractures over the study period. Open reduction and internal fixation remains the most frequently used option, with the use of new fixation devices (eg, locking plates) increasing. The use of RHA more than doubled over the past 10 years while the number of radial head resections decreased. *(J Hand Surg Am. 2020;■(■):1.e1-e8.* *Copyright © 2020 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Prognostic II.

Key words Radial head fracture, radial head arthroplasty, screw fixation, locking-plate, epidemiology.

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RADIAL HEAD FRACTURE is one of the most frequently occurring fractures in adults, with an incidence of 1.7% to 5.4% of all fractures and about one-third of fractures around the elbow. Historically, most fractures have been reported to occur in patients 20 to 60 years of age, with a variable male-to-female ratio of 1:2 to 1:1.[1,2] However, recent publications have provided some slightly different insights into the epidemiology of radial head fractures, with only a few large database studies currently available in the literature.[3–5]

Whereas nondisplaced and stable and partially displaced articular fractures can be successfully treated nonsurgically,[6,7] most comminuted fractures require surgical treatment. Although Mason[2] originally suggested resection of comminuted fractured radial heads, numerous other surgical techniques have been described over the past decades. Treatment strategies range from open reduction and internal fixation (ORIF) with screws, plates, K-wires, or biodegradable pins, to implantation of a prosthesis or radial head resection. However, restoration of severely comminuted fractures remains challenging and is prone to hardware failure or nonunion. In these cases, radial head arthroplasty (RHA) is often considered the treatment of choice, even though revision and removal rates remain high in some series and larger long-term studies are still lacking.[8,9] With the evolving surgical techniques and implant designs and improved knowledge of these fractures, the actual impact of these advances remains to be determined. There are currently only a few established nationwide fracture databases and only one larger registry study,[10] so most observations have been performed at single institutions with relatively small numbers of patients. Although informative, these smaller studies cannot identify changes in the incidence or treatment trends. Therefore, the purpose of this study was to examine the epidemiology of radial head fractures and to evaluate the trends in treatment approaches using a large, registry-based database. As a secondary objective, we tried to evaluate whether the promising results of RHA in the past and present literature may have led to an increased utilization in the context of radial head fracture during the study period.

MATERIALS AND METHODS

We conducted a retrospective analysis of data provided by the Federal Statistical Office of Germany (FSOG). This database includes all inpatient cases based on disease classification codes and procedures performed at all German hospitals and medical institutions. The data were acquired using the International Statistical Classification of Diseases and Related Health Problems, 10th Edition (ICD-10) codes and the associated German Procedure Classification codes (OPS), which is the official classification system for coding surgical procedures in Germany.

A database query was performed to identify all patients older than 18 years with an ICD-10 code of S52.11 (radial head fracture) and its associated OPS codes (Table 1). Isolated radial neck fractures and undefined fractures of the proximal radius were excluded. Owing to the design of the database, no outpatient treatment modalities could be assessed. However, most surgeries for radial head fractures have historically been performed in an inpatient setting in Germany.

The statistical analysis was mainly descriptive to determine the annual trends in different surgical procedures and the differences in age and sex distributions. Nonsurgical treatment number was evaluated by subtracting the total number of surgeries from the total number of reported radial head fractures. Owing to the anonymization of the diagnosis-related group data, we could not reidentify patients who underwent a revision and, therefore, could not provide exact risk estimates of the different surgical procedures. Instead, we used the revision burden (RB) as a surrogate parameter for an estimated revision rate per year, as defined by the Swedish hip arthroplasty registry, and previously used in other studies from this database.[11,12] For that, we divided the number of major revision procedures (hardware removals, revision arthroplasty, explantation) by the number of all primary and revision procedures for every year.

Analysis of variance, chi-square tests, and 2-tailed z tests for proportions were used where appropriate. A P value less than .05 was considered statistically significant. The study was conducted in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines.

No investigational or ethical review board approval was required for this study.

RESULTS

From 2007 to 2016, a total of 70,118 inpatient radial head fractures were reported in Germany and could be included in this study. During this period, the annual number rose from 6,343 in 2007 to 7,566 in

TABLE 1. Associated OPS Codes Used in this Study (ORIF: Open Reduction and Internal Fixation)

OPS Code	Description
5-793.14	ORIF of a simple radial head fracture with screws
5-794.04	ORIF of a multifragmentary radial head fracture with screws
5-793.34	ORIF of a simple radial head fracture with a plate
5-794.24	ORIF of a multifragmentary radial head fracture with a plate
5-793.k4	ORIF of a simple radial head fracture with a locking plate
5-794.k4	ORIF of a multifragmentary radial head fracture with a locking plate
5-824.3	Radial head arthroplasty
5-829.k	Additional code for modular prosthesis (a prosthesis is considered "modular," if it contains 3 or more parts, which ensure in their combination the mechanical component safety of the entire prosthesis)
5-782.24	Radial head resection
5-787.14	Screw removal (radial head)
5-787.34	Plate removal (radial head)
5-787.k4	Locking plate removal (radial head)
5-825.3	Revision radial head arthroplasty
5-825.9	Explanation of a radial head prosthesis

FIGURE 1: Annual number of inpatient radial head fractures reported in Germany between 2007 and 2016.

2016, which represents an increase of about 20% (Fig. 1).

Considering the current population growth derived from the national (annual) population reports, the annual incidence of inpatient radial head fractures changed significantly from 9.1 per 100,000 inhabitants to 10.9 per 100,000 ($P < .05$) over the 10-year period This increase may be mainly attributed to an increased number of patients older than 65 years, a number that more than doubled during that 10-year period (Fig. 2).

Almost 57% of the radial head fractures occurred in women, leading to a sex-based ratio of 1:1.3 men:women over that time period. Regarding the age distribution, a significant difference was observed between men and women ($P < .05$). The peak incidence of radial head fractures among female patients occurred between 55 and 64 years of age compared with a peak incidence among male patients, which was between 30 and 39 years.

During the study period, we saw a rising number of surgical interventions, while the number of nonsurgically treated radial head fractures significantly decreased (Table 2). Procedures undertaken in comminuted conditions represented the main portion at about 58% and this number steadily increased over the 10-year study period.

Considering the current common fixation techniques, screw fixation was performed in most cases with simple and comminuted radial head fractures, although no distinction between the different screw implants could be made based on the data available (Fig. 3).

However, throughout the course of the study, we detected substantial trends in the treatment of comminuted radial head fracture. First, there was an almost 2.5-fold increase in plate fixations, from 312 cases in 2007 to 778 cases in 2016, with the number of angular-stable locking plate procedures rising more than 10-fold. Simultaneously the number of RHAs performed in the context of a radial head fracture exhibited a rise of about 105%, with the greatest increase occurring in patients older than 65 years (Fig. 4).

In 2013, an additional ICD-10 code for modular prothesis was introduced. Since then, modular RHAs performed have almost tripled (from 32 to 93 cases).

In contrast, radial head resections were significantly less frequently performed over the study period and were instead more frequently used in patients older than 60 years ($P < .05$).

During the study period, a total of 3,071 major revision procedures for radial head fractures were documented, with screw fixation showing the lowest and nonlocking plate fixation the highest RB (Table 3). In this group, locking plates showed a significantly lower RB compared with nonlocking plates ($P < .05$). In RHA, the number of revision RHAs performed from 2007 to 2016 nearly doubled (n = 21 in 2007; n = 49 in 2016), while explantations

FIGURE 2: Annual proportional share of patients older and younger than 65 years of age with a radial head fracture between 2007 and 2016.

TABLE 2. Management of Radial Head Fractures Between 2007 and 2016*

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total	6,343	6,565	6,767	6,873	7,189	7,238	7,042	7,159	7,376	7,566
Surgical	4,351	4,619	4,880	5,361	5,605	5,650	5,589	5,707	6,094	6,424
Nonsurgical	1,992	1,946	1,887	1,512	1,584	1,588	1,453	1,452	1,282	1,142
% Surgery	68.6	70.4	72.1	78.0	78.0	78.1	79.4	79.7	82.6	84.9

*Total numbers given.

significantly decreased at the same time (from 10.6% in 2007 to 5.8% in 2016).

DISCUSSION

Surgical treatment strategies for radial head fractures have changed over the years.

Based on our data, we identified an increasing number of radial head fractures, with an even higher increase in surgical treatment over the study period. Although screw fixation remains the main treatment option, there has been a significant increase in the use of locking plates and RHAs, and a notable decrease in radial head resections. Although the total number of revision procedures increased over the years, the RB remained unchanged.

In 2010, Kaas et al[4] investigated the epidemiology of 328 radial head fractures at a single institution and found an estimated incidence of 2.8 per 100,000 inhabitants with a male-to-female ratio of 2:3. This was consistent with previously published data on radial head fractures.[13,14] In addition, a significant difference in the age distribution was reported, with the peak age incidence for women being 10 to 15 years higher than for men (37–41 years vs 48–54 years, respectively). These results are similar to those of the present study. Based on our data, the incidence of radial head fractures peaked between 55 and 64 years of age in women and between 30 and 39 years in men. However, the incidence of radial head fractures (9.1 to 10.9 per 100,000 inhabitants) in this study was considerably lower in the aforementioned study. This can probably be explained by the fact that our database only contains inpatient cases. However, many non- or minimally displaced radial head fractures can be treated in an outpatient setting.[15]

FIGURE 3: Treatment of *simple* radial head fractures between 2007 and 2016.

Furthermore, our study revealed an increase in surgical treatment, with a rising incidence in older patients. As previously confirmed by Kaas et al,[16] radial head fractures show characteristics of typical osteoporotic fractures, which may be one explanation for the increasing number of surgeries performed for comminuted conditions in our study. In addition, it may also be possible that these changes are attributable to our sample that only contained inpatient cases, which usually tend to be the more severe injuries and regularly require surgery. However, we also assumed that an enhanced understanding of the importance of the radial head in elbow kinematics[17,18] and the growing number of studies reporting excellent results with low complications after surgical interventions[19,20] may have led to a higher rate of radial head surgeries in the past 10 years.

However, the best surgical treatment method is still a topic of ongoing controversy. In a large meta-analysis of 841 clinical studies, Zwingmann et al[20] reported the outcomes of different surgical treatments for radial head fractures. According to those authors, screw fixation showed the best success rate for more complex radial head fractures, which may be the reason why screw fixation was the most common treatment option, in both simple (91.0% of all procedures) and comminuted radial head fractures (79.8%) in our study. This is also in line with the findings of the largest study cohort of RHF in Northern America,[10] that also reported that ORIF has the highest share among all surgical treatment methods for RHF.

However, in displaced articular fractures, screw fixation alone may be unsatisfactory when the radial head articular surface must be stabilized to the shaft.[21] In these cases, plate fixation can be a sufficient treatment option.[22–25] Several plate designs have been described in recent years,[24–28] with anatomically preshaped plates presumably providing the best results with relatively low complication rates.[24,25,28] However, despite good clinical results, hardware removal may be required in many cases of plate fixation.[26] These findings were consistent with those of our study because we observed an almost 2.5-fold increase in the overall rate of plate fixation and a greater than 10-fold increase in locking plate fixation over the past decade, although the RB was the highest among the different fixation techniques. However, we also found a lower RB for locking plates than for nonlocking plates. This may be related to a lower risk for secondary displacement of the fractures, when using locking screws, and also to the low-profile design of most locking-plates, which aims to decrease hardware irritation issues.[24,25]

Although ORIF with screws and plates can provide excellent clinical results even in comminuted cases, anatomical restoration can be challenging, or even impossible, for highly comminuted articular fractures.[29] For this reason, Ring et al[30] suggested that ORIF is best reserved for fractures with 3 or fewer articular fragments, whereas attempting fixation in patients with more than 3 fragments at the site of an unstable, displaced fracture risks fixation failure, fragment nonunion, and/or osteonecrosis[31] and may lead to unpredictable restrictions of ulnohumeral and forearm motion.[32] In these patients, radial head resection or RHAs are the most suitable options.

Although some authors reported acceptable clinical outcomes following acute radial head resection,[1,2,26,33,34] biomechanical studies,[3,18,35] show that radial head resection alters elbow kinematics, increases varus-valgus instability even with intact ligaments, and accelerates the appearance of long-term complications such as proximal radial migration, persistent pain, decreased strength, and degenerative osteoarthritis.[33,36,37] Therefore, radial head resection should only be considered for highly selected patients, with no concomitant capsuloligamentous injuries. Accordingly, we found a nearly 40% decrease in radial head resection over the past 10 years, with an associated shift toward its use in elderly patients.

In contrast, RHA helps to stabilize elbows with traumatic instability when stable fixation of a multifragmentary articular fracture of the radial head is not possible,[38–40] and it also provides more predictable functional results.[30,31,41–44] Correspondingly, a recent national database study of orthopedic

FIGURE 4: Number and share of different surgical treatment options in *comminuted* cases from 2007 to 2016 (in total).

TABLE 3. RB for Different Surgical Options in the Management of Radial Head Fractures per Year

RB (%)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	All
Screw fixation	4.6	3.7	3.8	3.4	3.4	3.6	3.3	3.5	3.6	3.2	**3.6**
Nonlocking plate	30.5	26.6	25.2	23.9	21.9	24.4	24.8	26.6	19.9	18.5	**24.2**
Locking plate	10.6	16.4	10.7	18.1	17.6	11.8	12.9	13.7	17.7	13.6	**14.6**
RHA	14.6	10.6	9.9	11.5	13.0	12.6	13.5	10.4	11.5	10.4	**11.7**

insurance records showed that the rates of arthroplasty were significantly higher when associated with further injuries around the elbow, particularly in the setting of a coronoid fracture or elbow dislocation.[10] A variety of implant designs are available (bipolar-monopolar, monoblock-modular, smooth-roughened surface, cemented-uncemented) and have mostly been associated with good outcomes in short- and mid-term follow-up.[41–46] Some authors favor modular implants because they allow the surgeon to alter the height and diameter of the prosthesis to facilitate accurate reconstruction.[21,46,47] In addition, the reimbursement for these prostheses tends to be higher in Germany, which also has to be considered when interpreting our data.

Overall, the present study identified that the number of RHAs performed more than doubled from 2007 to 2016, with a concomitant increase in the number of modular prostheses since 2013. However, the number of RHA revisions increased as well, although the RB showed no significant change over time. These findings reflect the trends in the current literature. In a recently published meta-analysis of 8 studies, Sun et al[19] compared the outcomes of ORIF and RHA in patients with comminuted radial head fractures. In their study, RHAs afforded a higher satisfaction rate, better elbow scores, shorter surgical times, and a lower incidence of bone resorption and internal fixation failure than ORIF.

However, there is still a lack of evidence regarding the long-term results with these prostheses, although a few studies have reported acceptable results with moderate complications even in long-term follow-up.[48,49] For comminuted fractures in low-maintenance or elderly patients with poor bone stock, RHA seems to be a sufficient treatment option,[10] which is confirmed by our study because the share of patients older than 65 years had the highest increase in RHAs during the observation period.

This study had some limitations, which were mainly associated with the database design. First, owing to the fact that the data are derived from a national hospital inpatient registry, the total incidence rate was underestimated because these registries only include hospitalized patients and exclude patients treated in outpatient emergency departments. Therefore, no conclusions could be drawn regarding the actual proportion of surgical and nonsurgical radial head fracture treatments or whether there has been an actual change in practice toward surgical treatment, given that most non- or minimally displaced fractures can be treated without hospital admission. In addition, it may have also been possible that a rising number of radial head fractures had been treated in an outpatient setting over the course of this study, especially in the light of cost containment, leading to an underestimation of the actual numbers. Furthermore, the data, especially on surgical treatment, shown in this study may be biased in terms of injury severity because it may be possible that only the more severe injuries were addressed by hospital admission. However, most radial head surgeries are still performed in an inpatient setting in Germany, which has not been the case for other countries like the United States. In addition, our focus was rather on the trends of surgical procedures than on the actual total numbers because trends are much less likely to be heavily biased during a 10-year period. The data were anonymized, which meant that individual follow-up for each patient, including reporting of the outcome, the identification of specific factors regarding short- or long-term complications, actual revision rates, or implant survival, was not possible. In addition, large registries are always limited by possible coding issues, for example, the accurate differentiation of simple and comminuted fracture types.

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