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ORIGINAL ARTICLE

# Characteristics and treatment options of 272,152 geriatric patients with very high and high fracture risk

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## Abstract

**Summary** Our study of 272,152 geriatric patients assessed osteoporosis treatment requirement and eligibility. Over 75% qualified for therapy, with 54% at very high fracture risk, classifying for bone anabolic treatment. Despite contraindications in 8–20%, most were suitable for treatment. Especially in geriatric patients, early risk-assessment and timely intervention are essential.

**Purpose** The German osteoporosis guideline defines high and very high fracture-risk based on quantifiable evidence-based risk-factors, recommending bone anabolic treatment as first-line therapy for the latter. Given age as a major risk factor, we investigated the proportion of geriatric patients with very high fracture risk, their characteristics, and the percentage suitable for bone anabolic treatment considering contraindications.

**Methods** Data from the Geriatrics in Bavaria-Database (GiB-DAT, Geriatrie in Bayern Datenbank) included 272,152 participants (mean age 82 ± 7 years) between 2013 and 2023. Risk-factors and contraindications were evaluated using ICD-10-(International Statistical Classification of Diseases) and ATC-codes (Anatomical Therapeutical Chemical Classification). We analyzed the proportion in the high-risk and very high-risk group, their characteristics, and the share with a contraindication for specific anti-osteoporotic treatments.

**Results** > 75% of the patients qualified for specific anti-osteoporotic treatment, with the majority (54%) at very high-risk requiring bone anabolic treatment. Patients in the very high-risk group had the lowest mini mental status examination (MMSE) (23 ± 5 points) and activities of daily living (ADL) scores (45 ± 20 points). Contraindications for bone anabolic treatments were found in 20% of women and 8% of all very high-risk patients. Seventy percent of the total study population had no contraindication for any specific anti-osteoporotic medications.

**Conclusion** The majority of geriatric patients is at a very high-risk for osteoporotic fractures, characterized by cognitive impairment, ADL limitations, and increased vulnerability. While some patients had contraindications, most were eligible for anti-osteoporotic and particularly bone anabolic treatments. Timely risk-assessment and treatment initiation is crucial and barriers need to be addressed.

**Keywords** Bisphosphonates · Denosumab · Fragility fracture · Osteoporosis · Romosozumab · Teriparatid

## Introduction

Osteoporosis is a systemic skeletal disorder characterized by a reduced bone mass and decline in micro-architecture of the bone tissue leading to an increased fragility (1). Within the recent years, not only poor bone quality, clinically measured by bone mineral density, but the concomitant fracture-risk, which is based on a variety of clinical risk-factors, was identified as the decisive issue for therapy initiation (2). Therefore, a fracture-risk-based approach for osteoporosis diagnostics and therapy has prevailed in European (3) and

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international guidelines (4). Within this framework, a very high-risk group (5) requiring highly potent treatment was identified (3, 6–8). Compared to oral bisphosphonate therapy, bone anabolic treatment has been shown to be superior especially in this group (7, 9).

Within the current German osteoporosis guideline the very high-risk (> 10% fracture-risk within the next 3 years for hip- and vertebral fracture) and three further fracture-risk groups (< 3%, 3–5%, 5–10%) were clearly defined based on 33 quantifiable, evidence-based, clinical risk-factors (10). For high-risk patients (5–10% fracture-risk) mainly antiresorptive treatment and for very high-risk patients (> 10% fracture-risk) bone anabolic treatment is recommended (10).

As age is the major risk-factor for osteoporosis, we have examined data from more than a quarter million patients from The Geriatrics in Bavaria-Database (GiB-DAT, Geriatrie in Bayern Datenbank) to identify the proportion of geriatric patients who require specific anti-osteoporotic treatment. Based on the German osteoporosis guideline, we wanted to determine (i) the percentage distribution and (ii) patient characteristics of the high-risk and very high-risk group in this cohort. Also, as contraindications for specific anti-osteoporotic treatment such as stroke, myocardial infarction and a reduced kidney function, might be present more often in geriatric patients we aimed to investigate (iii) the percentage of patients who qualify for specific anti-osteoporotic treatment according to the guideline in the light of indication and contraindications named in the SmPC (summary of product characteristics).

## Methods

### Participants

Data were taken from The Geriatrics in Bavaria-Database (GiB-DAT, Geriatrie in Bayern Datenbank) which collects data from different types of geriatric care including inpatient acute geriatrics, geriatric traumatology, inpatient geriatric rehabilitation, geriatric day care clinics, and ambulatory or mobile geriatric rehabilitation facilities. Participating hospitals provide their data quarterly to the database and therefore receive analyses of their data. For our analysis, the different settings were subsumed as inpatient rehabilitation, inpatient acute geriatrics, and others. A detailed description of the data set can be found online (GiB-DAT Datensatzbeschreibung (January 26th 2016) (GiB-DAT-Geriatrics-in-Bavaria database Home (gibdat.com))) (11). From 2013 to 2023, data from approximately 650,000 patients were included in the database. As for our analyses, complete information on the investigated variables was necessary, only patients in which at least one medication and one diagnosis were reported were included as in these patients usually all of the required data are submitted by the attending hospital, leading to a total number of 272,152 included cases. Data were transferred anonymized, for which no longitudinal analysis was possible.

### Included variables

Sociodemographic variables included age, sex, marital status, living situation, and level of care. Age was calculated as the date of admission minus the date of birth in years. Sex was dichotomized in female/male. Marital status was reported as unknown, single, widowed, married, divorced, or living with a partner. Patients who were married and were living with a partner were subsumed as one group. The living situation was evaluated based on the place of living (apartment/house, assisted living facility, nursing home, etc.) and the need for help (no care, from family, or professional). For our analysis, data were subsumed by the need for help as "single-person household without help"; "privately with help" (from a partner, family, professional or both); or "institutionalized." As a measure of the extent of needed care, care levels (0–5) were evaluated with higher levels of care representing higher need of care. A detailed description of the different care levels can be found in the supplement (supplement SI Table 4). Also, diagnoses including the main diagnosis and secondary diagnoses as well as the type and number of prescribed medications were captured. Main parts of the geriatric assessment, e.g., cognition-(Mini Mental State Examination) screening and evaluation of activities of daily living (ADL) by the Barthel Index, were reported.

### Evaluation of fracture risk

Fracture risk calculation for each patient was based on the 33 clinical risk-factors from the current fracture risk model included in the German guideline on osteoporosis (supplement SI Table 1) (10, 12). The risk-factors and contraindications were identified using ICD-10 diagnoses (International Statistical Classification of Disease and Related Health Problems-10) and ATC-codes (Anatomical Therapeutic Chemical-codes), or both as indicated in the guideline (e.g., both, the diagnosis "epilepsia" or the intake of anti-epileptics can be included for risk calculation) (10). A detailed description of the applied codes is attached in the supplement (SI Table 3). The Timed-up and Go-Test (TUG) was taken from the geriatric assessment.

The DVO fracture risk calculator uses the age- and sex-dependent basic fracture risk of the healthy population and multiplies it with numeric factors of the respective clinical risk factors (13). The definition of the numeric factor of each clinical risk factor is based on systematic literature review and expert consent process within the guideline group. For example, primary hyperparathyroidism has a numeric factor

of 2.2, which means that the absolute fracture risk of a person with primary hyperparathyroidism is 2.2-fold higher than the basic fracture risk of healthy persons with same sex and age. In case a patient has 2 or more clinical risk factors, the two highest numeric factors may be multiplied. There are certain exceptions for related clinical risk factors that must not be considered simultaneously (e.g., fall and TUG). Twenty-eight of 33 risk factors were available in the data set. Bone mineral density (expressed as minimal total hip T score) may be used within the calculator to modify the fracture risk, but it is not mandatory for fracture risk calculation. As the data set does not contain BMD data, we used the "DVO without BMD" calculation for this analysis. Further details regarding the DVO fracture risk calculator were previously published (10) and are described in the supplement (supplement point 1).

Due to the survey method, we could not assess clinical risk-factors that were not coded by ICD-10- or ATC-Codes or were not routinely assessed. Missing parameters were parental hip fracture, body height, and number of falls within the last 12 months. If medication details (e.g., glucocorticoid dosage/duration) or fracture recency/severity were needed for risk calculation, the lowest risk factor was used due to missing data.

### Statistical analyses

Continuous variables were expressed as mean and standard deviation, categorial variables as n and percentage. Group differences were evaluated by ANOVA for parametric data and by Chi-square-test for non-parametric data. All analyses were performed using SPSS Version 18, figures were drawn using Excel 2016 (version 16.0), $p$ values $\leq 0.05$ were considered significant.

### Ethic statement

As all analyses were performed by GiB-DAT and only anonymized results were provided, the ethics committee of the LMU hospital Munich declared no advisory duties were necessary for this project (No: 24–0459 KB, 06–05-2024).

## Results

### Baseline characteristics

Table 1 shows the characteristics of patients stratified for the four fracture risk groups (< 3%, 3–5%, 5–10%, and > 10%). In total, data from 272,152 participants were included. Mean age was 82 ± 7 years. Most of the participants (54%) were allocated to the very high-risk group, followed by the high-risk group (23%), the moderate-risk group (13%), and the low-risk group (10%). Participants in the very high-risk group were significantly older (86 ± 5 years) than participants allocated to other fracture risk-groups (high-risk, 81 ± 5; moderate-risk, 78 ± 5; low-risk, 71 ± 6, $p < 0.001$). Most of the included women were allocated to the very high-risk group (72%; high-risk, 20%; moderate-risk, 5%; low-risk, 3%; $p < 0.001$), whereas most of the included men were allocated to the high-risk group (29%; very high-risk, 20%; moderate-risk, 28%; low-risk, 22%; $p < 0.001$). Participants in the low-risk (10 ± 4) and moderate-risk group (10 ± 4) received significantly more medications than participants in the high-risk (9 ± 4) and very high-risk (9 ± 4, $p < 0.001$) group whereas participants in the very high-risk group had the highest number of diagnoses (9 ± 4; high-risk, 8 ± 4; moderate-risk, 8 ± 4; low-risk, 8 ± 4; $p < 0.001$). Also, the number of fracture risk-factors was significantly highest in the very high-risk group (3 ± 1; high-risk, 2 ± 1; moderate-risk, 2 ± 1; low-risk, 2 ± 1; $p < 0.001$).

Most of the participants who lived institutionalized and had the lowest ADL score were allocated to the very high-risk group (institutionalization: very high-risk, 47%; high-risk, 25%; moderate-risk, 16%; low-risk, 12%; $p < 0.001$; ADL score: very high-risk, 45 ± 20; high-risk, 49 ± 21; moderate-risk, 49 ± 22; low-risk, 50 ± 23; $p < 0.001$) and the lowest score in the Mini Mental State Examination (MMSE) score (very high-risk, 23 ± 5; high-risk, 24 ± 5; moderate-risk, 24 ± 5; low-risk, 25 ± 5, $p < 0.001$).

Figure 1 shows the comparison of the distribution of the care levels between the different fracture-risk groups. None of the investigated patients had care level 5 (highest care level: severe impairment with special care needs). In the low-, moderate, and high-risk group, approximately 50% of the patients had any care level. Due to an increase in care level 2, by 60% patients in the very high-risk group formed the largest portion with any care level.

### Contraindications

Table 2 shows the portion of participants with contraindications to specific anti-osteoporotic treatment stratified for the high-risk and the very high-risk group. Eight percent of the participants in the high-risk group and 7% of the participants in the very high-risk group showed contraindications for bisphosphonates. In both groups, an impaired kidney function was the most common cause for a contraindication for bisphosphonate use whereas a history of medication related osteonecrosis of the jaw (MR-ONJ) only occurred in a marginal number of patients. Only 0.6% in the high-risk and 0.5% in the very high-risk group had contraindications for denosumab therapy which was caused by a history of MR-ONJ or hypocalcemia. Regarding bone anabolic treatment, 21% of women in the high-risk group and 20% of women in the very high-risk group had contraindications

**Table 1** The table shows the characteristics of patients stratified for fracture-risk groups. All measures are presented as mean and (SD), unless otherwise noted. *P* values indicate significant differences between the fracture risk groups

| Characteristics* | Total | < 3% fracture risk | 3– < 5% fracture risk | 5– < 10% fracture risk | ≥ 10% fracture risk | *p*-value |
|---|---|---|---|---|---|---|
| ***n*** (%) | 272,152 (100) | 26,312 (10) | 35,641 (13) | 63,049 (23) | 147,150 (54) | |
| **Age in years** | 82 (7) | 71 (6) | 78 (5) | 81 (5) | 86 (5) | < 0.001˜ |
| **Female *n* (%)** | 180,086 (66) | 5941 (3) | 9416 (5) | 36,094 (20) | 128,635 (72) | < 0.001° |
| **Male *n* (%)** | 92,066 (100) | 20,371 (22) | 26,225 (28) | 26,955 (29) | 18,515 (20) | < 0.001° |
| **ADL**[1] | 47 (21) | 50 (23) | 49 (22) | 49 (21) | 45 (20) | < 0.001˜ |
| **MMSE**[2] | 24 (5) | 25 (5) | 24 (5) | 24 (5) | 23 (5) | < 0.001˜ |
| **No. medications** | 9 (4) | 10 (4) | 10 (4) | 9 (4) | 9 (4) | < 0.001˜ |
| **No. diagnoses**[3] | 8 (4) | 8 (4) | 8 (4) | 8 (4) | 9 (4) | < 0.001˜ |
| **No. risk-factors** | 3 (1) | 2 (1) | 2 (1) | 2 (1) | 3 (1) | < 0.001˜ |
| **Setting *n*** (%) | | | | | | < 0.001° |
| Inpatient rehabilitation | 192,308 (100) | 19,283 (10) | 25,280 (13) | 44,023 (23) | 103,722 (54) | |
| Acute inpatient care | 68,478 (100) | 5497 (8) | 8322 (12) | 15,776 (23) | 38,883 (57) | |
| Other | 11,366 (100) | 1532 (13) | 2039 (18) | 3250 (29) | 4545 (40) | |
| **Care level**[4]***n*** (%) | | | | | | < 0.001° |
| No care level | 91,847 | 9439 (10) | 13,414 (15) | 23,260 (25) | 45,734 (50) | |
| Care level 1 | 15,411 | 1207 (8) | 1730 (11) | 3657 (24) | 8817 (57) | |
| Care level 2 | 62,942 | 5117 (8) | 7051 (11) | 13,334 (21) | 37,440 (60) | |
| Care level 3 | 28,250 | 2774 (10) | 3477 (12) | 5935 (21) | 16,064 (57) | |
| Care level 4 | 5839 | 661 (11) | 764 (13) | 1185 (20) | 3229 (56) | |
| **Family status**[5]***n*** (%) | | | | | | < 0.001° |
| Single | 14,192 | 2909 (21) | 2136 (15) | 2732 (19) | 6415 (45) | |
| Widowed | 95,524 | 2754 (3) | 6400 (7) | 19,007 (20) | 67,363 (70) | |
| Married or living with a partner | 83,640 | 11,883 (14) | 16,588 (20) | 23,641 (28) | 31,528 (38) | |
| Divorced | 14,862 | 2204 (15) | 2231 (15) | 3474 (23) | 6953 (47) | |
| **Living situation**[6]***n*** (%) | | | | | | < 0.001° |
| Private without help | 28,947 | 2903 (10) | 3662 (13) | 6944 (24) | 15,438 (53) | |
| Private with help | 98,017 | 6026 (6) | 9385 (10) | 20,675 (21) | 61,931 (63) | |
| Institutionalisation | 110,888 | 13,441 (12) | 18,002 (16) | 27,748 (25) | 51,697 (47) | |

*All measures are presented as mean and (SD), unless otherwise noted

°Chi-square-test

˜ANOVA

[1]$n = 265{,}739$, [2]$n = 221{,}053$, [3]$n = 272{,}029$, [4]$n = 204{,}289$, [5]$n = 208{,}218$, [6]$n = 237{,}852$

Abbreviations: *ADL* activities of daily living, *MMSE* mini mental status examination, *No.* number of

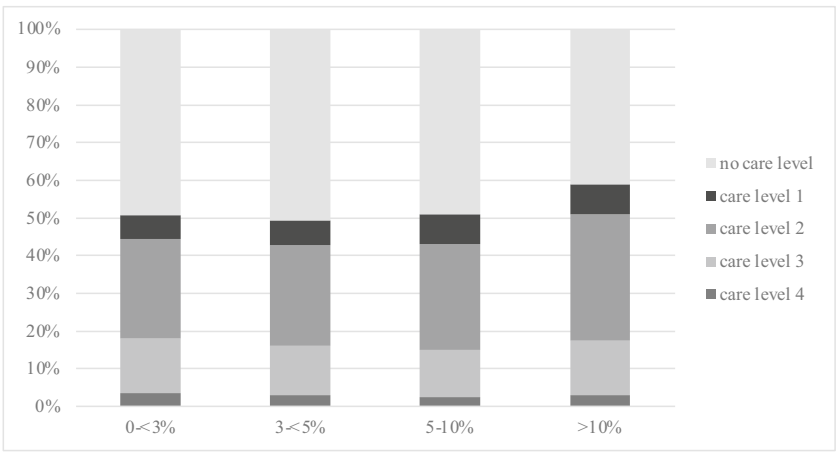


**Fig. 1** Distribution of care levels as a marker of impairment and independence stratified by fracture-risk groups. Care level 4: most severe impairment with special care needs, care level 3: severe impairments of independence, care level 2: significant impairment of independence, care level 1: low impairment of independence, no care level: no impairment of independence, (for more detailed explanations see supplement Table 4)

**Table 2** Contraindications for specific anti-osteoporotic treatment stratified by high-risk and very high-risk group

| Contraindication | High-risk group $N=63,049$ | Very high-risk group $N=147,150$ |
|---|---|---|
| **Bisphosphonates** | **4774 (8%)** | **10,388 (7%)** |
| Impaired kidney function | 4428 (7%) | 9767 (7%) |
| MR-ONJ | 346 (1%) | 621 (0.4%) |
| **Denosumab** | **351 (0.6%)** | **689 (0.5%)** |
| MR-ONJ | 346 (0.6%) | 621 (0.4%) |
| Hypocalcemia | 5 (0.01%) | 68 (0.1%) |
| **Teriparatide** | **5018 (8%)** | **11,115 (8%)** |
| Impaired kidney function | 4428 (7%) | 9767 (7%) |
| Hypercalcemia | 27 (0.04%) | 124 (0.08%) |
| MDS | 201 (0.5%) | 407 (0.3%) |
| MGUS | 130 (0.2%) | 535 (0.4%) |
| Morbus Paget | 12 (0.02%) | 28 (0.02%) |
| Bone tumors | 21 (0.03%) | 33 (0.02%) |
| Bone metastasis | 199 (0.3%) | 221 (0.2%) |
| Previous skeletal irradiation | Not included | Not included |
| **Romosozumab** | **7621 (21%)** | **25,834 (20%)** |
| | **Women only $N=36,094$** | **Women only $N=128,635$** |
| History of myocardial infarction | 1369 (4%) | 5854 (5%) |
| History of stroke | 6013 (17%) | 19,338 (15%) |
| Hypocalcemia | 2 (0.006%) | 55 (0.04%) |
| MR-ONJ | 237 (0.7%) | 587 (0.5%) |

Abbreviations: *MR-ONJ* medication related osteonecrosis of the jaw, *MDS* Myelodysplastic syndrome, *MGUS* Monoclonal gammopathy of undetermined significance

for Romosozumab therapy. A history of stroke was the most common cause for a contraindication in both groups (very high-risk, 15%; high-risk, 17%) followed by a history of myocardial infarction (very high-risk, 5%; high-risk, 4%). Hypocalcemia and a history of bone osteonecrosis only occurred in a few patients in both groups. For Teriparatide, approximately 8% in both groups had contraindications for its use which was most commonly caused by an impaired kidney function. Of note, as a previous skeletal irradiation was not detectable by ICD-10 coding this variable could not be included.

Figure 2 presents the number of patients in whom any contraindication for no, one, two, three, or four of the investigated medications were present. In 71% of the patients of the high-risk and 75% of the very high-risk group, no contraindication for any medication was present. 22% of the high-risk and 18% of the very high-risk group had a contraindication for one medication. Five percent of both groups had a contraindication for two and 2% of both groups had a contraindication for three medications. Only 0.05% of the high-risk and 0.04% of the very high-risk group had contraindications for all four investigated medications.

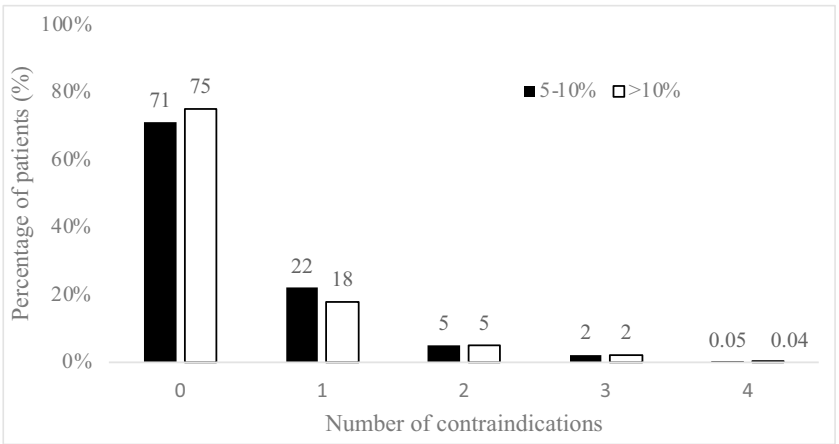


**Fig. 2** Percentage of patients with contraindications for none, one, two, three or four of the investigated medications depending on the calculated 3-year risk for vertebral or hip fractures (5–10% vs. > 10%)

## Discussion

The majority of geriatric patients was found to have a very high fracture risk, accompanied by cognitive impairment, limitations in ADLs, highest level of care, number of diagnoses, and risk-factors highlighting the vulnerability of this group. Even though contraindications were present, specific-anti osteoporotic medication can be found for almost every geriatric patient.

### Distribution and characteristics of very high-risk and high-risk patients

Even though European-wide estimations identified on average, only 18% of the population to be at high-risk or very high-risk (2); in our study population, a much higher proportion of 75% was found. As one major difference between the studies is the average age of the included participants (European-wide estimations, 50 years or older (2); our study population, 82 ± 7 years) and the included population (European-wide, total population aged 50 years or older; our study population, geriatric cohort), our results highlight the striking fracture-risk (5, 13) and increased demand for specific anti-osteoporotic treatment in geriatric patients (10, 14). In another cohort of geriatric day care patients, we observed similar prevalences (15). Likewise, Hadji et al. reported a significant increase in osteoporosis prevalence among older adults (16), although their reported prevalence was notably lower than in our cohort. As their data stem from German insurance records, this may reflect widespread under-diagnosis in the general population (16). In contrast, our data mainly come from geriatric clinic patients, likely representing a population with a higher disease burden and thus higher osteoporosis prevalence. This becomes even more apparent when taking into account that the majority of our geriatric study population, in particular 54%, were allocated to the very high-risk group in which the fracture-risk is most striking and therefore highly effective treatment is required (5). Nevertheless, only 36% of the total study population already had any type of specific anti-osteoporotic treatment listed as a regular medication. Of note, not only 72% of all included women were allocated to the very high-risk group for which our results support female sex as a major risk-factor (5, 13, 17) but also 20% of the included men were identified to be at very high-risk (20%), so that the fracture-risk must also not be underrated especially in aged men (18).

Even though in our study cohort mild cognitive impairment was present in all fracture-risk groups, patients in the very high-risk group had the lowest MMSE-score. Since cognitive impairment is known to increase the risk for complications and mortality after hip fractures, but is not included as a risk-factor for fracture risk calculation, screening for cognitive decline is highly recommended, especially in very high fracture risk patients (19). Additionally, also physical limitations in, e.g., ADLs—also not included in the fracture risk calculation—were mostly present in the very high-risk group leading to a loss of independency accompanied by the need for help when living at home or institutionalized (20, 21). In line with these findings, the percentage of patients with any care level also increased with increasing fracture-risk. Osteoporosis and osteoporotic fractures therefore still pose a huge socioeconomic burden as it is known that most of the money spent on osteoporosis is not spent on primary prevention but on the treatment of its consequences, including hospitalization and institutionalization (22). However, even in the very high-risk group, care level 2 was the most common care level indicating some preserved activity, and along with that an increased risk for falls and consecutively fractures. Since falls are well known to significantly increase the overall fracture risk, and data from the DUBBOS study population also demonstrated the substantial impact of falls on hip fractures, this finding particularly emphasizes that timely initiation of treatment is especially beneficial for older patients at very high risk (23, 24). In line with this, bone anabolic treatment for example has been shown to be most efficient and cost-effective especially in very high-risk patients (25–27). Interestingly, even though polypharmacy was evident in all fracture-risk groups, patients in the very high-risk group took on average one regular medication less than patients in the other fracture-risk groups but on the other hand had on average one more diagnosis and risk-factor. A risk–benefit-based prioritization of drugs or a reduction of fall-increasing drugs in multimorbid patients might be possible explanations for the difference in the number of regularly taken medications between the fracture-risk groups. But also, Ageism-related reasons leading to a less conscious prescription could be a possible explanation (28).

### Contraindications for specific anti-osteoporotic/bone anabolic treatment

The majority of our study population was allocated to the very high-risk group for which, also in many other guidelines (25, 29), bone anabolic treatment is recommended (10). The striking demand for these medications especially in geriatric patients becomes apparent. As clinicians might worry about the applicability of bone anabolic agents in geriatric patients with regard to potential contraindications, we investigated the percentage of patients with a contraindication for bone anabolic- and antiresorptive treatment (7, 30). In 19%

of the women and 8% of all patients from the very high-risk group, contraindications for Romosozumab or Teriparatide were found, respectively. Notably, impaired kidney function was the most common contraindication for Teriparatide use in our analysis. Still, even though only limited data are available, they suggest that even in severe cases, Teriparatide can improve bone density without worsening kidney function or increasing adverse events (31). It is also worth noting that the proportion of patients with contraindications for Teriparatide was likely underestimated, as certain factors, such as a history skeletal irradiation, could not be assessed due to limitations in the survey methodology (32). Using breast carcinoma in women and prostate carcinoma in men aged 80 years or older as surrogate parameters for a history of radiation therapy—since they are the most frequent cancers and typically require radiation therapy—their prevalence in 2022 was estimated at 23.8% and 26.3%, respectively, according to the International Agency for Research on Cancer (33). Therefore, the actual percentage of patients with a contraindication to Teriparatide might rather be approximately 30% (31). For Romosozumab, prior myocardial infarction or stroke was the most common contraindication. While the FDA (Food and Drug Administration) limits this to events within the past year, the EMA (European Medicines Agency) considers any such history a contraindication (34, 35). As our study followed EMA guidelines, all patients with an ICD-10 code for MI or stroke were included for contraindication calculation. Due to missing data on event timing, a comparison with FDA criteria was not feasible. The EMA also advises assessing overall cardiovascular risk, recommending use only after careful risk–benefit evaluation (34). Still, as Romosozumab is not renally eliminated, it has proven safe across varying kidney function levels, making it suitable for older patients (36).

However, even if the actual percentage of patients with a contraindication is underestimated, many geriatric patients will still be eligible for bone anabolic therapy.

As an alternative medication for the very high-risk- and first-line treatment for the high-risk group (10) for Denosumab, as confirmed by other authors, hardly anyone had any contraindications (37). This is most likely due to its non-renal elimination, making it a very suitable medication especially for geriatric patients in whom an impaired kidney function often is present (37–39). On the contrary, for bisphosphonates, a reduced kidney function poses a potential contraindication (40). In line with results of a population-based kidney-function study, only in 7–8% of the study population an impaired kidney function (defined as a glomerular filtration rate < 30 ml/min/1.73 $m^2$ ≙ ICD-10 N18.3) was identified as a contraindication for bisphosphonate use (41). MR-ONJ is a dreaded but rare complication but if present poses a contraindication for antiresorptive treatment (42). However, in only a very small number of patients (0.4–0.5%), MR-ONJ was identified as a contraindication, reflecting its insignificant role in osteoporosis therapy (43).

With regard to the number of patients suitable for specific anti-osteoporotic treatment in the overall analysis, only a vanishingly small percentage (0.04–0.05%) of all patients requiring specific anti-osteoporotic treatment had a contraindication for all of the investigated medications (bisphosphonates, Denosumab, Romosozumab, and Teriparatide). Furthermore, more than 70% had no and approximately 20% only had a contraindication for one of the potential medications of which we concluded that suitable anti-osteoporotic medication can be found for almost every patient.

## Limitations

The analysis of a large geriatric population from different geriatric institutions provides a good real-world description of the patients geriatricians deal with in their daily work in hospitals, day care clinics, and rehabilitation facilities. However, this approach means that the data do not represent a cross-section of the overall population of higher age. Secondly, the evaluation of the risk-factors and contraindications had to be based on retrospective analyses using ICD-10 and ATC-Codes leading to an underestimation of the risks and contraindications due to a lack of the reported data (e.g., limitations in kidney function were subsumed to levels of chronic kidney disease (CKD) as reflected in the ICD-10 codes and were not extracted from laboratory measurements). When timing of diagnosis, medication details (e.g., glucocorticoids), or fracture severity were relevant for risk calculation, the most conservative assumption was used due to missing duration data (e.g., as described in 2.3 if a type 2 diabetes mellitus was present in a patient the lowest numerical risk according to the duration (5–10 years, 1.1; > 10 years, 1.6) had to be applied). Although recent fractures indicate an imminent fracture risk, their timing could not be assessed, as this information was not included in the dataset. Additionally, risk-factors and contraindications that were not included in the geriatric assessment or routine data query such as "hip fracture of the parents" and "history of skeletal irradiation" could not be captured. Falls, a key fracture risk factor, could not be considered due to missing data, despite their strong link to imminent fracture risk. Similarly, the lack of BMD data limited the accuracy of risk estimation, as its omission can alter fracture risk gradients (44). For the identification of the number of patients suitable for any anti-osteoporotic treatment, no difference between the recommendations for each fracture risk group or female/male gender was made. As in 2017, the care levels in Germany were adapted; data had to be merged (also see supplement Table 3). Also, as data were mainly drawn from inpatient geriatric rehabilitation,

to which patients with a very high care level usually are no longer transferred, none of the patients had care level 5 and the portion of patients with care level 4 was very small. Even though we filtered the data set for participants with preferably complete data on the interested variables, an underreporting of diagnoses or medications by the registering hospital, but also bias of included patients, cannot be excluded. For the evaluation of contraindications, contrary to daily clinical practice, we were not able to include aspects, such as intolerances against specific medications, or the patient's preference regarding the application type or simply the fact that especially bone anabolic treatment is not started during hospital stay due to financial issues. As our study identified a relatively high portion of geriatric patients potentially requiring bone anabolic treatment, one might fear huge expenses for the healthcare institutions. However, one has to consider that our study included highly selected geriatric patients treated at geriatric institutions and therefore not representing the total population at this age. Especially, in this group of patients, the usage of bone anabolic treatment is probably rather cost-effective as they have been demonstrated to prevent many fractures and therefore safe costs for the healthcare system. Nevertheless, a personalized drug-prescribing process is still needed as some geriatric patients (e.g., with a longer life expectancy and high quality of life) might benefit more than others (e.g., highly care-dependent patients with a reduced life expectancy).

## Conclusion

The majority of geriatric patients is at a very high-risk for osteoporotic fractures. Even though contraindications are present, suitable medication can be found for almost every geriatric patient, including bone anabolic treatments in particular. As osteoporosis-related consequences still pose a huge socioeconomic burden, clinicians need to force timely risk-assessment and treatment initiation. Also, limiting factors such as reimbursement issues need to be addressed.

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**Author contribution** M.D., R.S., M.R., P.G., and T.T. conceived and designed the analysis. T.T. collected the data and performed the analyses. M.R. wrote the first draft of the manuscript. P.G. designed the tables and figures. M.D. and R.S. supervised the project. P.G., S.M., O.T., S.S., K.M., T.T., M.D., and R.S. reviewed and edited the manuscript. All members discussed the results and agreed on the final version of the manuscript.

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**Data availability** The data of the current study are available upon interest from the corresponding author and obtained permission by the Geriatrics in Bavaria-Database (GiB-DAT).

## Declarations

**Conflict of interest** TT is a member in the data commission of GiB-DAT. RS and MD are members of the osteoporosis guideline commission. All other authors declare no conflicts of interest.



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