BJR

BONE FRACTURE

The epidemiology and direct healthcare costs of aseptic nonunions in Germany – a descriptive report

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Aims

This observational cross-sectional study aimed to answer the following questions: 1) how has nonunion incidence developed from 2009 to 2019 in a nationwide cohort; 2) what is the age and sex distribution of nonunions for distinct anatomical nonunion localizations; and 3) how high were the costs for surgical nonunion treatment in a level 1 trauma centre in Germany?

Methods

Data consisting of annual International Classification of Diseases (ICD)-10 diagnosis codes from German medical institutions from 2009 to 2019, provided by the Federal Statistical Office of Germany (Destatis), were analyzed. Nonunion incidence was calculated for anatomical localization, sex, and age groups. Incidence rate ratios (IRRs) were determined and compared with a two-sample z-test. Diagnosis-related group (DRG)-reimbursement and length of hospital stay were retrospectively retrieved for each anatomical localization, considering 210 patients.

Results

In 2019, a total of 11,840 nonunion cases (17.4/100,000 inhabitants) were treated. In comparison to 2018, the incidence of nonunion increased by 3% (IRR 1.03, 95% confidence interval (CI) 0.53 to 1.99, p = 0.935). The incidence was higher for male cases (IRR female/male: 0.79, 95% CI 0.76 to 0.82, p = 0.484). Most nonunions occurred at the pelvic and hip region (3.6/100,000 inhabitants, 95% CI 3.5 to 3.8), followed by the ankle and foot as well as the hand (2.9/100,000 inhabitants each). Mean estimated DRG reimbursement for in-hospital treatment of nonunions was highest for nonunions at the pelvic and hip region (€8,319 (SD 2,410), p < 0.001).

Conclusion

Despite attempts to improve fracture treatment in recent years, nonunions remain a problem for orthopaedic and trauma surgery, with a stable incidence throughout the last decade.

Cite this article: *Bone Joint Res* 2022;11(8):541–547.

Keywords: Epidemiology, Nonunion, Direct healthcare costs

Article focus

- The epidemiology of nonunion after fracture is unknown, which makes it difficult to estimate healthcare costs and foresee future demands.
- This study investigated how nonunion incidence has developed over the last decade in a nationwide cohort depending on age, sex, and anatomical localization.
- Direct costs for surgical nonunion treatment were analyzed using data from a level 1 trauma centre in Germany.

Key messages

- Nonunion cases remained relatively stable from 2009 to 2019, with an incidence of 17.4/100,000 inhabitants in 2019.
- Most nonunions occurred at the pelvic and hip region, the hand, and the ankle and foot.
- Direct costs were estimated to be relatively low, whereby nonunions at the pelvic and hip region and the lower leg were the most costly.

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doi: 10.1302/2046-3758.118.BJR-2021-0238.R3

Bone Joint Res 2022;11(8):541–547.

Strengths and limitations

- An outstanding characteristic is that presented findings are based on nationwide registry data.
- The study is limited by the fact that individual patient data such as comorbidities could not be derived from the International Classification of Diseases-10 codes.

Introduction

Fracture healing can be a tedious process. Complications such as nonunion are still sometimes unavoidable. For the definition of a nonunion, Food and Drug Administration (FDA)[1] and National Institute for Health and Care Excellence (NICE)[2] guidelines determine a minimum of nine months after injury without visible bone healing progress for three months. Further definitions, such as fractures that do not heal without surgical intervention, are also common in the literature.[3,4] The management of nonunion depicts a clinical challenge, as diverse treatment strategies are available to restore bone consolidation.[5] Besides having a detrimental effect on patients' quality of life,[6,7] healthcare costs are statistically significantly higher than in uncomplicated fracture cases, mainly driven by indirect costs such as productivity loss.[5,8] In addition, depending on different healthcare systems and treatment concepts, direct costs such as surgical and medical treatment for nonunion differ substantially between different countries.[8,9] Hence, cost estimations vary widely in the literature, and epidemiological data are required as a keystone to estimate direct and indirect healthcare costs.

Proportions of fractures that result in nonunions between 5% and 10% have been reported.[10,11] However, as recently highlighted by the Danish Orthopedic Trauma Society, at least 25 studies refer to a textbook published in 1999, which seems not to be a reliable source for nonunion proportions.[4,12] Further, only a few studies used registry data to estimate nonunion incidence. For instance, 12,373 nonunions were included in an inception cohort study of a payer database from 2011 to 2012 in the USA.[13] In Scotland, the nonunion incidence was calculated as 18.9 per 100,000 population per annum, based on hospital admission data between 2005 and 2010.[14] However, the epidemiology of nonunion in European countries is largely unknown.

We have therefore aimed to answer the following questions using an observational cross-sectional study design: 1) how has nonunion incidence developed from 2009 to 2019 in a nationwide cohort; 2) what is the age and sex distribution of nonunions for distinct anatomical nonunion localizations; and 3) how high were the costs for surgical nonunion treatment in a level 1 trauma centre in Germany?

Methods

Data consisting of annual International Classification of Diseases (ICD)-10 diagnosis codes from German medical institutions, including private ones from 2009 to 2019, were provided by the Federal Statistical Office of Germany (Destatis). These included all inpatient diagnoses, which were reported from medical institutions in all 16 German federal states. The coding is usually performed by physicians. The ICD-10 code "M84.1, nonunion of fracture"[15] was used to identify patients aged 20 years or older to ensure that all patients reached skeletal maturity diagnosed with nonunion (Table I). A detailed breakdown of these data by age group in ten-year increments, sex, and anatomical localization (M84.11-M84.17) was performed. First, the incidences for each year were calculated based on Germany's historical population aged 20 years or older provided by Destatis.[16] Here, the number of inhabitants in each of the 16 German federal states was considered by year of birth for each year of the period 2009 to 2019. The deadline of each year was 31 December. Second, age- and sex-standardized incidence rates were estimated for each anatomical localization. Incidence rate ratios (IRRs) with the corresponding 95% confidence intervals (CIs) and percentage changes were calculated by dividing the incidence in 2019 by the incidence of the preceding year for all nonunions. For each anatomical localization, IRRs were determined relative to the year 2009.

Table I. Descriptions of the used International Classification of Diseases (ICD)-10 codes.

ICD-10 codes nonunion	Description
M84.1	Nonunion of fracture
M84.11	Shoulder region (clavicula, scapula, acromioclavicular-, glenohumeral-, sternoclavicular joint)
M84.12	Upper arm (humerus)
M84.13	Forearm (radius, ulna, scaphoid)
M84.14	Hand (finger, carpus, metacarpal)
M84.15	Pelvic region and thigh (pelvis, femur)
M84.16	Lower leg (fibula, tibia)
M84.17	Ankle and foot (tarsal, metatarsal, toes, ankle)

ICD, International Classification of Diseases.

To estimate direct total healthcare cost for surgical treatment, diagnosis-related groups (DRGs) reimbursement from nonunion cases treated in our department between 2009 and 2019 were retrospectively retrieved. For the ICD-10 code "M84.13", only 30 patients were treated. Hence, this sample size was chosen for each anatomical localization to ensure comparability, and for each ICD-10 subcode of nonunion (M84.11-M84.17) 30 patients were considered. In total, 210 cases were reviewed. Patient records were selected in backward chronological order. No patient was excluded. All patients underwent only one inpatient surgical treatment. Further, all cases were solely diagnosed with aseptic nonunion; septic cases, which would have been coded as "T84.6, infection and inflammatory reaction due to internal fixation device" or "M86.-, osteomyelitis" were not considered. Correct coding was ensured by reviewing patients' medical charts, surgery protocols, and radiographs. For each subgroup, the amount of the DRG-based payment was averaged (mean, standard deviation (SD)). Further, the

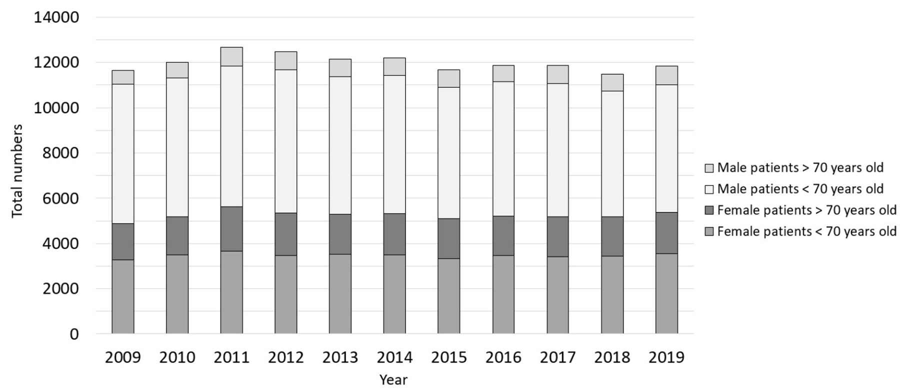

Fig. 1

Historical development of total number of nonunion cases from 2009 to 2019 shown for female and male patients younger and older than 70 years.

length of hospital stay was determined and averaged for each cohort (mean, SD). The study was approved by the institutional ethics committee of the University Hospital Regensburg according to the Declaration of Helsinki (2013) (file number 20-1681-104).

Statistical analysis. Data were analyzed using SPSS statistics version 24.0 (IBM, USA). Descriptive statistics were calculated for all variables. After determining that the distribution was appropriate for parametric testing by Shapiro-Wilk test, homogeneity of variances was asserted using Levene's test, which showed that equal variances could not be assumed ($p < 0.05$). Therefore, the Welch test with a Games-Howell post hoc analysis was used to compare DRG reimbursement and length of hospital stay for each M84.1 subcode.[17,18] Incidence rates were compared using the two-sample z-test. Statistical significance was set at $p < 0.01$ to reduce the type I error rate.[19]

Results

In 2009, a total of 11,653 nonunion cases were listed in Germany, constituting an annual incidence of 17.5 cases per 100,000 inhabitants (95% CI 17.2 to 17.9). In the following years the incidence rose, resulting in a maximum of 19.4 cases per 100,000 inhabitants (95% CI 19.0 to 19.7) in 2011. From this point on, numbers went down to an incidence of 17.0/100,000 inhabitants (95% CI 16.7 to 17.3) in 2018. In 2019, a total number of 11,840 nonunion cases were listed in Germany, constituting an annual incidence of 17.4 cases per 100,000 inhabitants. Compared to 2018, numbers had increased by 3% (IRR 1.03, 95% CI 0.53 to 1.99; $p = 0.935$, two-sample z-test). Of all cases, 78% (n = 9,208) were younger than 70 years old. Male patients constituted 55% (n = 6,475) of the whole cohort (Figure 1, Table II).

In comparison to 2009, increasing incidence was found for nonunion at the ankle and foot with +17%, and the pelvic and hip region with +9% in 2019. A decrease could be observed for the forearm (-18%), shoulder (-16%), upper arm (-10%), hand (-10%), as well as the lower leg (-7%). However, none of these developments were statistically significant (Table III).

Regarding the age and sex distribution in 2019, highest standardized nonunion incidences at the shoulder were registered for patients aged 50 to 59 years (2.5/100,000 men and 1.5/100,000 women) (Figure 2a). At the upper arm, incidence increased with age for female cases up to 3.6/100,000 women aged older than 90 years, whereas for male cases incidence peaked in the age group of 60 to 69 years (1.8/100,000 inhabitants). Nonunions at the forearm occurred most often in female patients aged 60 to 69 years (1.9/100,000 inhabitants), followed by male patients aged 50 to 59 years (1.8/100,000 inhabitants) (Figure 2c). Nonunions at the hand mainly affected male patients (IRR female/male: 0.20, 95% CI 0.18 to 0.22; $p = 0.928$, two-sample z-test) with a peak in the age group 20 to 29 years (15.9/100,000 inhabitants) (Figure 2d). The incidence for nonunions at the pelvic and hip region was higher for female patients (IRR female/male: 1.39, 95% CI 1.28 to 1.50; $p = 0.334$, two-sample z-test) and patients aged older than 70 years (IRR 0.35, 95% CI 0.33 to 0.38; $p = 0.003$, two-sample z-test). Incidence increased with age for both sexes up to a maximum of 15.3/100,000 women and 13.1/100,000 men aged older than 90 years (Figure 2e). Nonunions at the lower leg reached a maximum for patients aged 50 to 59 years (3.3/100,000 women, 5.4/100,000 men) (Figure 2f). Cases concerning the ankle and foot predominantly comprised female patients aged 50 to 59 years (5.0/100,000 women) and 60 to 69 years (4.4/100,000 women), as well as male patients aged 60 to 69 years (3.4/100,000 men) (Figure 2g).

For overall nonunions in 2019 regardless of anatomical localization, the sex distribution revealed a higher incidence for male cases, although this was not statistically significant (IRR female/male: 0.79, 95% CI 0.76 to 0.82; $p = 0.484$, two-sample z-test). In 2019, the nonunion incidence was 19.6/100,000 inhabitants (95% CI 19.1 to 20.0) for men and 15.4/100,000 inhabitants (95% CI 15.0 to 15.9) for women. For female patients, the incidence steadily increased with age. For male patients, the incidence was highest in the age group 20 to 29 years

Table II. Historic development of nonunion diagnoses from 2009 to 2019.

Year	n	German population (20 yrs or older)	Incidence per 100,000 inhabitants (95% CI)	Incidence relative to the preceding year, %	IRR relative to the preceding year (95% CI)	Comparison of incidences, p-value*	Female/male, % (n)	Aged ≤ 70 years/> 70 years, % (n)
2009	11,653	66,400,066	17.5 (17.2 to 17.9)	N/A	N/A	N/A	42/58(4,883/6,770)	81/19 (9,443/2,210)
2010	12,000	66,549,975	18.0 (17.7 to 18.4)	+3	1.03 (0.53 to 1.98)	0.935	43/57 (5,168/6,832)	80/20 (9,647/2,353)
2011	12,664	65,398,514	19.4 (19.0 to 19.7)	+7	1.07 (0.57 to 2.04)	0.827	44/56 (5,615/7,049)	78/22 (9,883/2,781)
2012	12,471	65,665,069	19.0 (18.7 to 19.3)	-2	0.98 (0.52 to 1.85)	0.952	43/57 (5,340/7,131)	79/21 (9,808/2,663)
2013	12,132	65,943,867	18.4 (18.1 to 18.7)	-3	0.97 (0.51 to 1.84)	0.923	44/56 (5,295/6,837)	79/21 (9,593/2,539)
2014	12,198	66,677,665	18.3 (18.0 to 18.6)	-1	0.99 (0.52 to 1.90)	0.986	44/56 (5,325/6,873)	79/21 (9,590/2,608)
2015	11,686	67,097,676	17.4 (17.1 to 17.7)	-5	0.95 (0.49 to 1.83)	0.883	44/56 (5,094/6,592)	78/22 (9,137/2,549)
2016	11,876	67,440,230	17.6 (17.3 to 17.9)	+1	1.01 (0.52 to 1.96)	0.974	44/56 (5,198/6,678)	79/21 (9,432/2,444)
2017	11,874	67,540,025	17.6 (17.3 to 17.9)	0	1.00 (0.52 to 1.93)	0.996	44/56 (5,181/6,693)	79/21 (9,317/2,557)
2018	11,493	67,724,921	17.0 (16.7 to 17.3)	-3	0.97 (0.50 to 1.88)	0.917	45/55 (5,178/6,315)	78/22 (8,982/2,511)
2019	11,840	67,864,036	17.4 (17.1 to 17.8)	+3	1.03 (0.53 to 1.99)	0.935	45/55 (5,365/6,475)	78/22 (9,208/2,632)

Statistical significance set at p < 0.01.
*Two-sample z-test.
CI, confidence interval; IRR, incidence rate ratio; N/A, not applicable.

(26.3/100,000 inhabitants), followed by the age group 50 to 59 years (21.6/100,000 inhabitants) (Figure 2h).

Nonunions at the pelvic and hip region were the most costly, and were associated with the longest stay in hospital (Table IV). DRG reimbursement differed statistically significantly for the anatomical localizations (Welch's F (6, 88.9) = 34.63; p < 0.001, Games-Howell post hoc analysis). Nonunions at the pelvic and hip region were the most costly, and significantly more expensive than the other anatomical localizations (p < 0.001, Games-Howell post hoc analysis). Costs for the treatment of nonunion at the lower leg were the second highest, which were statistically significantly higher compared to nonunions at the shoulder (p < 0.001), the forearm (p < 0.001), the hand (p < 0.001), and the ankle and foot region (p = 0.008, all Games-Howell post hoc analysis). Also, length of hospital stay was significantly different for the distinct anatomical localizations (Welch's F (6, 86.1) = 17.98; p < 0.001, Games-Howell post hoc analysis) (Table IV). In comparison to other anatomical localizations, patients with a nonunion at the pelvic and hip region had the longest stay in hospital (p < 0.001, Games-Howell post hoc analysis).

Discussion

In this observational cross-sectional study, the development of nonunion incidence from 2009 to 2019 in Germany was determined, presenting nationwide data from one of the largest countries in Europe. Nonunion cases were analyzed depending on anatomical localization, sex, and age for Germany. Whereas studies relying on data from single hospitals may yield skewed results, the findings presented here are based on nationwide reports from one of the largest countries of the European Union. Additionally, direct healthcare costs for surgical treatment based on DRG reimbursement were estimated.

The incidence of nonunions depending on age and sex. The results demonstrate a fluctuation of nonunion cases in the range of -5% to +7% considering the IRR of the preceding years, respectively. Between 2018 and 2019, the incidence increased by 3%, resulting in an incidence of 17.4/100,000 inhabitants (95% CI 17.1 to 17.8). There was no statistically significant trend in the development of nonunion incidence observable and hence, the variations could be regarded as regularly as, for instance, those also shown for the epidemiology of fracture-related infections.[20] Thus, the fluctuations might not be attributed to specific factors such as advances in diagnostics.[21–23] In the same stance, the clinical importance of the heightened incidence is questionable.

The overall nonunion incidence is comparable with findings by Mills and Simpson[14] analyzing nationwide registry data for the population of Scotland from 2005 to 2010. The authors reported a mean incidence of 18.9/100,000 population per annum, whereby numbers also varied in a range of 18.0 to 20.0 per 100,000 inhabitants between the considered calendar years.[14] Further, in accordance with our findings, Mills and Simpson[14]

Table III. Nonunion rates in 2019 divided by anatomical localization.

Anatomical localization	n	Incidence per 100,000 inhabitants (95% CI)	Incidence in 2019 relative to 2009, %	IRR relative to 2009 (95% CI), p-value*	Female/ male, % (n)	IRR female/ male (95% CI), p-value*	Aged ≤ 70 years/> 70 years, % (n)	IRR aged ≤ 70 yrs/> 70 yrs (95% CI), p-value*
All	11,840	17.4 (17.1 to 17.8)	-1	0.99 (0.51 to 1.93), 0.986	45/55 (5,365/6,475)	0.79 (0.76 to 0.82), 0.484	78/22 (9,208/2,632)	0.15 (0.14 to 0.16), 0.178
Shoulder	912	1.3 (1.3 to 1.4)	-16	0.84 (0.77 to 0.92), 0.559	40/60 (362/550)	0.63 (0.55 to 0.72), 0.711	88/12 (803/109)	3.37 (2.76 to 4.12), 0.119
Upper arm	905	1.3 (1.3 to 1.4)	-10	0.90 (0.82 to 0.98), 0.536	59/41 (531/374)	1.35 (1.18 to 1.54), 0.810	63/37 (573/332)	0.68 (0.60 to 0.78), 0.509
Forearm	859	1.3 (1.2 to 1.4)	-18	0.82 (0.75 to 0.89), 0.567	48/52 (412/447)	0.88 (0.77 to 1.00), 0.540	81/19 (692/167)	1.96 (1.65 to 2.32), 0.330
Hand	1,997	2.9 (2.8 to 3.0)	-10	0.90 (0.85 to 0.95), 0.553	18/82 (349/1,648)	0.20 (0.18 to 0.22), 0.928	98/2 (1,961/36)	29.73 (21.38 to 41.34), 0.008
Pelvis and hip	2,454	3.6 (3.5 to 3.8)	+9	1.09 (1.03 to 1.15), 0.456	59/41 (1,455/999)	1.39 (1.28 to 1.50), 0.334	51/49 (1,242/1,212)	0.35 (0.33 to 0.38), 0.003
Lower leg	1,927	2.8 (2.7 to 3.0)	-7	0.94 (0.88 to 1.00), 0.532	40/60(776/1,151)	0.64 (0.59 to 0.70), 0.698	86/14 (1,656/271)	3.11 (2.73 to 3.53), 0.032
Ankle and foot	1,985	2.9 (2.8 to 3.0)	+17	1.17 (1.10 to 1.25), 0.427	57/43 (1,127/858)	1.25 (1.14 to 1.37), 0.394	86/14 (1,714/271)	3.62 (3.19 to 4.12), 0.019
Other, not specified	801	1.3 (1.2 to 1.4)	+36	1.51 (1.35 to 1.69), 0.388	44/56 (352/449)	0.75 (0.65 to 0.86), 0.826	71/29 (569/232)	0.74 (0.63 to 0.86), 0.596

Statistical significance set at p < 0.01.
*Two-sample z-test.
CI, confidence interval; IRR, Incidence rate ratio.

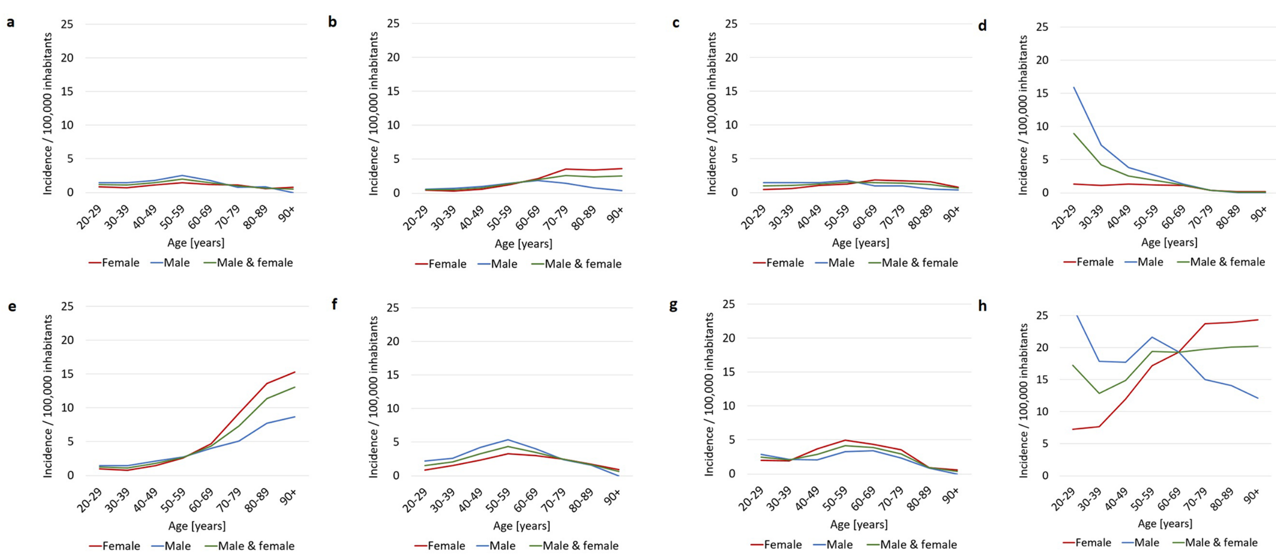

Fig. 2

Age-standardized nonunion incidence rates per 100,000 inhabitants in 2019 shown for: a) the shoulder region; b) the upper arm; c) the forearm; d) the hand; e) the pelvic and hip region; f) the lower leg; g) the ankle and foot; and h) all anatomical localizations. Female patients are illustrated in the red curve, male patients in the blue curve, while both male and female cases are shown in the dark green curve.

Table IV. Diagnosis-related group reimbursement and length of hospital stay.

Anatomical localization	Mean DRG reimbursement from 30 patients, € (SD; range; 95% CI)	Mean length of hospital stay from 30 patients, days (SD; range; 95% CI)
Shoulder	3,018 (973; 1,712 to 5,220; 2,655 to 3,381)	3.4 (1.0; 1 to 5; 3.0 to 3.8)
Upper arm	5,095 (2092; 1,963 to 9,562; 4,314 to 5876)	5.6 (2.9; 2 to 13; 4.6 to 6.8)
Forearm	4,004 (1558; 1,876 to 8,319; 3,422 to 4,586)	5.3 (3.3; 1 to 12; 4.0 to 6.5)
Hand	2,922 (967; 2,022 to 6,964; 2,561 to 3,283)	3.5 (1.7; 1 to 7; 2.8 to 4.1)
Pelvis and hip	8,319 (2410; 4,944 to 14,847; 7,419 to 9,219)	13.5 (6.9; 5 to 34; 11.0 to 16.1)
Lower leg	6,377 (1997; 4,587 to 11,274; 5,632 to 7,124)	6.58 (3.7; 3 to 15; 5.4 to 8.2)
Ankle and foot	4,524 (1859; 2,114 to 8,913; 4,554 to 5,235)	5.5 (3.0; 1 to 13; 4.4 to 6.7)

CI, confidence interval; DRG, diagnosis-related group; SD, standard deviation.

also observed higher incidence for men than for women (22.4/100,000 men vs 15.7/100,000 women per annum). Similarly to the results shown in Figure 2h, the distribution was bimodal for male cases and unimodal for female cases, whereby the highest peaks were observed for males in the age group 25 to 29 years and for females in the age group 75 to 79 years.[14]

Here, the peak in the age distribution for male sex aged 20 to 29 years was mainly driven by nonunions occurring in the hand, which might reflect higher fracture incidences of the scaphoid (1.1./100,000 men vs 3.5/100,000 women), as well as carpal and metacarpal bones in the male German population (17.5/100,000 men vs 7.5/100,000 women).[24] Further, it was found that most nonunions occurred at the pelvic and hip region (3.6/100,000 inhabitants, 95% CI 3.5 to 3.8), affecting more women than men (IRR female/male: 1.39, 95% CI 1.28 to 1.50). Incidence heightened with age, which contributed to the steady increase of the overall incidence with age for female sex. This is in line with current data on the epidemiology of fractures in the adult population in Germany, reporting higher incidences in women regarding femoral neck fractures (157.3/100,000 women vs 81.3/100,000 men), pertrochanteric femur fractures (148.2/100,000 women vs 67.4/100,000 men), and pelvic ring fractures (94.4/100,000 women vs 23.5/100,000 men), whereby age-standardized incidences increased with longer lifetime for both sexes.[24]

Costs for surgical treatment. Highest healthcare costs were calculated for nonunion treatment at the pelvic and hip region (mean €8,319 (SD 2,410)/patient) followed by the lower leg (mean €6,377 (SD 1,997)/patient). Importantly, these calculated costs should be interpreted with caution. In Germany, each federal state provides different base payment rates, and the presented numbers are only based on one federal state. Furthermore, the base payment rates differed over the last ten years with continuously rising values. Also, the analyzed patients underwent only one inpatient surgical treatment. However, in some cases the management of nonunion requires multiple inpatient treatments. Hence, the findings may be underestimated, and generalizability of the cost analysis is limited.

Cost estimations vary widely in the literature depending on the inclusion of direct or indirect cost, fracture site, as well as treatment procedures. In a review, Kanakaris and Giannoudis[25] calculated best-case scenario costs per patient as £15,566 (~ €18,000) for a humeral nonunion and £17,000 (~ €19,650) for a nonunion after femur fracture including indirect costs. Ekegren et al[26] reported median inpatient cost of $14,957 AUD (~ €9,600) per patient, including all complication admissions within two years of index fracture. However, their cohort was mixed, consisting of patients with humeral, femoral, and tibial nonunion.[26] In Germany, cost of therapy for humeral nonunion including surgical interventions was calculated as €6,432 per patient, which was higher than in our findings.[27] Whereas studies on the economics of femoral nonunions are scarce, costs of tibial nonunions have been addressed more frequently. In the USA, total median healthcare costs for tibial shaft nonunions were estimated to be approximately 2.2 times higher with an amount of $25,556 (~ €20,900) compared to tibial shaft fractures, achieving union within one year. However, in contrast to our approach, inpatient, outpatient, and pharmaceutical costs were included in the analysis.[9] In the UK, direct treatment costs of complex tibial nonunion within the Taylor spatial frame of £26,000/case (~ €30,000) were revealed,[28] whereas £23,604 (~ €27,000) per patient was calculated using the Ilizarov technique.[29] Dahabreh et al[30] conducted a cost analysis comparing the treatment of tibial nonunions by bone grafting or bone morphogenetic protein-7. Direct costs were higher for the latter with £7,292 (~ €8,400) versus £6,830 (~ €7,800). These results underpin the variance in costs regarding the treatment procedure. Since previously reported healthcare costs were higher in comparison to the estimated DRG reimbursement in our department, further studies differentiating treatment procedure are required. Further, to draw conclusions about the overall economic burden of nonunions, indirect costs such as productivity losses should be considered, as these have been handled as the key driver contributing to 67% to 79% and 82.8% to 93% of the overall treatment costs in the Canadian and European healthcare systems, respectively.[8]

The main limitation of this study is that it represents a purely descriptive report. Furthermore, it is important to note that the analysis is only based on inpatient data. However, surgical treatment is required in the majority of nonunion cases. Although ICD-10 codes divided by age and sex were available, the ICD codes did not allow a precise anatomical assignment of nonunions within a single bone, as is the case with the AO/OTA fracture classification and, accordingly, the ICD codes for fractures. Besides, individual patient characteristics could not be derived, including different surgical strategies. Therefore, it was not possible to differentiate possible driving factors for nonunion development and treatment costs. In addition, correct coding cannot be guaranteed.

In conclusion, despite attempts to improve fracture treatment in recent years, nonunions remain a problem for orthopaedic and trauma surgery with a stable incidence throughout the last decade. The most costly in-hospital treatment is found in nonunion of the pelvic and hip region and lower leg.

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Funding statement:
- The authors received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:
- Each author certifies that he or she has no conflict of interest in connection with the submitted article.

Data sharing:
- The data that support the findings of this study are available from the corresponding author, M. Rupp, upon reasonable request.

Acknowledgements:
- We thank the Federal Statistical Office of Germany (Destatis) for their support of this work.

Ethical review statement:
- This study was approved by the institutional ethics committee of the University Hospital Regensburg (file number 20-1681-104).

Open access funding
- The authors report that they received open access funding for their manuscript from the open access scheme of University Library of Regensburg.