Clinical Interventions in Aging

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Geriatric-Typical Characteristic Complexes Predict Short-Term Outcome of Proximal Humeral Fractures in Geriatric Patients

Jan-Philipp Happe[1], J Christoph Katthagen[1], Karen Fischhuber[2], Ursula Marschall[3], Andreas Faldum[2], Michael J Raschke[1], Jeanette Koeppe[2,*], Josef Stolberg-Stolberg[1,*]

[1]Department of Trauma-, Hand- and Reconstructive Surgery, University Hospital Muenster, Muenster, Germany; [2]Institute of Biostatistics and Clinical Research, University of Muenster, Muenster, Germany; [3]BARMER Institute for Health System Research, Wuppertal, Germany

*These authors contributed equally to this work

Correspondence: Josef Stolberg-Stolberg, Department of Trauma-, Hand- and Reconstructive Surgery, University Hospital Muenster, Albert-Schweitzer-Campus 1, Building W1, Muenster, 48149, Germany, Tel +49 251 83 59231, Email Josef.Stolberg-Stolberg@ukmuenster.de

Purpose: Geriatric-typical multimorbidity (GTMM) categorizes older patients with multiple geriatric syndromes, but its impact on PHF outcomes remains unexplored. This study evaluates GTMM's influence on PHF patients within three months after fracture, aiming to improve geriatric care strategies.

Methods: Patients ≥65 years with a PHF diagnosis (ICD S42.2) between 2011 and 2022 were included. GTMMs were collected within two years prior to PHF. Patients were categorized into five treatment groups based on surgical intervention (reverse total shoulder arthroplasty (RTSA), locked plate fixation (LPF, sLPF), other fracture fixations) or non-surgical management. A multivariable Cox hazard model analyzed associations between treatment groups, GTMMs, and three-month outcomes: complications, major adverse events (MAE), thromboembolic events (TE), and mortality.

Results: Between January 2011 and December 2022, 95,324 patients were identified with PHF, 43% of whom underwent surgery. The median patient age was 79, and 70% were categorized as geriatric. Mortality within three months was 4.3% (95%-CI: 4.15–4.41%), with major adverse events (MAE) and thromboembolic events (TE) occurring in 7.1% (95%-CI: 6.90–7.23%) and 5.6% (95%-CI: 5.41–5.70%) of cases, respectively. Geriatric-typical multimorbidity (GTMK) cognitive deficits were an independent risk associated factor for inferior outcome in surgically treated patients, while conditions like incontinence and malnutrition resulted in increased rates of mortality, MAEs, and TEs in all patients ($p < 0.05$).

Conclusion: GTMKs are associated with worse outcome in both operative and non-operative treated patients. The impact of GTMKs, such as cognitive deficits, incontinence, decubitus ulcers and malnutrition, were found to be risk-associated factors.

Plain Language Sumary:

- **Aim**: To investigate the impact of geriatric-typical multimorbidity on clinical outcomes and treatment decisions in elderly patients with proximal humeral fractures.
- **Findings**: Multimorbidity complexes such as incontinence and malnutrition significantly predict mortality, major adverse, and thromboembolic events. Conditions like sensory impairments, high complication risks, mood disorders, and fall tendency are highly prevalent.
- **Message**: Cognitive assessment is crucial in determining surgical eligibility in elderly patients.

Keywords: shoulder fractures, arthroplasty, replacement, shoulder, fracture fixation, internal, comorbidity, evidence-based practice

https://doi.org/10.2147/CIA.S562164
Received: 20 August 2025
Accepted: 13 December 2025
Published: 18 February 2026

Introduction

The world's population is aging rapidly with profound implications on social structures and health care systems.[1,2] Amongst older people, the geriatric patient is characterized by multimorbidity, geriatric syndromes, frailty and loss of autonomy.[3,4] Vulnerability to musculoskeletal deterioration due to sarcopenia and osteoporosis causes an increased number of age-related fractures with high demand for specialized treatment.[5,6] Osteoporosis substantially increases the burden of fractures by raising both the incidence and severity of these injuries and by worsening functional outcomes and quality of life.[7] Patients with osteoporosis have a markedly higher risk of sustaining proximal humeral fractures, with hazard ratios as high as 7.43 compared to non-osteoporotic individuals.[8,9] Hence, early identification and management of geriatric patients might reduce disability and mortality.[10,11]

The proximal humeral fracture (PHF) is the third most common fracture amongst older people with an incidence of up to 503 in women.[12–14] There is inconsistent evidence on the superiority of surgical over non-surgical treatment, with no proof of improved long-term functionality or quality of life in prospective randomized studies such as the ProFHER trial.[15,16] Amongst surgical interventions, humeral head preserving locked plate fixation (LPF) and joint replacement using reverse total shoulder arthroplasty (RTSA) are the most frequently used procedures.[17–19] However, currently there is no consensus on the best surgical treatment even amongst experts.[20,21] Hence, recent studies emphasize the importance of patient-specific factors such as age, sex, bone quality, Charlson Comorbidity Index and comorbidities on treatment success.[17,20,22–25] However, there is little information about geriatric patients after PHF in the literature.

The concept of geriatric-typical multimorbidity (GTMM) identifies geriatric patients by ICD-10-GM codes.[26] According to Borchelt et al, patients with GTMM are aged 70 years and above, characterized by at least two out of 15 geriatric-typical characteristic complexes (GTMK) including immobility, a tendency for falls and dizziness, cognitive deficits, incontinence, pressure ulcers, malnutrition, fluid and electrolyte imbalances, depression and anxiety disorders, chronic pain, sensory deficits, reduced resilience (frailty), severe visual or hearing impairment, medication-related issues, high risk of complications, and prolonged recovery times.[26] Currently, there are no published studies that analyze the effect of GTMM on patients with PHF.

The aim of this study was to investigate the impact of GTMM on older patients within the first three months after PHF diagnosis. The findings will help physicians to identify patients at risk, to choose optimal treatment modalities and ultimately guide healthcare providers to deliver care that is both effective and specific to the complex needs of geriatric patients.

Materials and Methods

Patients with proximal humeral fractures were identified using retrospective inpatient and outpatient data from the BARMER health insurance company. The BARMER, one of Germany's largest statutory health insurance providers with over 8 million insurance holders, supplied data for all inpatient and outpatient cases coded for PHF (ICD S42.2) from 2011 to 2022.

Patient Cohort

All patients aged 65 years or higher with an inpatient and/or outpatient coded PHF (ICD S42.2) between January 2011 and December 2022 were included in the study. Exclusion criteria are depicted in Figure 1. Surgical interventions included the use of reverse total shoulder arthroplasty (RTSA; OPS 5–824.21), locked plate fixation for multi-fragment fractures (LPF; OPS 5–794.k1 or 5–794.21), locked plate fixation for simple fracture (sLPF; OPS 5–793.k1 or 5–793.31) or different surgical treatment variants (see Supplementary Table S1). Patients were categorized into five groups based on the received treatment (1. Non-operative treatment, 2. sLPF, 3. LPF, 4. RTSA, 5. other fracture fixation), with the determining criterion for this categorization being surgical treatment or lack of surgical treatment within the first 21 days after the initial PHF diagnosis.

Once the treatment group was assigned, the observation and analysis phase of the study for each treatment group began 21 days after the initial PHF diagnosis and ended after 3 months. Information related to comorbidities, previous medication and previous procedures were collected in a pre-phase of 5 years before PHF diagnosis. Data collection to

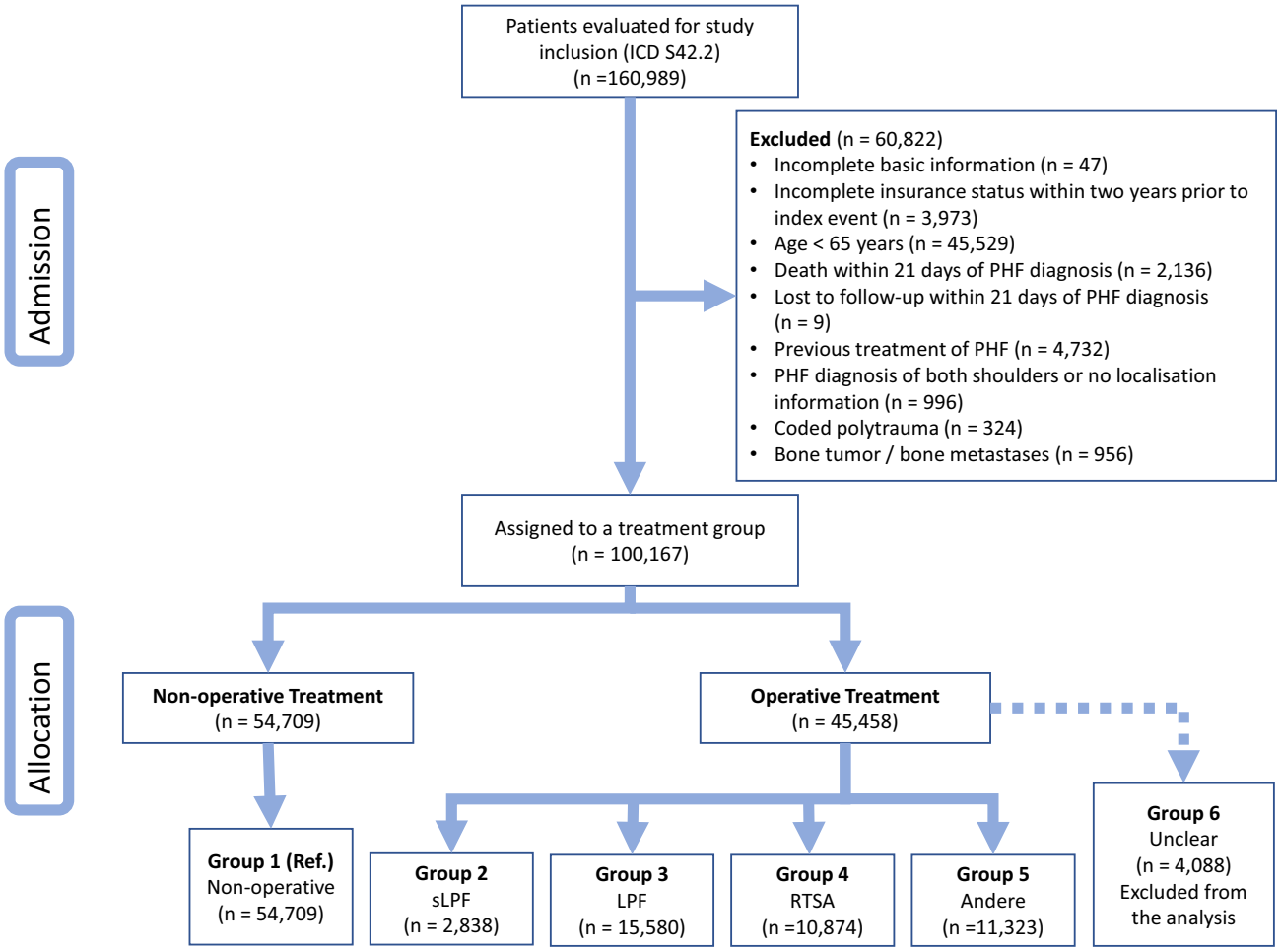

Figure 1 CONSORT flow-chart. Admission of suitable patients and their allocation to one of the treatment groups "non-operative", operative with a locked plate fixation for simple (sLPF) and multi-fragment fracture (LPF), reverse total shoulder arthroplasty (RTSA), as well as "other" or "not clearly assignable" (unclear) operative treatment. The unclear operative treated are excluded from the analysis.

assess GTMM was based on outpatient and inpatient information in the period of two years prior to the first coded PHF diagnosis. Different time periods apply for acute pain (3 months before PHF) and fractures (26 weeks before PHF). For more information and a detailed list of codes, see Table S1 of the Supplementary File.

Primary and Secondary Endpoints

The endpoints were defined as overall survival (OS), major adverse events (MAE), thromboembolic events (TE), injury/surgical complications (SC) and minor outpatient complications (MOC) within 3 months after PHF.

Missing Values

Apart from missing or inconsistent demographic information, such as sex, date of birth, or insurance period, no missing data occurred in this study. All variables were derived from existing ICD-10 or OPS codes, ensuring comprehensive data capture. If a relevant code was not present, the corresponding variable was assigned a value of zero.

Statistical Methods

Survival analysis was used to analyze the primary endpoints OS, MAE, TE, injury/surgical complications and MOC. Contrary to the other primary endpoints, death represents a competing risk for the injury/surgical complications and MOC. The observation started 21 days after first diagnosis of PHF and ended 3 months later; all patients were censored accordingly after 3 months. All patients with shorter survival than the predefined 21 days were excluded, other events

that occurred during this period were taken into account in the patient's risk profile in adjusted analyses. Unadjusted event rates were calculated for each endpoint at 3 months of follow up stratified by the number of GTMK present at the time of the PHF diagnosis using Kaplan–Meier estimates and Aalen-Johansen estimates in the case of competing events. Cox regression models were used for multivariable analysis. The resulting hazard ratios (HR) are presented along with its unadjusted 95% confidence intervals (95%-CIs) and illustrated in forest plots. In the case of competing events, cumulative incidence function determined by Aalen-Johansen estimate and sub-distributional hazards using Fine & Gray Cox models were calculated. Multivariable models included the treatment group, age, sex, year of diagnosis, sector of first diagnosis, comorbidities, previous medications, events happening during the initial 21 days, GTMK or the number of present GTMK at PHF diagnosis. The interaction p-values (p_{int}) are calculated using a Cox regression model that includes interaction terms for the individual GTMK and the binary operation variable and quantify the difference in GTMK influence between the non-operative and operative subgroups. Full results of all regression analysis were presented in Supplementary Tables S2–S12.

All analysis were fully explorative (hypotheses generating), not confirmatory and the results are interpreted accordingly. Two-sided p-values <0.05 were interpreted as statistically noticeable. No adjustment was made for multiple comparisons. R (version 4.3.1, R Core Team, 2023, Vienna) and SAS Enterprise Guide Version 8.3 Update 2 (SAS Institute Inc., Cary, NC, USA) were used for all statistical analyses and graph generation.

Results

Patient Demographics

Between January 2011 and December 2022, 95,324 patients with a PHF and a clearly defined treatment within 21 days were identified. About 42.6% were treated surgically, of which 38.4% received LPF, 26.8% RTSA, 7.0% sLPF and 27.9% were treated with other surgical procedures. Overall, patients were more often female (83.8%) with a median age of 79 years (interquartile range [IQR] 73–85). About 70.3% were defined as "geriatric". Within the surgically treated group, 63.7% were defined as geriatric and 71.0% in the non-operative group.

The most frequently identified GTMKs were "Severe visual and hearing impairment" (51.9%), "High risk of complications" (69.5%), "Depression and anxiety disorders" (34.3%) as well as "Falling tendency" (36.7%). When comparing the operative and the non-operative cohorts, the GTMKs were distributed similarly, showing a well equilibrated patient cohort. However, the GTMKs "Incontinence" and "Fluids and electrolytes disorders" were most common in the non-operative cohort, in comparison to the operative (27.9% vs 24.0% and 27.7% vs 25.1%, respectively). For further details on the Patient Demographics, refer to Table 1.

Similarities were also found when comparing the number of GTMKs identified within the two cohorts. Patients who suffered PHFs presented most often with 3 GTMKs, independent from their treatment form. To differentiate the effect of the number of GTMKs in the respective surgical subgroups further, refer to the box plot in Figure 2. This graph shows that the mean number of GTMKs present at the time of PHF diagnosis in the surgical subgroups is balanced, ranging from 1 to 5, with a median of 3.

GTMKs in the Overall Cohort

Among all GTMKs, *malnutrition and malnourishment* were the most potent predictors of poor outcomes indicating a higher risk-associated factor of mortality (HR 1.68, 95% CI: 1.51–1.88, $p < 0.001$), MAE (HR 1.57, 95% CI: 1.43–1.73, $p < 0.001$), and TE (HR 1.58, 95% CI: 1.42–1.75, $p < 0.001$). Additionally, *fluid and electrolyte disorders* were associated with increased risk across all endpoints except minor outpatient complications, including OS (HR 1.40, 95% CI: 1.30–1.50, $p < 0.001$), MAE (HR 1.35, 95% CI: 1.28–1.42, $p < 0.001$), and TE (HR 1.32, 95% CI: 1.24–1.40, $p < 0.001$).

Similarly, *decubital ulcers* merged as a strong predictor of adverse outcomes, being notably associated with higher mortality (HR 1.51, 95% CI: 1.40–1.63, $p < 0.001$), increased risk of MAE (HR 1.42, 95% CI: 1.33–1.51, $p < 0.001$), and greater likelihood of TE (HR 1.41, 95% CI: 1.32–1.52, $p < 0.001$).

Table 1 Patient Characteristics at the Time of PHF Diagnosis. Patients Were Assigned to a Non-Operative or Surgical Treatment Group Based on Treatment Within the First 21 Days After PHF Diagnosis. The "Operative Treatment" in This Table Still Includes Group 6 Along with Group 2–5, Which are the "Not Clearly Assignable" Operations, Those are Excluded from Further Analysis

	Total Cohort (Group 1–5)	Non-Operative (Group 1)	Operative (Group 2–5)	sLPF (Group 2)	LPF (Group 3)	RTSA (Group 4)	Others (Group 5)	Unclear (Group 6)
Frequency – N (%)	95,324 (100.0%)	54,709 (57.4%)	40,615 (42.6%)	2838 (3.0%)	15,580 (16.3%)	10,874 (11.4%)	11,323 (11.9%)	4843 (5.1%)
Age in years – Median (Q1, Q3)	79 (73, 85)	79 (73, 85)	78 (72, 84)	77 (71, 83)	77 (71, 83)	80 (75, 84)	78 (72, 85)	76 (71, 82)
Over 70 years – N (%)	80,115 (84.0%)	46,002 (84.1%)	34,113 (84.0%)	2297 (80.9%)	12,480 (80.1%)	9814 (90.3%)	9522 (84.1%)	3818 (78.8%)
Geriatric – N (%)	66,963 (70.3%)	38,833 (71.0%)	28,130 (69.3%)	1902 (67.0%)	10,138 (65.1%)	8215 (75.6%)	7875 (69.5%)	3120 (64.4%)
Female – N (%)	79,854 (83.8%)	45,193 (82.6%)	34,661 (85.3%)	2426 (85.5%)	13,409 (86.1%)	9451 (87.0%)	9375 (82.8%)	4133 (85.3%)
Comorbidities								
Atrial fibrillation and atrial flutter – N (%)	18,389 (19.3%)	11,004 (20.1%)	7385 (18.2%)	454 (16%)	2492 (16.0%)	2209 (20.3%)	2230 (19.7%)	741 (15.3%)
Alcohol abuse – N (%)	4635 (4.9%)	2377 (4.3%)	2,258 (5.6%)	146 (5.1%)	731 (4.7%)	640 (5.9%)	741 (6.5%)	235 (4.9%)
Atherosclerosis – N (%)	15,765 (16.5%)	9194 (16.8%)	6571 (16.2%)	480 (16.9%)	2370 (15.2%)	1885 (17.3%)	1836 (16.2%)	760 (15.7%)
Bisphosphonate – N (%)	6246 (6.6%)	3470 (6.3%)	2,776 (6.8%)	189 (6.7%)	1039 (6.7%)	758 (7.0%)	790 (7.0%)	320 (6.6%)
Cancer – N (%)	26,299 (27.6%)	15,279 (27.9%)	11,020 (27.1%)	820 (28.9%)	4116 (26.4%)	3064 (28.2%)	3020 (26.7%)	1353 (27.9%)
Congestive heart failure – N (%)	23,170 (24.3%)	13,616 (24.9%)	9554 (23.5%)	612 (21.6%)	3184 (20.4%)	2812 (25.9%)	2946 (26.0%)	904 (18.7%)
Chronic polyarthritis – N (%)	6149 (6.5%)	3570 (6.5%)	2579 (6.4%)	173 (6.1%)	977 (6.3%)	717 (6.6%)	712 (6.3%)	283 (5.8%)
Chronic kidney disease – N (%)	23,600 (24.8%)	13,647 (24.9%)	9953 (24.5%)	628 (22.1%)	3301 (21.2%)	3082 (28.3%)	2942 (26.0%)	1008 (20.8%)
Dementia – N (%)	12,790 (13.4%)	8129 (14.9%)	4661 (11.5%)	335 (11.8%)	1548 (9.9%)	1191 (11.0%)	1587 (14.0%)	411 (8.5%)
Diabetes – N (%)	29,004 (30.4%)	16,631 (30.4%)	12,373 (30.5%)	753 (26.5%)	4484 (28.8%)	3638 (33.5%)	3498 (30.9%)	1272 (26.3%)
Frozen shoulder – N (%)	4,087 (4.3%)	2,505 (4.6%)	1,582 (3.9%)	90 (3.2%)	645 (4.1%)	434 (4.0%)	413 (3.6%)	190 (3.9%)
Any anticoagulant – N (%)	30,355 (31.8%)	18,453 (33.7%)	11,902 (29.3%)	797 (28.1%)	4210 (27.0%)	3466 (31.9%)	3429 (30.3%)	1272 (26.3%)
Hypertonus – N (%)	78,744 (82.6%)	44,994 (82.2%)	33,750 (83.1%)	2285 (80.5%)	12,599 (80.9%)	9409 (86.5%)	9457 (83.5%)	3822 (78.9%)
Coronary heart disease – N (%)	24,630 (25.8%)	1,4675 (26.8%)	9955 (24.5%)	642 (22.6%)	3563 (22.9%)	2755 (25.3%)	2995 (26.5%)	1064 (22.0%)
Nicotine abuse – N (%)	6181 (6.5%)	3367 (6.2%)	2814 (6.9%)	227 (8%)	1027 (6.6%)	773 (7.1%)	787 (7.0%)	391 (8.1%)
Obesity – N (%)	19,291 (20.2%)	10,636 (19.4%)	8655 (21.3%)	489 (17.2%)	3170 (20.3%)	2754 (25.3%)	2242 (19.8%)	1027 (21.2%)

(*Continued*)

https://doi.org/10.2147/CIA.S562164

Table 1 (Continued).

	Total Cohort (Group 1–5)	Non-Operative (Group 1)	Operative (Group 2–5)	sLPF (Group 2)	LPF (Group 3)	RTSA (Group 4)	Others (Group 5)	Unclear (Group 6)
Omarthrosis – N (%)	2808 (2.9%)	1838 (3.4%)	970 (2.4%)	51 (1.8%)	328 (2.1%)	328 (3.0%)	263 (2.3%)	123 (2.5%)
Any osteoporosis medication – N (%)	11,622 (12.2%)	6704 (12.3%)	4918 (12.1%)	336 (11.8%)	1779 (11.4%)	1415 (13.0%)	1388 (12.3%)	581 (12.0%)
Osteoporosis – N (%)	33,217 (34.8%)	18,716 (34.2%)	14,501 (35.7%)	945 (33.3%)	5295 (34.0%)	4264 (39.2%)	3997 (35.3%)	1610 (33.2%)
Parkinson – N (%)	3844 (4.0%)	2274 (4.2%)	1570 (3.9%)	106 (3.7%)	523 (3.4%)	427 (3.9%)	514 (4.5%)	145 (3.0%)
Previous Stroke – N (%)	25,919 (27.2%)	15,548 (28.4%)	10,371 (25.5%)	721 (25.4%)	3751 (24.1%)	2876 (26.4%)	3023 (26.7%)	1188 (24.5%)
Rotator cuff rupture – N (%)	2478 (2.6%)	1171 (2.1%)	1307 (3.2%)	62 (2.2%)	437 (2.8%)	425 (3.9%)	383 (3.4%)	137 (2.8%)
Vitamin D or Calcium – N (%)	6817 (7.2%)	4047 (7.4%)	2770 (6.8%)	189 (6.7%)	968 (6.2%)	862 (7.9%)	751 (6.6%)	363 (7.5%)
Geriatrics-typical characteristic complexes (GTMK)								
Immobility – N (%)	3204 (3.4%)	1980 (3.6%)	1224 (3.0%)	87 (3.1%)	379 (2.4%)	369 (3.4%)	389 (3.4%)	132 (2.7%)
Falling tendency – N (%)	35,002 (36.7%)	20,723 (37.9%)	14,279 (35.2%)	979 (34.5%)	4968 (31.9%)	4384 (40.3%)	3948 (34.9%)	1624 (33.5%)
Cognitive deficits – N (%)	13,948 (14.6%)	8880 (16.2%)	5068 (12.5%)	364 (12.8%)	1678 (10.8%)	1312 (12.1%)	1714 (15.1%)	475 (9.8%)
Incontinence – N (%)	24,999 (26.2%)	15,255 (27.9%)	9744 (24.0%)	691 (24.3%)	3393 (21.8%)	2746 (25.3%)	2914 (25.7%)	1001 (20.7%)
Decubital ulcers – N (%)	8251 (8.7%)	5136 (9.4%)	3115 (7.8%)	210 (7.4%)	1,015 (6.5%)	835 (7.7%)	1055 (9.3%)	306 (6.3%)
Malnutrition and malnourishment – N (%)	2569 (2.7%)	1566 (2.9%)	1003 (2.5%)	78 (2.7%)	340 (2.2%)	226 (2.1%)	359 (3.2%)	91 (1.9%)
Fluids and electrolytes disorders – N (%)	25,378 (26.6%)	15,175 (27.7%)	10,203 (25.1%)	690 (24.3%)	3536 (22.7%)	2845 (26.2%)	3132 (27.7%)	1056 (21.8%)
Depression and anxiety disorders – N (%)	32,715 (34.3%)	18,943 (34.6%)	13,772 (33.9%)	978 (34.5%)	5152 (33.1%)	3768 (34.7%)	3874 (34.2%)	1645 (34.0%)
Pain – N (%)	38,047 (39.9%)	22,350 (40.9%)	15,697 (38.7%)	1071 (37.7%)	5835 (37.5%)	4532 (41.7%)	4,259 (37.6%)	1827 (37.7%)
Sensory disorders – N (%)	26,752 (28.1%)	15,555 (28.4%)	11,197 (27.6%)	724 (25.5%)	4155 (26.7%)	3269 (30.1%)	3049 (26.9%)	1276 (26.3%)
Frailty – N (%)	11,674 (12.2%)	7037 (12.9%)	4637 (11.4%)	277 (9.8%)	1504 (9.7%)	1677 (15.4%)	1179 (10.4%)	492 (10.2%)
Severe visual and hearing impairment – N (%)	49,491 (51.9%)	28,641 (52.4%)	20,850 (51.3%)	1425 (50.2%)	7975 (51.2%)	5694 (52.4%)	5756 (50.8%)	503 (51.7%)
Medication problems – N (%)	720 (0.8%)	426 (0.8%)	294 (0.7%)	19 (0.7%)	110 (0.7%)	68 (0.6%)	97 (0.9%)	32 (0.7%)
High risk of complications – N (%)	66,275 (69.5%)	38,020 (69.5%)	28,255 (69.6%)	1990 (70.1%)	10,653 (68.4%)	7670 (70.5%)	7942 (70.1%)	3307 (68.3%)
Delayed convalescence– N (%)	419 (0.4%)	229 (0.4%)	190 (0.5%)	7 (0.2%)	57 (0.4%)	62 (0.6%)	64 (0.6%)	15 (0.3%)

https://doi.org/10.2147/CIA.S562164

Number of geriatric-typical characteristic complexes (GTMK) present at PHF diagnosis								
Mean (sd)	3.6 (2.2)	3.7 (2.3)	3.4 (2.2)	3.4 (2.2)	3.3 (2.1)	3.6 (2.2)	3.5 (2.2)	3.3 (2.1)
Median (1. Quantile, 3. Quantile)	3 (2,5)	3 (2,5)	3 (2,5)	3 (2,5)	3 (2,5)	3 (2,5)	3 (2,5)	3 (2,5)
No GTMK – N (%)	6366 (6.7%)	3484 (6.4%)	2882 (7.1%)	212 (7.5%)	1224 (7.9%)	662 (6.1%)	784 (6.9%)	377 (7.8%)
1 GTMK – N (%)	11,925 (12.5%)	6611 (12.1%)	5314 (13.1%)	363 (12.8%)	2241 (14.4%)	1242 (11.4%)	1468 (13.0%)	676 (14.0%)
2 GTMK – N (%)	15,696 (16.5%)	8683 (15.9%)	7013 (17.3%)	534 (18.8%)	2816 (18.1%)	1745 (16.0%)	1918 (16.9%)	908 (18.7%)
3 GTMK – N (%)	16,692 (17.5%)	9372 (17.1%)	7320 (18.0%)	499 (17.6%)	2909 (18.7%)	1926 (17.7%)	1986 (17.5%)	853 (17.6%)
4 GTMK – N (%)	14,539 (15.3%)	8313 (15.2%)	6226 (15.3%)	412 (14.5%)	2326 (14.9%)	1757 (16.2%)	1731 (15.3%)	763 (15.8%)
5 GTMK – N (%)	11,591 (12.2%)	6836 (12.5%)	4755 (11.7%)	338 (11.9%)	1707 (11.0%)	1415 (13.0%)	1295 (11.4%)	544 (11.2%)
6 GTMK – N (%)	8,174 (8.6%)	4944 (9.0%)	3230 (8.0%)	232 (8.2%)	1112 (7.1%)	949 (8.7%)	937 (8.3%)	354 (7.3%)
7 GTMK – N (%)	5,174 (5.4%)	3158 (5.8%)	2016 (5.0%)	124 (4.4%)	686 (4.4%)	612 (5.6%)	594 (5.2%)	208 (4.3%)
8 GTMK – N (%)	2,954 (3.1%)	1883 (3.4%)	1071 (2.6%)	77 (2.7%)	323 (2.1%)	335 (3.1%)	336 (3.0%)	93 (1.9%)
9 and more – N (%)	2,205 (2.3%)	1,421 (2.6%)	784 (0.8%)	46 (1.6%)	234 (1.5%)	231 (2.1%)	273 (2.4%)	67 (1.4%)

Abbreviations: sLPF, locked plate fixation for simple fracture; LPF, locked plated fixation for multi-fragment fracture; PHF, proximal humeral fracture; RTSA, reverse total shoulder arthroplasty.

https://doi.org/10.2147/CIA.S562164

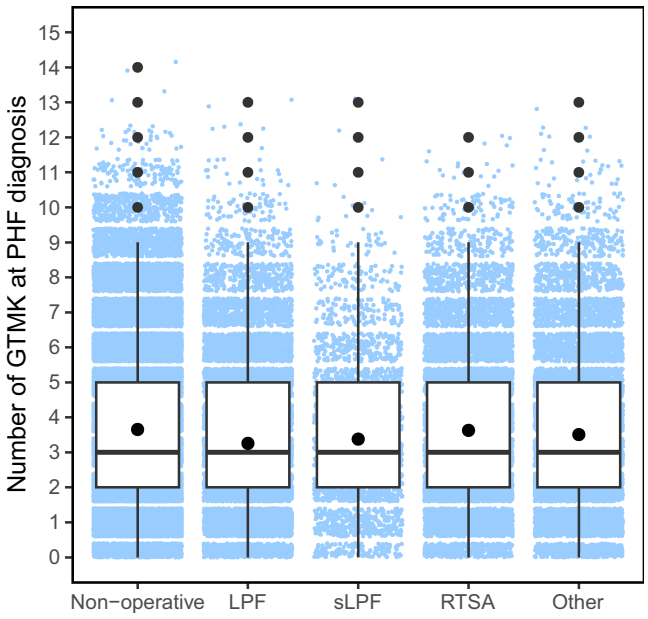

Figure 2 Boxplot and Mean of the number of Geriatrics-typical characteristic complexes (GTMK) prevalent at PHF diagnosis for the non-operative and different surgical treatment groups.
Abbreviation: sLPF; locked plate fixation for simple fracture; LPF, locked plate fixation for multi-fragment fracture; RTSA, reverse total shoulder arthroplasty.

Surgical vs Non-Surgically Treated Patients

Several geriatric-typical multimorbidity complexes (GTMKs) were strongly associated with adverse outcomes, independent of treatment approach. *Incontinence* increased the risk of mortality in surgically (HR 1.16, 95% CI: 1.03–1.30, p = 0.013) and non-surgically treated patients (HR 1.23, 95% CI: 1.13–1.35 p < 0.001), showing no difference between the groups (p_{int}= 0.771). The observation of MAE showed a similar behavior with an increased risk in surgically (HR 1.11, 95% CI: 1.02–1.21, p = 0.021) and non-surgically treated patients (HR 1.15, 95% CI: 1.07–1.23, p < 0.001, p_{int}= 0.963).

Similarly, *decubital ulcers* were a predictor of higher mortality (HR 1.35, 95% CI: 1.17–1.54, *p* < 0.001) and increased MAE (HR 1.30, 95% CI: 1.17–1.45, p < 0.001) in surgically treated patients, with non-surgically treated patients exhibiting similar risks (OS: HR 1.59, 95% CI: 1.45–1.75, p < 0.001; MAE: HR 1.48, 95% CI: 1.37–1.60, p < 0.001) and no difference between treatment groups (OS: p_{int} = 0.148; MAE: p_{int} = 0.259).

Even when considering the subgroups of surgically and non-surgically treated patients separately, the GTMK *malnutrition* (all p_{int} > 0.200) and *fluid and electronic disorders* (all p_{int} >0.200 except MOC) remained among the strongest predictors within both groups with no notable difference in risk regarding the endpoints, reinforcing the broad impact of these risk factors across all patients, regardless of surgical intervention.

The only GTMK that showed a notable difference between treatment groups regarding OS, MAE, TE and SC was *cognitive deficits* (all p_{int} < 0.010). While cognitive deficits were associated with higher risk for all endpoints for surgically treated patients with the largest risk difference for injury- or surgical-related complications (OP: HR 1.10, 95% CI: 0.91–1.31, p = 0.359, non-OP: HR 0.84, 95%-CI: 0.69–1.03, p = 0.095, p_{int}< 0.001), see Figures S1–S6.

Interestingly, certain GTMKs appeared to have a protective effect. *Sensory disorders* were associated with a lower risk of MAE in surgically (HR 0.90, 95% CI: 0.82–0.98, p = 0.016) and non-surgically treated patients (HR 0.93, 95% CI: 0.87–1.00, p = 0.059, p_{int}= 0.621) and TE in surgically (HR 0.89, 95% CI: 0.80–0.99, p = 0.026) and non-surgically treated patients (HR 0.92, 95% CI: 0.85–1.00, p = 0.048, p_{int}= 0.449), while *severe visual or hearing impairment* was linked to reduced MAE risk for surgically treated (HR 0.86, 95% CI: 0.80–0.93, p < 0.001) and non-surgically treated patients (HR 0.81, 95% CI.0.76–0.86, p < 0.001, p_{int}= 0.108) and TE risk for surgically (HR 0.84, 95% CI: 0.77–0.92, p < 0.001) and non-surgically treated patients (HR 0.83, 95% CI: 0.77–0.89, p < 0.001, p_{int}= 0.587). Similarly, patients classified as *high risk* demonstrated a 25% lower likelihood of MAE for surgically (HR 0.75, 95% CI: 0.68–0.82, p <

0.001) and 19% for non-surgically treated patients (HR 0.81, 95% CI: 0.74–0.88, p < 0.001, p_{int} = 0.461) and a notably reduced risk of TE (OP: HR 0.76, 95% CI: 0.68–0.82, p < 0.001, non-OP: HR 0.81, 95% CI 0.74–0.89, p < 0.001, p_{int} = 0.922). These protective associations persisted across treatment groups, with no differences between surgical and non-surgical approaches. For further details, refer to Figures 3 and S3–S6 in the Supplementary File, respectively.

Influence of GTMKs on the Endpoints OS, MAE and TE

In the first three months after the diagnosis of PHF, death occurred in 4.3% (95%-CI: 4.2–4.4%), whilst 7.1% experienced MAEs (95%-CI: 6.9–7.2%) and 5.6% experienced a thromboembolic event (95%-CI: 5.4–5.7%). A representation of the 3-month rates of the primary endpoints depending on the number of GTMKs present at the time of PHF diagnosis is provided in Figure 4.

When assessing the influence of treatment choice on the aforementioned endpoints contingent on the GTMKs, it was evident that both the nature of the GTMKs as well as the number of GTMKs were key factors for these findings (S. Figure 2). Overall, when investigating the influence of the number of GTMKs present at the time of PHF diagnosis, it was found that the risk for mortality, MAE or TE increased with increasing number of GTMKs within the first three months. Interestingly, the presence of 1–3 GTMKs had a significant protective effect for the aforementioned outcomes (Figure 5).

Influence of GTMKs on the Endpoints MOC and SC

During the 3-month observation period, MOC and SC occurred in 11.5% (95%-CI:11.3–11.7%) and 4.1% (95%-CI: 3.9–4.2%) of cases, respectively. Similar to the findings for OS, MAE, and TE, differences were observed depending on both the nature and number of GTMKs present. The GTMKs *pain* (HR 1.24, 95%-CI: 1.12–1.36, $p < 0.001$, $p_{int} < 0.001$) and *high risk of complications* (HR 1.16, 95%-CI: 1.04–1.30, $p = 0.008$, $p_{int} = 0.009$) were associated with an increased risk of injury or surgical related complications in the non-surgically treated group but not in the surgically treated group, leading to a difference in risk between the treatment groups (Figures 5 and S2). Additionally, the presence of GTMKs in the total cohort such as *pain* (HR 1.28, 95%-CI: 1.23–1.33, $p < 0.001$, $p_{int} = 0.069$), *sensory disorders* (HR 1.23, 95%-CI: 1.18–1.28, $p < 0.001$, $p_{int} = 0.550$), and *high risk of complications* (HR 1.21, 95%-CI: 1.16–1.27, $p < 0.001$, $p_{int} = 0.773$) increased the risk of MOC across all treatment groups. When differentiating between treatment options, *fluid and electrolytes disorder* differed in MOC between the treatment groups (OP: HR 1.01, 95%-CI: 0.94, 1.09, p = 0.718, non-OP: HR 0.88, 95%-CI: 0.82–0.94, p < 0.001, $p_{int} < 0.001$).

Discussion

The aim of this study was to investigate the short-term influence of GTMM of older patients with PHF. The most important finding of this study was that the GTMKs are independent risk-associated factors for the evaluated outcomes in both, operative and non-operative treated patients. The impact of GTMKs, such as incontinence, decubitus ulcers and malnutrition and malnourishment, emerged as relevant factors associated with inferior outcomes.

The PHF is the third most common fracture in older patients with a notable complication rate.[14,27–32] To quantify the risk-associated factors for complications and death, comorbidity scores like the modified Frailty Index, Charlson Comorbidity Index, and Elixhauser Comorbidity Index have been developed.[33–35] Whilst the Charlson Comorbidity as well as the Elixhauser Indices only include specific ICD10 diagnoses, the GTMKs use a wider spectrum of geriatric specific diagnoses allowing for a more precise analysis of older patients. Literature indicates that the number of comorbidities predicts complications after PHF. Similar to Maron et al and Fernandez et al, we found that suffering from more than 6 comorbidities significantly predicts mortality, MAEs, and TEs, regardless of treatment choice.[33,35] However, after adjusting for patient risk profiles and treatment choices, no difference could be found anymore. Hence, we agree with Fernandez et al that higher comorbidity loads increase complication risk and that patients with adverse events have higher comorbidity loads.[35]

Our study adds to the literature by emphasizing the importance of focusing on specific geriatric diagnostic complexes rather than solely assessing the overall comorbidity load. In our PHF cohort, we overserved that patients with coded incontinence and/or malnutrition and malnourishment had a higher risk for MAEs, TEs and death within 3 months.

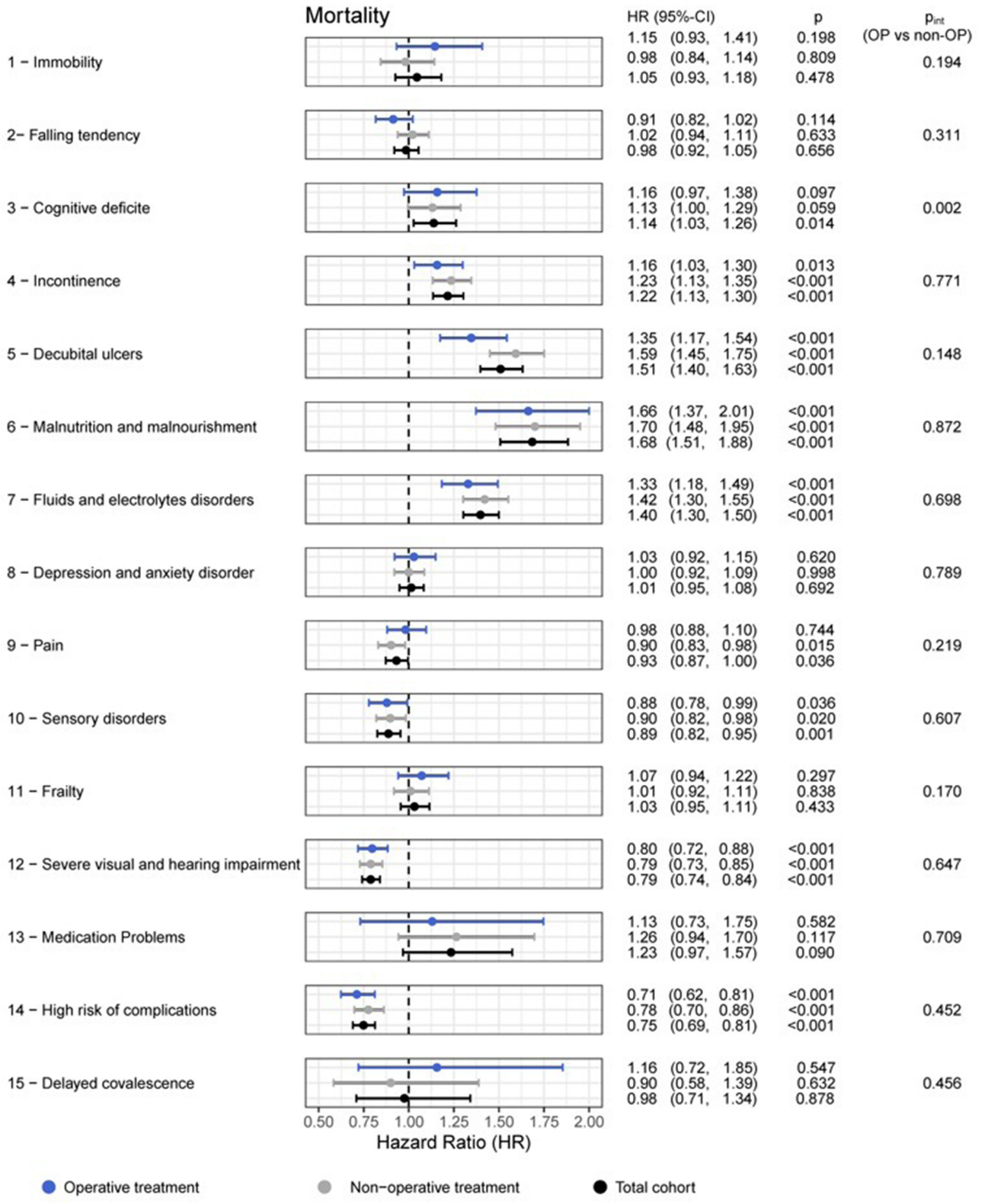

Figure 3 Influence of the individual GTMK on Major Adverse Events with adjustment for the patient risk profile. The influence was assessed for the subgroups of non-surgical (light gray), surgical (dark gray), and for the overall cohort (black diamond). The interaction p-values (p_int) are calculated using a Cox regression model that includes interaction terms for the individual GTMK and the binary operation variable and quantify the difference in GTMK influence between the non-operative and operative subgroups. Full regression results are presented in Table S6.

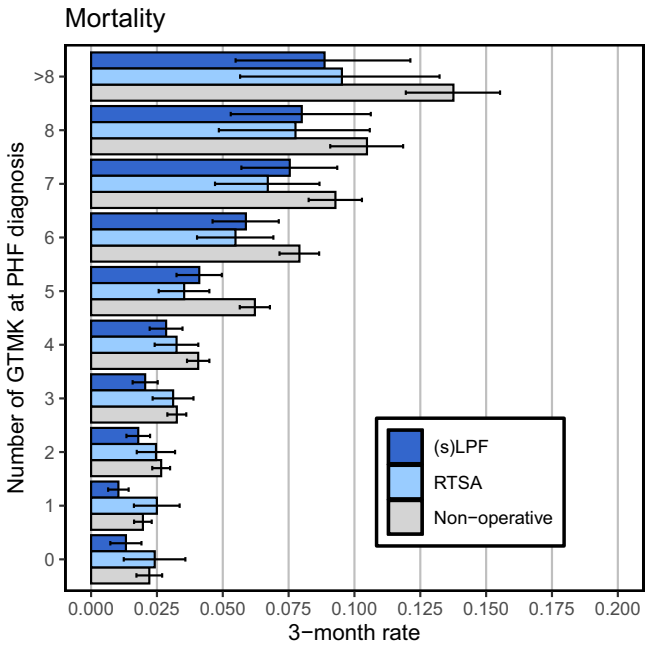

Figure 4 3-month mortality rates with 95% confidence interval depending on the number of GTMK present at the time of PHF of sLPF & LPF (dark blue), RTSA (light blue) and non-operative treatment (light gray). Mortality rate was determined using Kaplan–Meier estimator. sLPF – locked plate fixation for simple fracture, LPF – locked plated fixation for multi-fragment fracture, PHF – proximal humeral fracture, RTSA –reverse total shoulder arthroplasty.

Abbreviation: sLPF; locked plate fixation for simple fracture; LPF, locked plate fixation for multi-fragment fracture; PHF, proximal humeral fracture; RTSA, reverse total shoulder arthroplasty.

Previous studies have re-iterated the importance of the detection of specific diagnoses including osteoporosis, chronic kidney failure and rheumatoid arthritis; however, until today systematic comorbidity analysis has found little clinical application.[20,22,36–38] Our findings are in line with Gan et al, showing that older orthopedic patients with cognitive impairment are more prone to surgical complications.[39] Garcia Reza et al have taken this assumption one step further and categorized the comorbidities in functional groups. They discovered that neurological-psychiatric comorbidities were associated with a 24-fold increase in mortality risk.[23] This is consistent with our findings, indicating that cognitive impairment emerged as an independent risk-associated factor, increasing the risk of mortality and MAEs by 12%, and TEs by 13% in short term. This underscores the critical need for healthcare providers to consider the presence of such complexities when devising treatment plans for older patients.

In Contrary to our findings, sensory disorders, including severe visual and hearing impairment, are associated with increased OS and MAE in patients who have sustained fractures and undergone surgical treatment. The risk of death rises with the number and severity of sensory impairments, with dual vision and hearing impairment conferring the highest risk among older adults.[40] These impairments are highly prevalent in fracture populations, particularly hip fractures, and are linked to greater frailty, cognitive impairment, and functional decline, which may indirectly worsen survival after surgery.[41] Our findings are likely reflecting underlying frailty gradients or selection bias rather than true protective effects.

Our hypothesis that malnutrition is a risk-associated factor for adverse events including death has been previously published, however not specifically investigated in PHF patients.[39] Henkelmann et al postulated that a higher BMI was associated with a 23-fold increase in the probability of complications.[42] Interestingly, our findings suggest that GTMK malnutrition increases the risk of MAEs by 53% and TEs by 56% within the first three months after fracture. The elevated risk associated with malnutrition further emphasizes the importance of a holistic approach to patient care, incorporating nutritional assessments and interventions as part of the overall treatment strategy.

In accordance with the findings by Katthagen et al, in the presented study, in patients with surgical treatment lower risk for the occurrence of death, MAE and TE within the first three months compared to those with non-operative therapy was observed.[17] However, the choice of treatment and surgical technique should be individualized, considering the

https://doi.org/10.2147/CIA.S562164

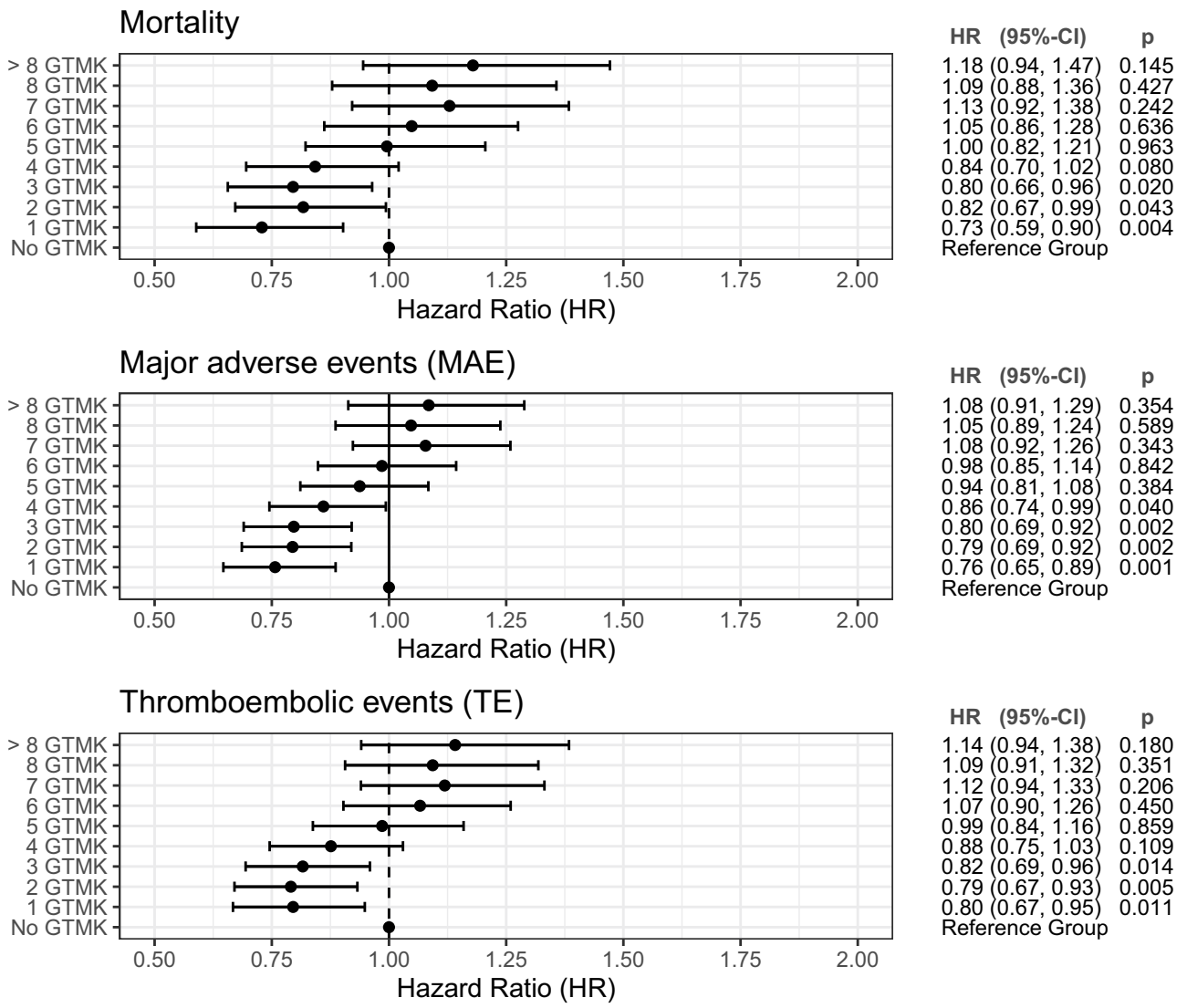

Figure 5 Association between the number of GTMK present at the time of PHF and the risk of experiencing a primary event within the first 3 months of observation. Adjustment for the patients' risk profile was done using multivariable Cox regression. The presented hazard ratios (HR) are thus independent from the treatment group. Full regression results are presented in the Supplementary File (Tables S1–S3).

patient's age, aspirations, and the number of fracture components, as noted by Fenwick et al.[43] To date, there is no definitive evidence indicating which treatment option for PHF in older patients is superior.

Garcia-Reza et al found no difference in medium to long-term mortality between surgically and non-operatively treated patients and noted that patients with a higher comorbidity load benefited more from conservative treatment.[23,44] Similarly, Mellstrand-Navarro et al observed no significant difference between surgical and non-surgical treatments in older people, advocating for a more restrictive approach to surgical treatment of PHF to reduce hospital costs.[45] However, after adjustment for patient-individual factors, we observed that surgical treatment does not represent a risk-associated factor for worse or fatal outcome in short-term, not even in highly morbid patients. Samborski et al matched 192 patients by age- comorbidity and fracture morphology and found that surgical treatment had significantly better clinical outcomes compared to non-operatively treated patients.[46] This is in line with our data showing that patients with lower number of GTMKs that were treated with LPF were associated with a lower risk for postoperative complications and a higher overall survival.

Once the choice for surgical treatment is made, the method of its treatment remains questionable. It is described that younger patients are treated with LPF and older patients receive more often an RTSA.[47] A recent study by Stolberg-

Stolberg et al found that RTSA was associated with more favorable outcomes than LPF in terms of overall survival, major adverse events, general and surgical complications, and rate of revision procedures in the long term.[20]

This retrospective study introduces limitations that must be considered: Given the retrospective nature, potential biases and confounding factors are possible. In this study, the cognitive deficits of patients when suffering a proximal humeral fracture were not quantified. Another critical limitation is the absence of detailed information on the severity of the fractures. PHF can vary greatly in terms of severity and displacement, which can influence treatment choice, recovery outcomes and the potential occurrence of complications. Another potential source of bias arises from the fact that the subjective clinical judgment of treating physicians is not captured in ICD coding. Consequently, patients who appear overall healthier and more resilient may be more likely to be chosen for surgical treatment, even if they have a high number of coded comorbidities. In general, the data were initially collected for financial purpose, not for research.

Concluding, the treatment of PHF in geriatric patients is challenging and often accompanied by complications and secondary conditions. To prevent these, the GTMKs are a useful tool to identify the risk-associated factors of patients by adding categories to the well-known scores. The GTMKs incontinence and malnutrition are important predictors of morbidity and complication occurrence. A close cooperation with patients and geriatric physicians is needed to tailor treatment options to patients wishes and expectations while limiting mortality and complication rates.

Data Sharing Statement

The authors confirm that the data used in this study cannot be made available in the manuscript, in the supplementary files or in a public repository due to the Federal Data Protection Act (BDSG). They are stored on a BARMER server to facilitate replication of the results. In general, access to statutory health insurance data for research purposes is only possible under the conditions laid down in the German Social Code (SGB V § 287).

Ethical Committee Approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by Ethics Committee Westfalen-Lippe (no. 2022-300-f-S). In Germany, the responsible ethics authority is the regional Medical Chamber (Ärztekammer), which is independent from hospitals or universities. Therefore, the approving committee is not affiliated with any of the authors' institutions. According to German regulations and as confirmed by the approving Ethics Committee, no individual written informed consent was required because the study used anonymized insurance data that cannot be traced back to individual patients. The waiver of consent was granted based on the minimal-risk nature of the study and the complete anonymization of all personal health information. All data were handled confidentially and in compliance with applicable data protection laws and the principles of the Declaration of Helsinki.

Disclosure

JK, JSS and JCK report research funding from the German Society for Trauma Surgery sponsored by Stryker, outside the submitted work. Professor J Christoph Katthagen reports personal fees from Rimasys, personal fees from DePuy Synthes, personal fees from Hofer Medical, personal fees from Medi, grants, personal fees from Arthrex, grants from Lima, outside the submitted work. Professor Michael J Raschke reports personal fees from OPED Advisory Board, outside the submitted work. On behalf of all other authors, the corresponding author states that there is no conflict of interest.

References

1. Jones CH, Dolsten M. Healthcare on the brink: navigating the challenges of an aging society in the United States. *Npj Aging*. 2024;10(1):22. doi:10.1038/s41514-024-00148-2
2. Vollset SE, Goren E, Yuan CW, et al. Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the global burden of disease study. *Lancet Lond Engl*. 2020;396(10258):1285–1306. doi:10.1016/S0140-6736(20)30677-2
3. Kotsani M, Kravvariti E, Avgerinou C, et al. The relevance and added value of geriatric medicine (GM): introducing GM to non-geriatricians. *J Clin Med*. 2021;10(14):3018. doi:10.3390/jcm10143018
4. Rahman MM, Rosenberg M, Flores G, et al. A systematic review and meta-analysis of unmet needs for healthcare and long-term care among older people. *Health Econ Rev*. 2022;12(1):60. doi:10.1186/s13561-022-00398-4
5. Tembo MC, Holloway-Kew KL, Mohebbi M, et al. The association between a fracture risk tool and frailty: geelong Osteoporosis Study. *BMC Geriatr*. 2020;20(1):196. doi:10.1186/s12877-020-01595-8

6. Curtis EM, Moon RJ, Harvey NC, Cooper C. The impact of fragility fracture and approaches to osteoporosis risk assessment worldwide. *Bone*. 2017;104:29–38. doi:10.1016/j.bone.2017.01.024
7. Moldovan F, Moldovan L. A modeling study for hip fracture rates in Romania. *J Clin Med*. 2025;14(9):3162. doi:10.3390/jcm14093162
8. Singh A, Adams AL, Burchette R, Dell RM, Funahashi TT, Navarro RA. The effect of osteoporosis management on proximal humeral fracture. *J Shoulder Elbow Surg*. 2015;24(2):191–198. doi:10.1016/j.jse.2014.07.005
9. Lee SH, Dargent-Molina P, Bréart G; EPIDOS Group. Epidemiologie de l'Osteoporose study. Risk factors for fractures of the proximal humerus: results from the EPIDOS prospective study. *J Bone Miner Res*. 2002;17(5):817–825. doi:10.1359/jbmr.2002.17.5.817
10. Ruiz JG, Dent E, Morley JE, et al. Screening for and managing the person with frailty in primary care: ICFSR consensus guidelines. *J Nutr Health Aging*. 2020;24(9):920–927. doi:10.1007/s12603-020-1498-x
11. Dent E, Dalla Via J, Bozanich T, et al. Frailty increases the long-term risk for fall and fracture-related hospitalizations and all-cause mortality in community-dwelling older women. *J Bone Miner Res Off*. 2024;39(3):222–230. doi:10.1093/jbmr/zjad019
12. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. *Injury*. 2006;37(8):691–697. doi:10.1016/j.injury.2006.04.130
13. Launonen AP, Lepola V, Saranko A, Flinkkilä T, Laitinen M, Mattila VM. Epidemiology of proximal humerus fractures. *Arch Osteoporos*. 2015;10:209. doi:10.1007/s11657-015-0209-4
14. Koeppe J, Stolberg-Stolberg J, Fischhuber K, et al. The incidence of proximal humerus fracture. *Dtsch Ärztebl Int*. 2023. doi:10.3238/arztebl.m2023.0132
15. Handoll H, Brealey S, Rangan A, et al. The ProFHER (PROximal Fracture of the Humerus: evaluation by Randomisation) trial - a pragmatic multicentre randomised controlled trial evaluating the clinical effectiveness and cost-effectiveness of surgical compared with non-surgical treatment for proximal fracture of the humerus in adults. *Health Technol Assess Winch Engl*. 2015;19(24):1–280.
16. Handoll HH, Elliott J, Thillemann TM, Aluko P, Brorson S. Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev*. 2022;6(6):CD000434. doi:10.1002/14651858.CD000434.pub5
17. Katthagen JC, Raschke MJ, Fischhuber K, et al. Conservative versus operative treatment of proximal humerus fractures in older individuals—an analysis of insurance data. *Dtsch Arzteblatt Int*. 2024;(Forthcoming):arztebl.m2024.0059.
18. Rischen R, Köppe J, Stolberg-Stolberg J, et al. Treatment reality of proximal humeral fractures in the elderly—trending variants of locking plate fixation in Germany. *J Clin Med*. 2023;12(4):1440. doi:10.3390/jcm12041440
19. Köppe J, Stolberg-Stolberg J, Rischen R, Faldum A, Raschke MJ, Katthagen JC. In-hospital complications are more likely to occur after reverse shoulder arthroplasty than after locked plating for proximal humeral fractures. *Clin Orthop*. 2021;479(10):2284–2292. doi:10.1097/CORR.0000000000001776
20. Stolberg-Stolberg J, Köppe J, Rischen R, et al. The surgical treatment of proximal humeral fractures in elderly patients—an analysis of the long-term course of locked plate fixation and reverse total shoulder arthroplasty based on health insurance data. *Dtsch Ärztebl Int*. 2021. doi:10.3238/arztebl.m2021.0326
21. Fraser AN, Bjørdal J, Wagle TM, et al. Reverse shoulder arthroplasty is superior to plate fixation at 2 years for displaced proximal humeral fractures in the elderly: a multicenter randomized controlled trial. *J Bone Joint Surg Am*. 2020;102(6):477–485. doi:10.2106/JBJS.19.01071
22. Koeppe J, Katthagen JC, Rischen R, et al. Male sex is associated with higher mortality and increased risk for complications after surgical treatment of proximal humeral fractures. *J Clin Med*. 2021;10(11):2500. doi:10.3390/jcm10112500
23. Garcia-Reza A, Dominguez-Prado DM, Iglesias-Nuñez C, et al. Analysis of predictors of mortality after surgical and non-surgical management in proximal humerus fractures. *J Orthop Traumatol*. 2021;22(1):43. doi:10.1186/s10195-021-00606-7
24. Doursounian L, Gregory T, Miquel A. A prognostic classification of proximal humerus fractures: the cephalic extension staging. *Eur J Orthop Surg Traumatol*. 2024;34(1):143–153. doi:10.1007/s00590-023-03626-7
25. Klute L, Henssler L, Schliemann B, et al. Factors influencing choice of treatment for proximal humeral fractures elaborated in a Delphi consensus process. *Arch Orthop Trauma Surg*. 2023;143(12):7053–7061. doi:10.1007/s00402-023-05028-0
26. Abgrenzungskriterien der Geriatrie - Version 1.3.
27. Adam J, Basil Ammori M, Isah I, Jeyam M, Butt U. Mortality after inpatient stay for proximal humeral fractures. *J Shoulder Elbow Surg*. 2020;29(1):e22–8. doi:10.1016/j.jse.2019.05.030
28. Ambrozič M, Bergman R, Hidnik L, et al. Decision-making and treatment results of complex proximal humeral fractures in geriatric patients: retrospective study from a level 1 trauma centre. *Signa Vitae*. 2022. doi:10.22514/sv.2022.040
29. Melton LJ, Achenbach SJ, Atkinson EJ, Therneau TM, Amin S. Long-term mortality following fractures at different skeletal sites: a population-based cohort study. *Osteoporos Int*. 2013;24(5):1689–1696. doi:10.1007/s00198-012-2225-1
30. Vu CCL, Runner RP, Reisman WM, Schenker ML. The frail fail: increased mortality and post-operative complications in orthopaedic trauma patients. *Injury*. 2017;48(11):2443–2450. doi:10.1016/j.injury.2017.08.026
31. Somersalo A, Paloneva J, Kautiainen H, Lönnroos E, Heinänen M, Kiviranta I. Increased mortality after upper extremity fracture requiring inpatient care. *Acta Orthop*. 2015;86(5):533–557. doi:10.3109/17453674.2015.1043833
32. Olsson C, Petersson C, Nordquist A. Increased mortality after fracture of the surgical neck of the humerusA case-control study of 253 patients with a 12-year follow-up. *Acta Orthop Scand*. 2003;74(6):714–717. doi:10.1080/00016470310018252
33. Maron SZ, Neifert SN, Ranson WA, et al. Elixhauser comorbidity measure is superior to charlson comorbidity index in-predicting hospital complications following elective posterior cervical decompression and fusion. *World Neurosurg*. 2020;138:e26–34. doi:10.1016/j.wneu.2020.01.141
34. Cher EWL, Allen JC, Howe TS, Koh JSB. Comorbidity as the dominant predictor of mortality after Hip fracture surgeries. *Osteoporos Int*. 2019;30(12):2477–2483. doi:10.1007/s00198-019-05139-8
35. Fernández-Cortiñas AB, Vidal Campos J, Paredes-Carnero X, Marco Martinez F. Is the Charlson comorbidity index a good predictor of mortality and adverse effects in proximal humerus fractures? *Orthop Traumatol Surg Res*. 2019;105(2):301–305. doi:10.1016/j.otsr.2018.11.016
36. Katthagen JC, Koeppe J, Stolberg-Stolberg J, et al. Effects of anti-osteoporosis therapy on the risk of secondary fractures and surgical complications following surgical fixation of proximal humerus fracture in older people. *Age Ageing*. 2023;52(6):afad097. doi:10.1093/ageing/afad097
37. Sanchez G, Vargas M, Gordon AM, et al. Risk factors for nonunion following open reduction and internal fixation for proximal humerus fractures. *Eur J Orthop Surg Traumatol*. 2022;33(4):883–888. doi:10.1007/s00590-022-03221-2

38. Ahlquist S, Hsiue PP, Chen CJ, et al. Renal disease is a risk factor for complications and mortality after open reduction internal fixation of proximal humerus fractures. *JSES Int*. 2022;6(5):736–742. doi:10.1016/j.jseint.2022.05.015
39. Gan S, Yu Y, Wu J, et al. Preoperative assessment of cognitive function and risk assessment of cognitive impairment in elderly patients with orthopedics: a cross-sectional study. *BMC Anesthesiol*. 2020;20(1):189. doi:10.1186/s12871-020-01096-6
40. Vohra V, Simonsick EM, Kamath V, Bandeen-Roche K, Agrawal Y, Rowan NR. Physical function trajectories and mortality in older adults with multisensory impairment. *JAMA Otolaryngol Neck Surg*. 2024;150(3):217. doi:10.1001/jamaoto.2023.4378
41. Grue EV, Kirkevold M, Ranhoff AH. Prevalence of vision, hearing, and combined vision and hearing impairments in patients with hip fractures. *J Clin Nurs*. 2009;18(21):3037–3049. doi:10.1111/j.1365-2702.2009.02856.x
42. Henkelmann R, Theopold J, Kitsche J, Link PV, Mende M, Hepp P. Comorbidities, substance abuse, weight and age are independent risk factors for postoperative complications following operation for proximal humerus fractures: a retrospective analysis of 1109 patients. *Arch Orthop Trauma Surg*. 2021;142(10):2701–2709. doi:10.1007/s00402-021-04022-8
43. Fenwick A, Schreiner S, Bund T, et al. Die proximale Humerusfraktur: ist die Operation immer die beste Wahl. *Obere Extrem*. 2023;18(3):195–201. doi:10.1007/s11678-023-00744-w
44. Razaeian S, Krettek C, Hawi N. Algorithmus zur konservativen Behandlung von proximalen Humerusfrakturen: erfahrungen aus dem Hannover Humerusregister. *Obere Extrem*. 2022;17(3):162–171. doi:10.1007/s11678-022-00702-y
45. Mellstrand Navarro C, Brolund A, Ekholm C, et al. Treatment of humerus fractures in the elderly: a systematic review covering effectiveness, safety, economic aspects and evolution of practice. *PLoS One*. 2018;13(12):e0207815. doi:10.1371/journal.pone.0207815
46. Samborski SA, Haws BE, Karnyski S, et al. Early outcomes of proximal humerus fractures in adults treated with locked plate fixation compared with nonoperative treatment: an age-, comorbidity-, and fracture morphology-matched analysis. *J Orthop Trauma*. 2023;37(3):142–148. doi:10.1097/BOT.0000000000002511
47. Bergdahl C, Wennergren D, Ekelund J, Möller M. Mortality after a proximal humeral fracture: data on 18,452 patients from the Swedish fracture register. *Bone Jt J*. 2020;102(11):1484–1490. doi:10.1302/0301-620X.102B11.BJJ-2020-0627.R1