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ORIGINAL PAPER

Stress fractures in elderly patients

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Abstract
Purpose The purpose of this study was to investigate specific risk factors, common fracture locations and possible sex-specific differences in elderly patients with stress fractures.
Methods This analysis enrolled 105 patients (83 women, 22 men) with stress fractures. For the analysis of possible risk factors related to increasing age, data from 82 patients (67 women, 15 men) aged 40 years and older (mean age of 57.4 ±11.0 years) were compared with that from a younger control group [23 patients (16 women, seven men), mean age 28.4±6.7 years]. Bone mineral density (BMD) was determined using dual-energy X-ray absorptiometry bone densitometry (DXA) and blood samples were taken.
Results A total of 211 stress fractures were found. Of these, 177 were found in the study group, of which 90.4 % were located in the lower limb. Lumbar and femoral BMD was significantly lower in elderly patients; however, the BMD of most patients was within the osteopenic or normal range. Within the study group, a total of 83.8 % had a vitamin D insufficiency (<30 μg/l); 75.5 % were not engaged in regular physical activity more than once a week. Overweight patients within the study group had significantly more stress fractures compared to normal weight patients (2.6±1.7 vs. 1.9±1.1, $p<0.05$).
Conclusions A similar contribution of risk factors has been found for stress fractures in elderly patients and younger controls of the general population. Stress fracture incidence seems to be rather multifactorial and not based on osteoporotic changes alone. A balanced calcium and vitamin D metabolism seems to be of paramount importance for stress fracture prevention in elderly patients.

Stefan Breer and Matthias Krause contributed equally to this work and therefore share first authorship.

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Introduction

Stress fractures have been reported to be a common problem in young and active people such as athletes and military recruits [1–5]. Based on their aetiology, stress fractures can be subdivided into either fatigue- or insufficiency-related fractures. While fatigue stress fractures occur due to abnormal and/or repeated stress on normal bone and are regularly seen in athletes [6–11], insufficiency stress fractures are linked to normal stress on impaired bone structure and thus are often observed in postmenopausal osteoporotic women [12, 13]. Whereas in the past, diagnosis of stress fractures was performed by radiography or scintigraphy [14], today magnetic resonance imaging (MRI) is the diagnostic agent of choice due to its higher sensitivity and specificity [15, 16].

The cause of stress fractures is often multifactorial [17, 18] and various modifiable and non-modifiable factors have been proposed to play a role: white race [12], high bone turnover [1], vitamin D insufficiency [19], nicotine and alcohol abuse [5], steroid use [5], low bone density [20], low adult weight [5], anorexia [21], or bisphosphonate therapy [22, 23]. Furthermore, female gender has been identified as an important risk factor and thus sex-specific effects appear to play a role in the pathogenesis of stress fractures [1]. Numerous studies on young female athletes and military recruits have revealed that factors such as poor physical fitness, low BMD, eating disorders, a body mass index (BMI) less than 20 or disturbed menstrual function lead to an increased risk for stress fractures in young women [12, 24, 25]. While almost all of these studies focused on patients in their late second to fourth decade of life, studies on stress fractures in elderly patients and their respective risk factors are rare [26, 27]. Nevertheless, the incidence of stress fractures in elderly patients is an increasingly important issue due to the aging society and the growing interest of elderly people in physical activity, whether to remain fit or as part of therapeutic regimens [26].

Therefore, the objective of this study was to analyse and characterise elderly patients with stress fractures, and to identify specific risk factors, frequent fracture locations and gender-specific differences.

Patients and methods

A retrospective analysis was conducted on 105 patients (82 women, 23 men) with stress fractures. Eighty-two patients above the age of 40 years (with an average age of 57.4±11.0 years) were admitted to our outpatient clinic between April 2008 and January 2012 with MRI diagnosed stress fractures (Table 1 and Fig. 1). To elucidate potential risk factors for elderly patients, 23 patients under the age of 40 years (average age 28.5±6.7 years) with diagnosed stress fractures served as controls (Table 2).

A detailed medical history (including age, sex, height, weight, BMI, medication, affected location, possible history of stress fracture) was taken from every patient with special emphasis on possible risk factors for bone diseases and stress fractures such as vitamin D insufficiency, proton pump inhibitor (PPI) medication, immunosuppressive medication, lactose intolerance, type 2 diabetes, alcohol and nicotine abuse, cortisone therapy, chemotherapy, positive family history of bone diseases, anorexia, and rheumatoid arthritis (Tables 3 and 4). In addition, blood samples were drawn from the patients at their first appointment to determine the calcium and vitamin D serum level. As vitamin D serum levels of at least 30 ng/ml or 75 nmol/l, have been considered to be of paramount importance for skeletal health [28], we considered a level below 30 ng/ml or 75 nmol/l to indicate vitamin D insufficiency. Following the guidelines of the German Society of Osteology [29] a real BMD was determined using DXA (Lunar Prodigy, Lunar Corporation, Madison, WI, USA) for the lumbar spine and both proximal femurs. Thus, we were able to categorise the patients' BMD

Table 1 Baseline characteristics of the study group

	Total (n=82)	Women (n=67)	Men (n=15)
Baseline			
Age (years)	57.4 (±11.0)	59.4 (±10.9)	48.7 (±7.1)*
Height (cm)	168.0 (±9.7)	165.1 (±7.0)	180.4 (±10.3)*
Weight (kg)	71.0 (±14.2)	68.5 (±13.0)	81.7 (±14.4)*
BMI (kg/m^2)	25.2 (±5.1)	25.2 (±5.4)	25.0 (±3.6)
Total number of fractures	177 (100 %)	142 (100 %)	35 (100 %)
Location			
Tarsus	34 (19.2 %)	27 (19.0 %)	7 (20.0 %)
Metatarsal	74 (41.8 %)	57 (40.1 %)	17 (48.6 %)
Calcaneus	19 (10.7 %)	15 (10.6 %)	4 (11.4 %)
Tibia	21 (11.9 %)	17 (12.0 %)	4 (11.4 %)
Pelvis	16 (9.0 %)	16 (11.3 %)	–
Femur	9 (5.1 %)	8 (5.6 %)	1 (2.9 %)
Fibula	3 (1.7 %)	1 (0.7 %)	2 (5.7 %)
Radius	1 (0.6 %)	1 (0.7 %)	–
Affected side			
Left	91 (51.4 %)	74 (52.1 %)	17 (48.6 %)
Right	86 (48.6 %)	68 (47.9 %)	18 (51.4 %)
DXA T-score			
Lumbar spine (L_1–L_4)	−1,7 (±1.2)[a]	−1.7 (±1.3)	−1.6 (±1.4)
Left femur (Total)	−1,5 (±1.0)[a]	−1.5 (±1.0)	−1.4 (±1.4)
Physical activity level (>30 min)			
<1× per week	52 (63.4 %)	43 (64.2 %)	9 (60.0 %)
1× per week	10 (12.2 %)	8 (11.9 %)	2 (13.3 %)
2× per week	10 (12.2 %)	8 (11.9 %)	2 (13.3 %)
3× or >3 times per week	10 (12.2 %)	8 (11.9 %)	2 (13.3 %)

Characteristics are presented as mean ± standard deviation

*sex-specific difference, p<0.05

[a]differences between study group and control, p<0.05

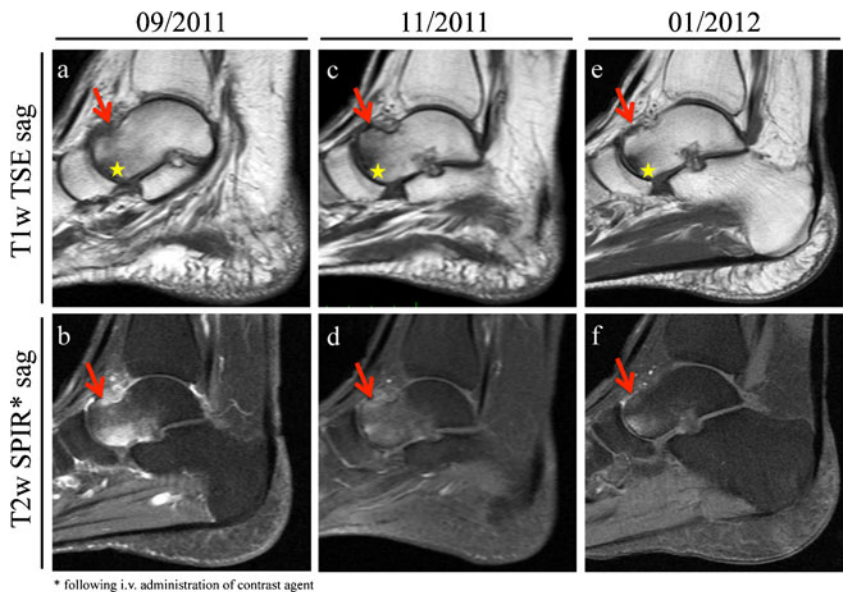

Fig. 1 A 55-year-old female patient complained of persistent pain in her left foot after a long hike. **a**, **b** Subsequent MRI revealed a stress-fracture at the left ventromedial talus (red arrows) accompanied by bone marrow oedema. Furthermore an osteoarthritis of the talonavicular joint with subchondral cyst formation has been noted (yellow asterisks). **c**, **d** After pain-adapted weight bearing and correction of vitamin D insufficiency, the MRI at 8-week follow-up showed improvement of the talus. **e**, **f** Another 8 weeks later, the patient reported to be free of pain. The follow-up MRI revealed a fully healed stress fracture and an almost complete remission of the bone marrow oedema

Table 2 Baseline characteristics of the control group

	Total (n=23)	Women (n=15)	Men (n=8)
Baseline			
Age (years)	28.5 (±6.7)[a]	28.0 (±6.2)	29.4 (±8.1)
Height (cm)	174.4 (±14.6)[a]	168.0 (±7.2)	185.5 (±17.9)
Weight (kg)	73.8 (±21.3)	64.8 (±13.8)	89.6 (±23.6)
BMI (kg/m^2)	23.9 (±4.3)	22.8 (±4.2)	25.8 (±4.1)
Total number of fractures	34 (100 %)	23 (100 %)	11 (100 %)
Location			
Tarsus	4 (11.8 %)	3 (13.0 %)	1 (9.1 %)
Metatarsal	13 (38.2 %)	9 (39.1 %)	4 (36.4 %)
Calcaneus	3 (8.8 %)	2 (8.7 %)	1 (9.1 %)
Tibia	7 (20.6 %)	4 (17.4 %)	3 (27.3 %)
Pelvis	6 (17.7 %)	4 (17.4 %)	2 (18.2 %)
Femur	1 (2.9 %)	1 (4.3 %)	–
Fibula	–	–	–
Radius	–	–	–
Affected side			
Left	14 (41.2 %)	10 (43.5 %)	4 (36.4 %)
Right	20 (58.2 %)	13 (56.5 %)	7 (63.6 %)
DXA T-score			
Lumbar spine (L_1–L_4)	−0.8 (±1.4)[a]	−0.8 (±1.5)	−0.8 (±1.3)
Left femur (Total)	−0.8 (±1.3)[a]	−0.9 (±1.2)	−0.6 (±1.3)
Physical activity level (>30 min)			
<1× per week	12 (52.2 %)	10 (66.7 %)	2 (25.0 %)
1× per week	1 (4.3 %)	1 (6.7 %)	–
2× per week	4 (17.4 %)	1 (6.7 %)	3 (37.5 %)
3× or >3 times per week	6 (26.1 %)	3 (20.0 %)	3 (37.5 %)

Characteristics are presented as mean ± standard deviation

Table 3 Distribution of potential risk factors in the study group, stratified by sex

Risk factor	Total (n=82)	Women (n=67)	Men (n=15)
Vitamin D insufficiency	60/72 (83.3 %)	49/58 (84.5 %)	11/14 (78.6 %)
Family history	25/80 (31.3 %)[a]	23/65 (35.8 %)	2/15 (13.3 %)
Nicotine abuse	21/80 (26.3 %)	14/65 (22.4 %)	7/15 (46.7 %)*
PPI medication	18/80 (22.5 %)	13/65 (22.4 %)	5/15 (33.3 %)
Cortisone therapy	14/80 (17.5 %)	12/65 (17.9 %)	2/15 (13.3 %)
Immunosuppressives	11/80 (13.8 %)	10/65 (14.9 %)	1/15 (6.7 %)
Alcohol abuse	10/80 (12.5 %)	7/65 (10.4 %)	3/15 (20.0 %)
Type 2 diabetes	4/80 (5.0 %)	4/65 (6.0 %)	–
Chemotherapy	4/80 (5.0 %)	4/65 (6.0 %)	–
Lactose intolerance	4/80 (5.0 %)	2/65 (3.0 %)	–
Anorexia nervosa	1/80 (1.3 %)[a]	1/65 (1.5 %)	–

*sex-specific differences, $p<0.05$

[a]group-specific differences, $p<0.05$

according to WHO criteria [30] into a) normal bone mass (t-score>−1.0), b) osteopenia (t-score of −2.5 to −1.0) and c) osteoporosis (t-score<−2.5). Furthermore, all patients were asked whether and how often per week they regularly participated in sports or fitness activities such as jogging, cycling, fitness or Nordic walking. Possible answers were: a) no regular physical activity, b) >30 min, 1× per week, c) >30 min, 2× per week or d) >30 min, ≥3× per week. In addition, informed consent to participate in the study was obtained from every patient.

Statistical analysis

Statistical analysis was carried out using SPSS 14.0 (SPSS Inc, Chicago, IL). Mean values ± standard deviations (SD) are reported for all parameters. Student's t-test was used to report mean differences. Since fracture location and affected sides clearly deviated from a normal distribution non-parametric test methods (Mann–Whitney-U) were applied. Chi-square tests were performed to test univariate relations between categorical variables. All tests were two-sided and a p-value of less than 0.05 was considered significant.

Results

A total of 211 stress fractures were found in 105 patients. Of these, 177 were found in the study group (Table 1) while 34 were found in the younger controls (Table 2). In the study group, eight out of 15 men (53.3 %) and 25 out of 67 women (37.3 %) reported a history of stress fractures. None of the included patients had a history of bone or bone marrow malignancy.

Within the study cohort we found significant sex-specific differences, as the men were significantly younger, heavier and larger than the women ($p<0.05$) (Table 1). The study group presented with a normal to slightly overweight BMI (25.2±5.1 kg/m^2). In detail, 40.4 % of the patients were found to be overweight with a BMI over 25 kg/m^2. Overweight patients suffered significantly more stress fractures compared to normal weight (BMI of 18.5–25 kg/m^2) patients: 2.6±1.7 vs. 1.9±1.1, $p<0.05$.

The lumbar as well as the femoral BMD was significantly lower in the study group compared to controls ($p<0.05$) (Tables 1 and 2). A detailed BMD analysis of the study group revealed that 75.3 % of the stress fractures occurred in

Table 4 Distribution of potential risk factors in the control group, stratified by sex

Risk factor	Controls (n=23)	Women (n=15)	Men (n=8)
Vitamin D insufficiency	21/23 (91.3 %)	13/15 (86.7 %)	8/8 (100.0 %)
Family history	1/22 (4.5 %)	–	1/8 (13.3 %)
Nicotine abuse	3/22 (13.6 %)	3/14 (22.4 %)	–
PPI medication	6/22 (27.3 %)	6/14 (42.9 %)	–
Cortisone therapy	1/22 (4.5 %)	–	1/8 (13.3 %)
Immunosuppression	1/22 (4.5 %)	1/14 (14.9 %)	–
Alcohol abuse	2/22 (9.1 %)	2/14 (10.4 %)	–
Type 2 diabetes	1/22 (4.5 %)	1/14 (6.0 %)	–
Chemotherapy	3/22 (13.6 %)	3/14 (6.0 %)	–
Lactose intolerance	1/22 (4.5 %)	–	1/8 (13.3 %)
Anorexia nervosa	3/23 (13.0 %)	3/15 (20.0 %)	–

patients with a lumbar BMD within the osteopenic or normal range. This observation was even more pronounced for the femoral BMD, as 83.1 % of the stress fractures were found in patients with an osteopenic or normal t-score.

Within the study group, 90.4 % of the stress fractures were located in the lower limb. The most common locations were the metatarsals (41.8 %), the tarsus (19.2 %), the tibia (11.9 %) and the calcaneus (10.7 %) (Table 1). There were no significant differences compared with controls (Tables 1 and 2). The distribution of affected sides in the study group was even and comparable for both sexes (women: 52.1 % left and 47.9 % right; men: 48.6 % left and 52.1 % right) with no differences to controls (Tables 1 and 2).

The analysis of physical activity levels revealed that 63.4 % of the patients within the study group were not engaged in any regular physical activity. Overall, more than three quarters of patients (75.5 %) within the study group did not exercise for more than 30 min once a week (Table 1). In contrast, 43.5 % of the patients within the younger control group did exercise at least twice a week or more (Table 2).

The risk factor analysis revealed significant differences between the study group and controls. Elderly patients reported a positive family history more frequently (31.3 % vs. 4.5 %, $p<0.05$), while younger controls were more likely to present with a history of anorexia (13 % vs. 1.3 %, $p<0.05$) (Tables 3 and 4). The sex-specific analysis of the study group revealed significantly higher nicotine abuse in affected men than women (46.7 % vs. 22.4 %, $p<0.05$). Other risk factors such as alcohol abuse and PPI medication occurred more frequently in men, while factors such as family history or immunosuppression were more common in women (Table 3). However, these differences were not significant.

Laboratory findings revealed vitamin D insufficiency (vitamin D serum level <30 ng/ml) in 60 out of 72 patients within the study group (49 of 58 women (84.5 %) and 11 of 14 men (78.6 %)) (Table 3). A similar situation was observed in the control group, in which overall 91.3 % presented with a vitamin D insufficiency (Table 4). However, there were no significant differences in stress fracture frequency in patients with vitamin D insufficiency compared to patients with sufficient vitamin D (2.2±1.5 vs. 1.92±1.3, $p=0.5$).

A quantitative analysis of cumulative risk factors revealed, that only six cases presented without any risk factor at all (7.3 %). The majority (85.4 %) presented with one to three risk factors. In detail, we found an almost even distribution of cases with one (28.1 %), two (29.3 %) or three (28.1 %) risk factors. However, only six cases (7.3 %) had more than three risk factors. The most common singular risk factor for all risk factor combinations was vitamin D insufficiency.

Discussion

This retrospective analysis was conducted to analyse the incidence of stress fractures in an elderly cohort. While osteoporosis is certainly one of the leading risk factors for stress fractures, especially in elderly patients, only 24.7 % of the patients within our study cohort actually had a t-score assessed by DXA within the osteoporotic range. Overall, the mean t-score for both the lumbar spine and the femur was within the osteopenic range. These findings may either indicate that stress fracture risk in the elderly already increases in the osteopenic t-score range or that impaired bone microarchitecture leading to stress fracture occurrence cannot be fully assessed according to the BMD of the proximal femur and lumbar spine as measured by DXA.

To gain further insight, we analysed additional risk factors that could contribute to the incidence of stress fractures. Particular attention was given to calcium homeostasis and vitamin D status, both of which are known to be of paramount importance for bone and skeletal health [28, 31, 32]. For instance, vitamin D insufficiency leads to a lower serum calcium concentration, which in turn results in secondary hyperparathyroidism [33]. Moreover, the demand for calcium further increases in physically active people, as bone formation is stimulated and microfractures require repair [34]. As previously shown, vitamin D serum levels of at least 30 ng/ml or 75 nmol/l are considered to be necessary for skeletal health [28, 35]. However, the majority of elderly patients in our study group as well as the younger controls presented with insufficient vitamin D levels. These observations are consistent with other studies, which found that vitamin D insufficiency significantly increases the risk for stress fractures in young and active patients. In a study on Israeli soldiers, Givon et al. found that vitamin D levels were lower in patients with high grade stress fractures compared to controls [36]. Ruohola et al. prospectively followed 800 randomly chosen male Finnish recruits and reported vitamin D serum levels below the median of 75.8 nmol/l to be a significant risk factor for the incidence of stress fractures [33]. Moreover, Lappe and colleagues analysed 5201 female Navy recruits in a randomised, double-blind, placebo-controlled study and were able to show a 20 % reduction in stress fracture incidence in a cohort with daily supplementation of 2,000 mg calcium and 800 IE vitamin D [34]. A case–control study by Burgi et al. analysed 600 female Navy recruits (mean age 19.5 years) with stress fractures of the tibia or fibula and found a two-fold higher risk of stress fractures of tibia and fibula in women with a vitamin D level of less than 20 ng/ml compared to women with concentrations of over 40 ng/ml [3]. They concluded that a target for stress fracture prevention would be a vitamin D serum level of 40 ng/ml or greater and underlined the importance of a balanced calcium and vitamin D metabolism in the prevention of stress fractures. Overall, this study on elderly patients from the general population supports the aforementioned findings on young and active people regarding a possible relationship between vitamin D insufficiency and an increased risk of stress fracture.

In addition, the widespread use of PPI among elderly patients has recently been linked to increased fracture risk and disrupted calcium absorption [37, 38]. Yang and co-workers found an association between long-term PPI therapy and an increased risk of hip fracture, which led us to investigate this issue within our study cohort. Although PPI therapy was reported in 22.5 % of affected patients within the study group, there was no significant difference in use of PPIs in comparison with younger controls. Previous studies further indicated an increased stress fracture risk for patients suffering from anorexia nervosa or other eating disorders such as lactose intolerance that can result in an insufficient calcium supply [1, 12]. However, in our study group only one elderly woman reported suffering from anorexia nervosa and only four women were lactose intolerant. In addition, anorexia nervosa was observed significantly more often in younger controls, indicating that lactose intolerance as well as anorexia nervosa are not typical risk factors for the occurrence of stress fractures in elderly patients.

We also considered stress fracture locations. Studies on young military recruits and athletes found that the tibia was the most common stress fracture location [24]. In contrast, in our elderly cohort from the general population the metatarsals were the most frequent stress fracture location. One reason for this observation might be that the physical stress leading to the incidence of stress fractures in elderly patients is different and often lower than that in professional athletes or military personnel. This was reflected by the fact that elderly patients often reported that long hikes or recently started endurance training had led to the stress fracture. On the other hand, 75.5 % of patients in the study cohort were not engaged in regular physical activity more than once a week. Thus, their bone microarchitecture could not adequately adapt to the sudden increased stress level that occurred during long mountain hikes or endurance sports. This is in accordance with Shaffer and colleagues who analysed 152 recruits with stress fractures and identified low aerobic fitness as the only modifiable risk factor for stress fractures within their study [24]. The authors further pointed out that training intensity should be increased gradually before exposure to larger loads to prevent stress fractures. Although all these studies were performed on young female military recruits, the principle may also apply to elderly patients. Thus elderly patients should be encouraged to increase their physical activity and improve their aerobic fitness. However, the intensity of physical exertion should not be increased too quickly.

Law and colleagues reported an increased risk for hip fracture in postmenopausal smokers over the age of 50 years [39]. In addition, Lappe et al. analysed 3,758 female recruits and found that after eight weeks of basic training stress fractures were more likely to be reported by recruits with a current or past history of smoking or regular consumption of alcohol [5]. We also analysed lifestyle risk factors and found nicotine abuse in 46.7 % of male patients within the study group and thus significantly more often compared to female patients. Overall, the incidence of smoking was more than twice that of daily alcohol consumption (26.3 % vs. 12.5 %) among study group patients. Thus our findings indicate that modifiable risk factors such as nicotine or alcohol abuse may also increase the risk of stress fracture incidence in the elderly as reported for young military recruits.

There are some limitations to this study. Firstly, this was a retrospective analysis with no control group of elderly patients without stress fractures was available. However, we included a control group of younger patients with stress fractures to look for possible risk factors, especially those related to increasing age. Second, the sample size in this study was relatively small compared to the large and prospective studies on stress fractures conducted on military recruits and athletes. However, comparably large and prospective studies on stress fracture incidence in the elderly general population are difficult to perform.

Conclusions

In conclusion, the results of this retrospective observational study indicate a similar contribution of stress fracture risk factors in elderly patients and younger controls. As more than 75 % of the analysed elderly patients presented with a DXA t-score within the osteopenic or even normal range, our data further suggests that stress fracture incidence in the elderly seems to be rather multifactorial and not based on osteoporotic changes alone. It is thus important to examine the patient's personal risk factors and to minimise them wherever possible. However, larger and prospective studies are needed to confirm our findings and to investigate the potential for stress fracture prevention in the elderly by ensuring a balanced calcium and vitamin D metabolism and minimising further possible risk factors.

Conflict of interest The authors state that there is no conflict of interest.

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