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Trends in surgical management of proximal humeral fractures in adults: a nationwide study of records in Germany from 2007 to 2016

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Abstract

Introduction Proximal humeral fractures (PHF) are among the most common adult fractures. However, valid epidemiologic population-based data, including differentiation of treatment modalities, are lacking.

Materials and methods Using the ICD codes and associated OPS codes for PHF, a retrospective analysis of 2007–2016 Federal Statistical Office of Germany data was performed. Data were evaluated for total incidence of PHF as well as total use, annual utilization rates, age, and sex distributions of all associated surgical procedures. Simple linear regressions were performed to evaluate trends in treatment modalities.

Results There were 642,556 cases of PHF. During the study period, incidence changed substantially from 65.2 to 74.2 per 100,000 inhabitants with a significant rise in elderly (> 70 years) patients ($P < 0.001$). The number of surgical procedures increased by 39%, with locking plate fixation being the most common procedure (48.3%), followed by intramedullary nailing (IMN) (20.0%), hemiarthroplasty (HA) (7.5%), K-wire fixation (6.4%), and reverse shoulder arthroplasty (RSA) (5.6%). The utilization rate increased for locking plates, K-wires, and RSA and decreased for HA and IMN. Particularly, the utilization of RSA exhibited a > eightfold increase. Significant linear correlation of procedure and time were found for all surgical treatments.

Conclusions During this period, the number of inpatient PHFs, especially in the elderly, increased. Although locking plate fixation remained the most common treatment method, RSA had the greatest proportional increase over time, supporting its growing popularity in the light of the current scientific evidence. This incline was offset by a corresponding decrease in HA and IMN, which may be related to a growing knowledge of their application limitations.

Level of evidence Descriptive epidemiology study, large database analysis.

Keywords Proximal humeral fractures · Treatment patterns · Hemiarthroplasty · Reverse shoulder arthroplasty · Locking plate · Epidemiology

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Introduction

Proximal humerus fractures (PHFs) account for about 6% of all adult fractures [1] and are the third-most common fracture in patients aged > 60 years. Based on recent literature, the age- and sex-specific incidence rate of PHF varies from 10 to 300 per 100,000 inhabitants in different populations [2, 3]. According to Palvanen et al. [3] these numbers are expected to rise even more in the next couple of years, mainly due to an increase of osteoporotic fractures among the elderly.

Most of the fractures are undisplaced or minimally displaced [4] and thus can successfully be treated nonoperatively [5–7]. Although the latest meta-analysis by Beks et al. [8] recommended a non-operative approach even in displaced fractures of the elderly, an increase in the use of surgical management of these fractures has been reported, with currently over 30% of fractures being treated operatively [2, 7, 9, 10]. However, the best treatment method, still remains controversial [11–14]. A variety of different methods can be used for surgical treatment of PHF, including closed reduction and percutaneous fixation (CRPF), closed or open reduction and internal fixation (CRIF and ORIF), and arthroplasty. In particular, locking plate technology has clearly resulted in an increased number of patients undergoing a surgical procedure [2, 7, 9], although complication rates remain rather high [15–18]. If anatomic reduction is not attainable, shoulder arthroplasty often remains the only surgical option. In the past, hemiarthroplasty (HA) has been the treatment of choice in these cases. However, since Bufuquin et al. [19] first reported about the use of reverse shoulder arthroplasty (RSA) in PHFs in 2007, there has been growing evidence that RSA provides equal or even superior outcomes compared to HA [20–22]. This paradigm shift has already led to a significantly decreasing use of HA in the U.S. population over the last couple of years [9, 23]. Despite the advances in surgical options and techniques for the management of PHF, multiple systematic reviews have been unable to provide evidence-based recommendations in selecting an optimal treatment method for PHF fixation [24, 25]. With new technologies evolving and an increased knowledge about the chances and limits of surgical procedures of the proximal humerus, the aim of the current study was to detect the current epidemiologic trends of PHF and to assess the incidence and trends in the surgical treatment of PHF over the last decade.

Material and methods

A retrospective analysis of the public data provided by the Federal Statistical Office of Germany (FSOG) was conducted. This database includes all annual surgical procedures based on the coding of diseases and procedures performed by all German hospitals and medical institutions. The data is based on the International Statistical Classification of Diseases and Related Health Problems, Tenth Edition (ICD-10) and the German procedure classification system (OPS), which is the official classification system for encoding surgical procedures in Germany.

A query of the database was conducted for all patients who sustained a PHF by using the ICD-10 code S42.2. At the same time, the associated OPS codes for primary procedures including CRPF (5-790.11), intramedullary nailing (IMN) (5-790.41, 5-790.51, 5-793.a1/b1, 5-794.a1/b1) and ORIF by K-wire (5-793.11, 5-794.11), by screw (5-793.11, 5-794.01), by locking plate (5-793.k1, 5-794.k1), as well as HA (5-824.01), and RSA (5.824.21) were analysed. Furthermore, an analysis of fracture-type subgroups of S42.2 was performed to investigate possible differences in managing these fractures.

The statistical analysis was mainly descriptive in order to determine the annual trends of utilization for each treatment method as well as the differences in age and gender distributions. Total number of patients not requiring surgery was calculated by substracting the number of surgeries performed for PHF from the total number of PHF for each year. Incidence was measured by dividing the total amount by the overall population number per year. Age subgroup analysis was performed for those older than 70 years of age (elderly). Metric data were represented as mean and standard deviation with the minimum and maximum. Simple linear regression analyses were performed for each treatment modality to evaluate current treatment trends. Analysis of variance, linear regressions, Chi-squared test, and two-tailed z tests for proportions were used where appropriate. A p value of < 0.05 was considered statistically significant. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp).

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

Results

Overall incidence

From 2007 to 2016, a total of 642,556 PHFs were reported in Germany. During this decade, the annual numbers rose from 53,553 in 2007 to 61,231 in 2016, which represents an increase of about 14.3%. With regard to the current population growth in Germany, the annual incidence changed substantially from 65.2 to 74.2 per 100,000 inhabitants ($P < 0.001$), with a significant difference between men (38 per 100,000 person-years) and women (108 per 100,000 person-years). Regarding age distribution, 70.5% of all reported PHFs occurred among elderly patients (Fig. 1), with the peak incidence of PHFs in female patients occurring between the

ages of 75 and 85 years as compared with the peak incidence in male patients that occurred between the ages of 65 and 75 years. During the study period, there was also a substantial shift of fracture incidence towards elderly patients (Table 1), as evidenced by an increase of the age-adjusted incidence in this age group from 280.0 to 351.4 per 100,000 ($P < 0.01$).

Table 1 Annual incidence of proximal humerus fractures in elderly patients (per 100,000 person-years)

Year	*m*	*w*
2007	83	323
2008	89	334
2009	96	340
2010	108	360
2011	119	354
2012	102	353
2013	104	355
2014	100	347
2015	122	384
2016	124	392

Surgical treatment

In line with the rising number of PHFs, the number of all surgical interventions also increased by 38.8% during the observation period, with about 68.9% of all procedures being performed in elderly patients. ORIF was used in 72.1% of all cases, followed by CRIF (14.5%), and shoulder arthroplasty (13.4%). However, as joint replacement showed a steady increase over time, the number of ORIF procedures remained nearly constant (Fig. 2). Locking plate fixation was the most commonly used procedure, accounting for about 48.3% of all surgical interventions, followed by IMN (20.0%), HA (7.5%), ORIF by K-wires (6.4%), an RSA (5.6%). As the number and rate of fractures treated with CRPF (1.0%) were very low during the entire study period, they were excluded from further analysis (Fig. 3).

During this 10-year period, the total number of locking plates showed a significant increase by the year 2010 (+ 46.3%) and remained nearly constant within the subsequent period, with a mean annual utilization rate (of all surgical procedures) of 49.3% over the last 5 years. At the same time, the utilization rate of non-locking plates (−4.8%), as well as intramedullary nails (− 9.3%) substantially decreased over the course of the study, whereas the numbers of ORIF by K-wire showed an over fivefold increase, mainly rising in the elderly patients.

Regarding fracture arthroplasty during the last decade, we saw almost a doubling in the total number of implanted shoulder prostheses per year. Although, overall, HA (57.1%) was used more frequently than RSA (42.9%), the number of RSA rose from 586 in 2007 to 5977 in 2016. Particularly, in elderly patients, the total number of RSA had the highest growth rate of all age groups (+ 1218.2%), although it was also significantly more frequently implanted in younger patients (< 60 years of age) ($P < 0.001$).

At the same time, the number of HA decreased by 52.5%, with the highest regression in patients older than 70 years. However, even in younger patients HA was significantly less frequently used in the last decade (2007: 26.1%; 2016: 8.4%, $P < 0.001$). Corresponding with these

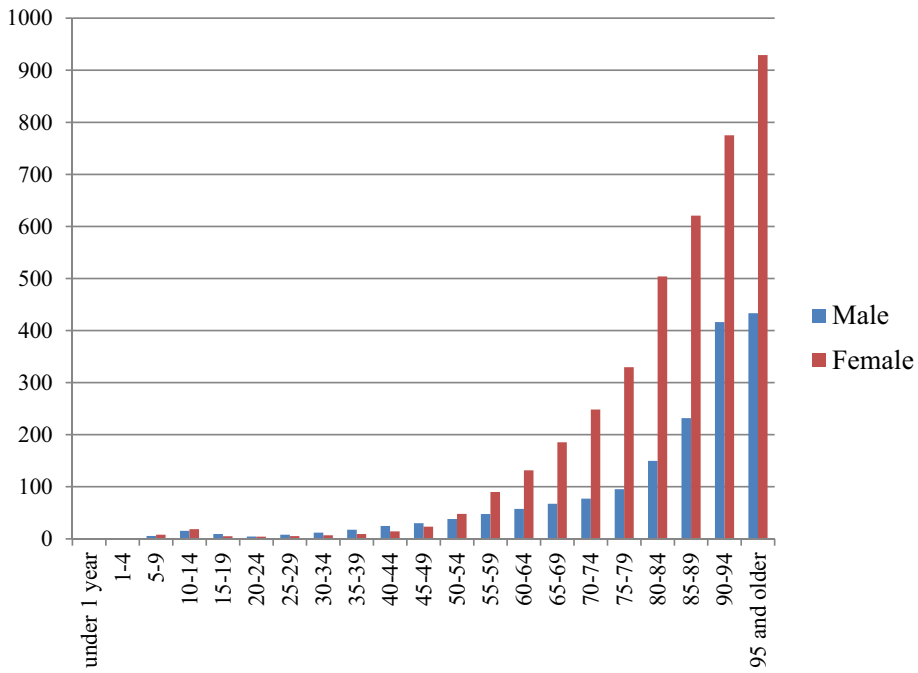

Fig. 1 Age distribution of the incidence of proximal humerus fractures from 2007 to 2016 (per 100,000 person-years)

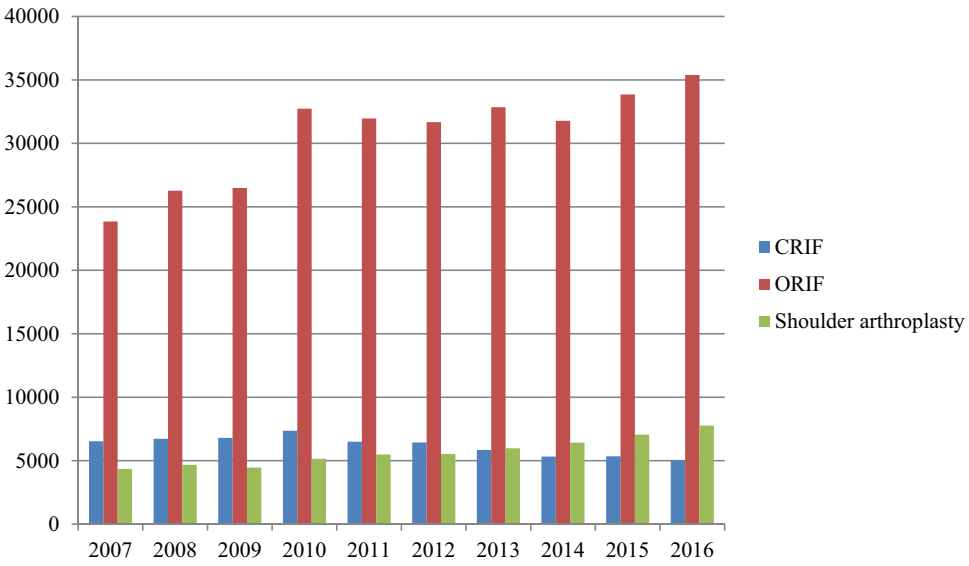

Fig. 2 Total number of closed reduction internal fixation (CRIF), open reduction internal fixation (ORIF), and shoulder arthroplasty per year

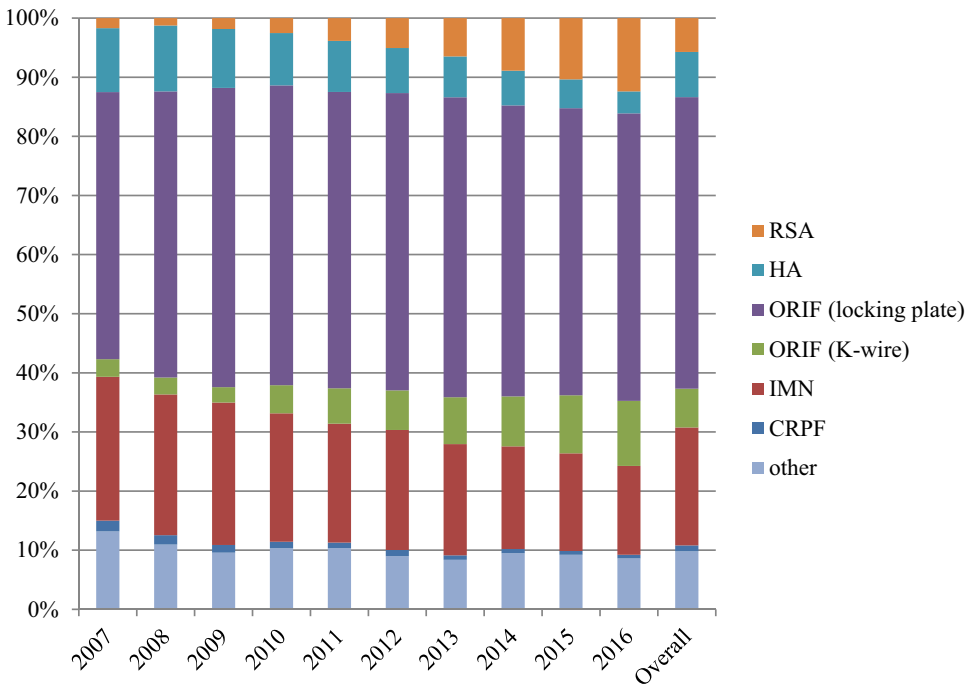

Fig. 3 Differentiation of surgical interventions for proximal humerus fracture per year (in percent of the total; *RSA* reverse shoulder arthroplasty, *HA* hemiarthroplasty, *ORIF* open reduction internal fixation, *IMN* intramedullary nailing, *CRPF* closed reduction percutaneous fixation)

trends, HA was superseded by RSA by the year 2014, with already almost 77.0% of the PHF prostheses coming from RSA in 2016 (Fig. 4).

Taking age and sex distribution into consideration, several procedure-related differences were detected. Under the age of 50 years, the age-standardized ratio was higher for men for all five most common procedures. A relatively balanced sex ratio for osteosynthesis by k-wire, IMN and locking plate, as well as HA was only observed among patients between the ages of 50 and 59 years. The most obvious sex differences could be found in the age group older than 80 years treated with RSA with up to eightfolds higher rates for women than men (Table 2).

During this 10-year period, significant linear correlations of treatment modality and time were found for RSA ($r = +0.963$, $P < 0.001$), HA ($r = -0.919$, $P = 0.002$), locking plates ($r = +0.754$, $P = 0.012$), IMN ($r = -0.735$, $P = 0.016$) and K-wires ($r = +0.974$, $P < 0.001$).

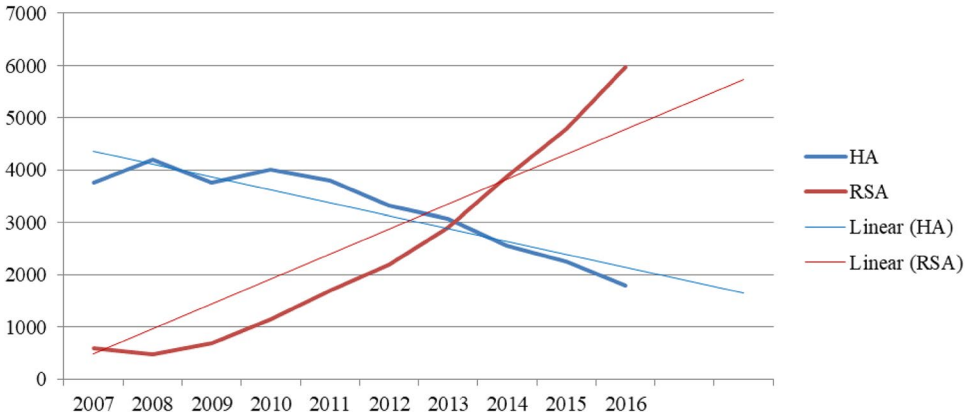

Fig. 4 Perennial total number of hemiarthroplasty (HA) and reverse shoulder arthroplasty (RSA) for proximal humerus fracture (including linear trend line)

Table 2 Gender ratio (female: male) per age group for different surgical procedures

Age	*K*-wires	IMN	Locking plate	HA	RSA
40–50	0.5	0.9	0.7	0.6	0.6
50–60	1.4	1.8	1.8	1.3	4.2
60–70	2.8	2.6	3.0	2.5	3.1
70–80	4.1	3.9	4.6	4.8	5.4
> 80	6.2	5.9	6.4	8.0	7.4
Overall	2.6	2.9	3.0	4.1	5.3

IMN intramedullary nail, *HA* hemiarthroplasty, *RSA* reverse shoulder arthroplasty

Fracture type

According to the ICD-10 classification system, a subgroup analysis for different PHF types was performed using the codes S42.20–S42.29. Fractures of the humeral head were the most common fracture type followed by fractures of the surgical neck, unspecified fractures with multiple fragments including fractures of the minor tuberosity, fractures of the greater tuberosity and anatomical neck fractures (Fig. 5). Regarding treatment specifics, obvious differences could be detected (Table 3). Intramedullary nail fixation was utilised maximally (~ 20%) in fractures of the surgical neck (S42.22) and was least likely used in humeral head fractures (S42.21). In contrast to that, RSA showed its highest utilization rate in humeral head fractures and fractures of the anatomical neck (S42.23), whereas fractures of the greater tuberosity (S42.24) were mainly managed by screw fixation (40.4%).

Discussion

Proximal humerus fractures predominantly affect elderly patients, and with this population group continuously rising, the number of these fractures seen in the inpatient setting are increasing. Between 2007 and 2016, we identified a 14.3% increase in PHF incidence by the year 2011, after which it

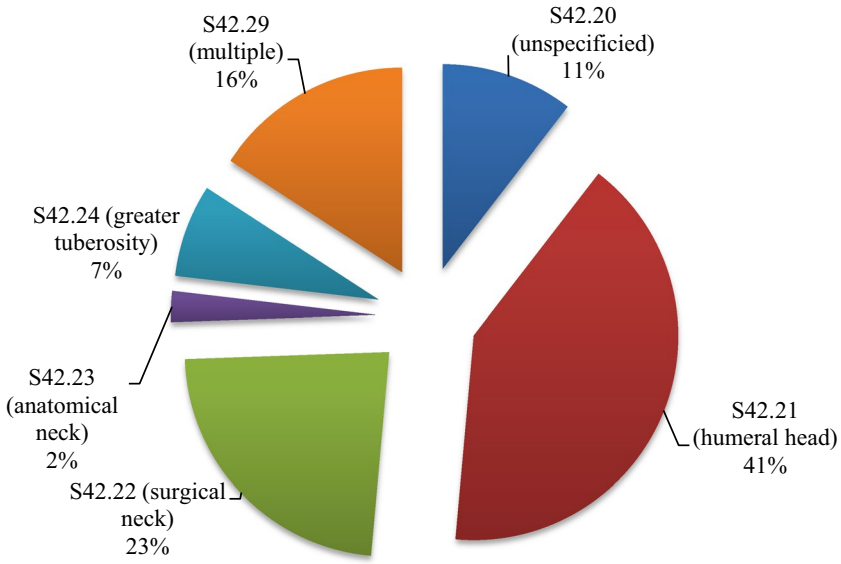

Fig. 5 Overall distribution of different fracture types according to the ICD-10 classification system

Table 3 Surgical procedures for various fracture types according to the ICD-10 classification, between 2007 and 2016

Fracture type	*K*-wire	Screw	IMN	Locking plate	HA	RSA
S42.21 (humeral head)	12,661	5838	21,979	80,950	19,689	14,662
S42.22 (surgical neck)	4517	1403	24,379	43,403	2885	2395
S42.23 (anatomical neck)	898	229	2382	5079	511	355
S42.24 (greater tuberosity)	2498	9343	763	7990	142	212
S42.29 (multiple)	5867	2423	14,145	36,870	5700	4395

IMN intramedullary nail, *HA* hemiarthroplasty, *RSA* reverse shoulder arthroplasty

seemingly levelled off. During this time, women were significantly more frequently affected than men and tended to be older at the time of the fracture. Additionally, the share and age-adjusted incidence of elderly patients significantly increased by about 11.8%, indicating, that these injuries seem to occur more often during the course of the study.,

Although the incidence of PHF appears to vary greatly in Western populations [7, 9, 10, 26], we observed an overall incidence of 73 per 100,000 person-years, which is consistent with the current literature [7, 26].

With the number of PHFs rising, we also found a higher percentage increase in surgical interventions (+38.8%) during the study period, supporting the current literature [7, 9, 10, 26, 27]. Khatib et al. [9] reported the trends of surgical interventions for PHF in New York, US, between 1990 and 2010 and found an almost 40% increase in operative management during that time; presuming, this trend may represent a tendency to a more aggressive treatment in the light of advances in approaches and new fixation devices, as well as an increasing severity of PHF in the elderly (osteoporotic) bone. However, most recent randomized trials have shown equal or even better results using a non-operative approach for PHF, especially in the elderly [5, 11, 12, 28, 29], which emphasizes the current gap between evidence and reality in managing these fractures. Locking plate fixation was the most commonly used procedure within all age groups, and its overall utilization rate rose remarkably till 2010. However, it has slightly decreased since then. Additionally, we could identify a shift in age distribution as we saw a steady decline in age-adjusted incidence for locking plate fixation in the elderly since 2011 with a concomitant increase in patients between 60 and 70 years of age. This may relate to improved bone quality in younger patients than in elderly patients, making fractures in the former more amenable to ORIF. Furthermore, this trend may reflect the conflicts surrounding locking plate technology for PHF. On the one hand, it has extended the indication for joint preserving surgery to fractures that have not been previously considered suitable, as many authors provided good results, even in complex fracture patterns [13, 16, 24, 30]. On the other hand, it has resulted in a greater number of complications and reoperation rates than initially thought [30]. In a systematic review of over 4500 patients, Gupta et al. [24] reported the highest values of functional scores for patients undergoing ORIF, although overall complication (15%) and reoperation rate (12.7%) were significantly higher than HA and RSA. Especially in the elderly population, concerns remain regarding soft-tissue dissection, which may further comprise the already inferior blood supply of the fracture fragments. With the goal of minimizing operation time, blood loss, and surgical trauma, some surgeons have rediscovered minimally invasive techniques [31, 32], which may be why, during the course of our study, fixation by k-wire had the biggest increase within the joint-preserving procedures (+8.0%) in Germany.

Owing to their biomechanical superiority, including higher initial stiffness for valgus, extension, and torsional loading, as well as their minimally invasive implantation, IMN have become an attractive option for PHF for many surgeons in recent years [33, 34]. However, controversies exist regarding their superiority over locking plates [35, 36]. In a most recent meta-analysis of 13 comparative studies, Sun et al. [37] concluded that both procedures have similar performance in terms of the functional scores and total complication rate. In our study, IMN was the second most common surgical treatment with an overall utilization rate of 15% and its highest usage in surgical neck fractures. However, we found a significantly decreasing trend in utilization during our study period, especially in elderly patients. Although the actual reasons are unclear, we hypothesized that along with an aging population, the number of complex fracture types and insufficient rotator cuffs may have risen as well, preventing an adequate indirect reduction of the fracture and thus making other surgical options more suitable.

In many of these cases, replacement of the humeral joint is the only rational option. We identified a steady increase in the number of shoulder arthroplasties for PHF. This increase was mainly attributed to a rapid rise in the use of RSA (from 1.7 to 12.4%) and came with a concomitant decreased utilization of HA between 2007 and 2016 (from 10.8 to 3.7%). These findings are consistent with the current literature [9, 10, 23, 38]. Rosas et al. [23] reported in a study of Medicare patients between 2009 and 2012, that the utilization rate of RSA for PHF nearly tripled for patients older than 65 years (11–29%), whereas HA significantly decreased (from 52 to 39%). However, HA still remained the most common

procedure in their population, which is in contrast to our study as we saw higher utilization rates for locking plates and RSA since 2013 in this age group. These changes likely relate to the growing popularity of RSA as a reliable option for managing complex proximal humeral fractures in the elderly population, because the use of HA has been associated with more unpredictable motion, higher complication rates, and higher rates of unsatisfactory results than RSA [11, 20, 21, 39]. In a most recent meta-analysis of 67 studies conducted by Gallinet et al. [40] RSA was found to provide more reproducible function with better recovery of forward flexion and abduction, as well as lower revision rates than HA.

Although long-term studies are still lacking, Sabesan et al. [10] indicated that RSA will continue to become even more prevalent in the treatment of PHF based on their analysis of the National Inpatient Sample (NIS) database in the United States, which could also be supported by our linear regression model.

This study has some limitations. First, due to the fact, that the data are derived from a national hospital inpatient register, the total incidence rate is underestimated, as these registers include only hospitalized patients and exclude patients treated on outpatient emergency departments. Therefore no specific number could be drawn regarding the proportion of operative and non-operative treatment of PHF, as most non-displaced and many conservatively treated displaced fractures are treated without a hospital admission. Second, hospitalizations are anonymized, which means that patients who are hospitalized more than once during the study period cannot be identified and were potentially counted more than one time. Additionally, an individual follow-up for each patient, allowing any specific statement regarding complications, actual revision rates or implant survival was not possible. Additonally, a fracture-discrimination based on any specific classification system could not be made, except for the distiction based on the different ICD-10 codes.

However, the major strength of this study is the completeness of data leading to highly reliable statements for the trends of surgical management of PHF in Germany.

Conclusion

From 2007 to 2016, the incidence of PHFs increased in the German population, with humeral head fractures being the most common fracture type. Concomitantly, a larger percentage increase in the number of surgical procedures was found, indicating, that a larger number of fractures may be treated operatively. Although locking plate fixation remained the most common surgical treatment for PHFs, there was a significant increase in the use of RSA and an associated decrease in the use of HA, especially in elderly patients, which is consistent with current scientific evidence. Besides that, IMN showed a steady decrease over time, hinting at possible limitations of this treatment method in the context of an aging population with more complex fracture patterns and concomitant lesions of the shoulder joint. Contrarily, K-wire fixation has been significantly more frequently used in recent time, maybe due to current advances of minimally invasive procedures in the elderly.

Owing to a lack of uniform treatment guidelines and an aging population leading to the increased incidence of PHF, value-based studies as well as a continuous development of large uniform registry databases are needed to compare the different treatment modalities and establish evidence-based protocols for the management of PHF.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval No ethical approval has been needed for this study.

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