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Clinical Utility of a Semiquantitative Method Using Lumbar Radiography as a Screening Tool for Osteoporosis in Elderly Subjects

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Background: Osteoporosis is a major global public health problem in the current aging era. Osteoporosis is often diagnosed only after patients have a fracture that causes a severe decline in ability to perform activities of daily life. Although the current criterion standard for diagnosing osteoporosis is dual-energy X-ray absorptiometry (DXA), this modality remains less prevalent among general practitioners in geriatric medicine. The aim of this study was to determine the diagnostic utility of visual inspection of lumbar radiography in detecting bone mineral density (BMD) decline.





Material/Methods: We retrospectively reviewed medical data of 78 patients who underwent both lateral lumbar radiography and DXA. Board-certified radiologists determined the clinical grade of each patient's condition according to the semi-quantitative (SQ) method of lumbar fracture assessment. We compared the grades and young adult means of BMD in the lumbar spine and hips as measured using DXA.

Results: BMD of the femoral neck was significantly lower in patients with severe osteoporosis (grades 2 and 3 as classified using the SQ method) than in those with mild osteoporosis (grades 0 and 1; $P < 0.05$). A receiver operating characteristic curve analysis showed that the SQ method can help predict the decrease in BMD (young adult mean score of $< 70\%$) in the femoral neck with moderate accuracy (sensitivity, 0.621; specificity, 0.829; area under the curve, 0.742).

Conclusions: These results suggest that lateral lumbar radiography can provide useful information about bone mineral status and can serve as a tool for osteoporosis screening by general practitioners.

MeSH Keywords: **Absorptiometry, Photon • Bone Density • Frail Elderly • Osteoporosis • Radiography**

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Background

Osteoporosis is a major global public health problem, the incidence of which increases proportionally according to age [1–4]. Although complex, multifactorial causes may predispose a person to the development of osteoporosis, aging itself has been regarded as a main risk factor [5]. Osteoporosis not only causes bone fractures but also shortens life expectancy. Therefore, its early detection and treatment, as well as prevention, are indispensable.

Monitoring a patient's bone mineral density (BMD) using dual-energy X-ray absorptiometry (DXA) is widely recommended as a standard practice. However, this method requires dedicated equipment, making it difficult to use in clinics. In the semi-quantitative (SQ) method of fracture assessment, lateral lumbar radiographs are used to compare the deformity with the estimated normal appearance of the vertebral body, without measurement of its height or area [6]; the severity of the deformity is classified into 4 grades. The SQ method is, thus, the easiest way for general practitioners to assess osteoporosis.

Among nonvertebral fractures, proximal femoral fracture causes the most severe decline in the ability to perform activities of daily living and in life expectancy [7]. Reportedly, 1-year risk of death after proximal femoral fracture increases by up to 3.7 times in men and 2.9 times in women [8]. Another report has shown that 10% of people who have proximal femoral fracture die within 1 year after the injury [9]. The most common osteoporotic fracture, however, is vertebral fracture [3]. This type of fracture affects patients' quality of life, resulting in restriction of activities of daily living and dysfunction of digestive and respiratory systems [10–13], but it does not directly increase the mortality rate [14]. We hypothesized that if a screening tool for predicting BMD decline could help predict the risk of subsequent vertebral compression and/or proximal femoral fractures, its use could be beneficial in reducing the risk of osteoporosis-induced death or being bedridden.

We aimed to evaluate the usefulness of the SQ method of fracture assessment using lumbar radiography for general practitioners in their daily practice. The bone status determined using the SQ method was compared with the DXA image for each patient. Then, the ability of the SQ method to predict BMD decline was calculated.

Material and Methods

Participants

We performed a retrospective, cross-sectional study of hospital records for elderly patients aged 50–99 years (median

age, 78.6 years; interquartile range, 74.0–84.0 years) who underwent both lumbar radiography and DXA at the Tohoku University Hospital from March 2017 to May 2018. In total, 78 patients (59 women) were included. The recruited patients had undergone a check-up for geriatric problems or dementia at the Department of Geriatrics and Neuroimaging in the Tohoku University Hospital. Ethics approval was obtained from the Ethics Committee of the Graduate School of Medicine, Tohoku University (Registry number: 2018-1-298). This study adhered to the ethical standards originating in the Declaration of Helsinki.

SQ methods with lumbar radiography

Lateral and frontal lumbar plane radiographs were obtained for each patient. Two board-certified radiologists used the SQ method to grade the deformities on the radiographs. A grade 0 vertebral body exhibited a normal form; grades 1, 2, and 3 vertebral bodies showed mild, moderate, and severe deformations, respectively (Figure 1). Patients with grade 3 fractures are at a greater risk of subsequent vertebral and nonvertebral fractures [15]. The radiologists performed scoring based mainly on 1 lateral view of the lumbar X-ray by referencing the height and area of vertebral bodies. If grading with a lateral view was difficult, a frontal view was supportively used.

DXA-based BMD measurements

All DXA images were obtained at the Tohoku University Hospital with specialized DXA equipment (QDR 4500a, Hologic, Inc., Bedford, MA, USA) by the same protocol in all cases, as part of the routine clinical examination. DXA provides both total and regional body composition via a 3-compartment method that distinguishes total bone mineral content from soft tissue, allowing for assessment of whole-body and site-specific lean mass. Femoral neck, lumbar, and whole-body DXA images were used for this study. Calculated BMD was automatically converted to the young adult mean (YAM) value, which indicates the percentage of BMDs of participants compared with those of healthy adults of the same sex; reference ages were 20–44 years and 20–40 years for lumbar and femoral neck BMDs, respectively. From these measurements, appendicular lean mass index (skeletal muscle mass index [SMI]) can be determined [16].

Statistical analysis

Data are expressed as mean \pm standard deviation if normally distributed and as median and interquartile range if non-normally distributed. Patient data included demographic characteristics; YAMs of the femoral neck, lumbar spine, and whole body according to DXA; and SQ grade. These data were analyzed using a correlation analysis and a one-way analysis of

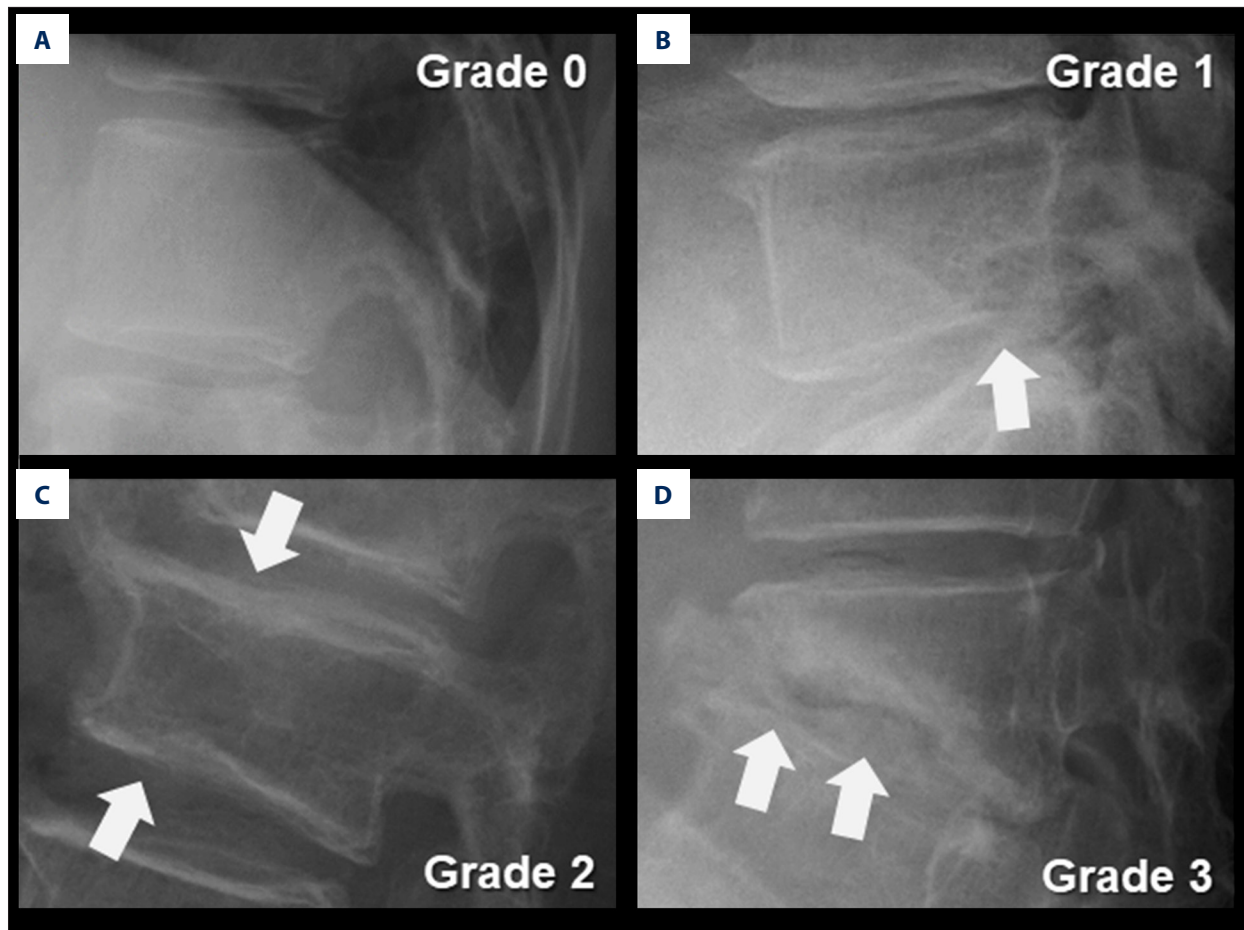


Figure 1. The criteria for visual inspection of a lateral lumbar radiograph using the SQ method. (A) Grade 0, normal vertebral bodies; (B) grade 1, mild deformity (reference value of reduction: vertebral height ranged from 20% to 24%; vertebral column area ranged from 10% to 19%); (C) Grade 2, moderate deformity (vertebral height ranged from 25% to 39%; vertebral column area ranged from 20% to -39%); and (D) Grade 3, severe deformity (vertebral height $\geq 40\%$; vertebral column area $\geq 40\%$). Arrows indicate detected deformations.

variance (ANOVA) with post hoc Tukey-Kramer test for multiple comparisons. Then, patients were divided into 2 groups: those with a mild deformity (SQ grade 0 or 1) and those with a severe deformity (SQ grade 2 or 3) and computed *t* test. The correlations between SQ grade and YAM in the femoral neck, lumbar spine, and whole body were tested using Kendall's rank correlation test. Age, sex, body mass index, and the SQ grade were used as variables in multiple regression analysis. The step-down method was used to choose the factors for the suitable model. We also estimated the SQ method's rate of predicting reductions in BMD on DXA using receiver operating characteristic (ROC) curve analysis with ROCR package in R (<http://rocr.bioinf.mpi-sb.mpg.de/>). A *P* value of 0.05 was considered significant. Statistical analyses were performed using R version 3.4.2.

Results

Participants' characteristics and comparisons according to the SQ grade are shown in Table 1. Mean age tended to be higher with the higher grades ($P=0.002$), which accompanied decreased YAMs for the femoral neck and whole body ($P<0.01$). There were no significant differences in the sex ratios, skeletal muscle indexes, body mass index distribution, or YAM scores among the participants in the 4 groups ($P\geq 0.05$).

Significant differences were detected between participants with SQ grade 1 and those with grade 2. Subgroup analysis revealed that YAM was higher in the group with less severe deformity in the femoral neck (77.2 vs. 63.7, respectively, $P\leq 0.001$) and in the whole body (89.1 vs. 81.2, respectively, $P=0.002$; Figure 2). The SQ grade and YAM in the femoral neck were negatively correlated. However, there was no correlation between the SQ grade and YAM in the lumbar spine. For multiple regression

Table 1. Characteristics of the participants.

SQ grade		0 (n=4)	1 (n=44)	2 (n=18)	3 (n=12)	P value
Age (years)		66±7	77±8	84±7	82±7	0.002
Sex (Female/Male)		3/1	29/15	16/2	11/1	0.15
BMD (YAM score, %)	Lumbar	79.6±9.9	91.3±21.7	80.7±11.8	86.9±19.7	0.13
	Femur neck	78.3±6.9	77.1±13.4	62.1±10.3	66.4±21.8	0.003
	Whole body	83.0±4.2	89.6±11.7	79.9±6.9	83.3±11.0	0.013
SMI		5.58±0.88	5.93±1.12	6.95±0.71	6.18±0.63	0.29
BMI		21.92±5.045	22.43±4.412	22.21±3.73	24.10±3.02	0.45

Data are expressed as the mean ± standard deviation. SQ – semiquantitative; BMD – bone mineral density; YAM – young adult mean; SMI – skeletal muscle mass index; BMI – body mass index. BMD, SMI, and BMI are acquired by the DXA (dual-energy X-ray absorptiometry) method. Body mass index (BMI) is defined as weight divided by height squared.

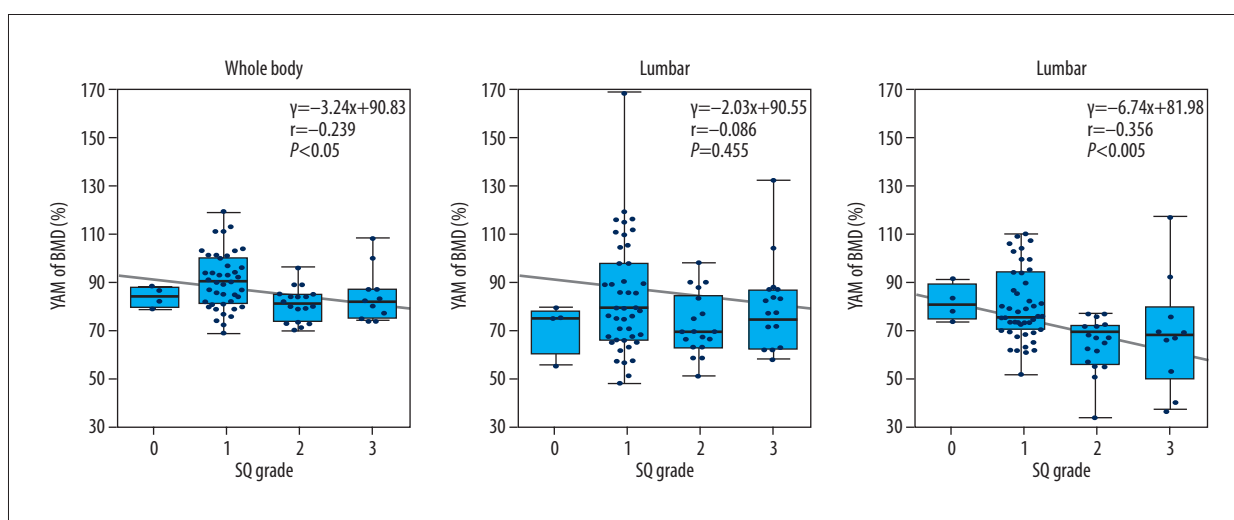


Figure 2. Box plots of young adult mean (YAM) of bone mineral density (BMD) from dual-energy X-ray absorptiometry (DXA) using semiquantitative (SQ) grades. Whiskers of the box plots represent minimum to maximum YAM. In all participants whose SQ grade was 0, YAM exceeded 70. Results of the analysis of correlation between the SQ grade and YAM in each area (r and P) are shown in the upper right area of each graph. YAMs in the femoral neck and whole body were negatively correlated with SQ grades. There was no correlation between lumbar YAM and SQ grade. Gray solid line: linear regression line.

analysis to predict a decline in YAM in the femoral neck, SQ grade demonstrated an adjusted r^2 of 0.282 ($P < 0.001$) and a negative correlation coefficient of -4.39 ($P = 0.04952$; Table 2).

Diagnostic results of the SQ method, defined either as grade ≥ 1 or as grade ≥ 2 are presented in Table 3. We further tested the rate of predicting decreased BMD (YAM of $< 70\%$) in the femoral neck using DXA (Figure 3). The cutoff for SQ grade 1 showed sensitivity (1.00) but not specificity (0.098) for low BMD (accuracy, 0.603). The cutoff for SQ grade 2 showed moderate sensitivity (0.621) and good specificity (0.829; accuracy, 0.731; Table 4). The ROC analysis showed that the SQ method

was moderately reliable for screening the decreased BMD in the femoral neck (area under the curve, 0.742).

Discussion

To reduce the risk of being bedridden or shorter life expectancy, adequate screening for osteoporosis is mandatory. This is, to the best of our knowledge, the first study to confirm the utility of the X-ray SQ method by visual inspection of the vertebral bodies to predict DXA-based BMD decline within the diagnostic range of osteoporosis. In particular, using such a

Table 2. Covariates of multiple regression analysis predicting femur neck YAM of <70%.

Coefficients	Estimate	Standard Error	t value	Pr (> t)
Intercept	87.8543	17.0473	5.154	2.44×10 ^{-6***}
SQ grade	-4.3939	2.1966	-2.000	0.04952*
Age	-0.4173	0.2002	-2.084	0.04097*
Sex	-6.2854	3.6349	-1.729	0.08838

* P<0.05; *** P<0.001. SQ – semiquantitative; YAM – young adult mean.

Table 3. Distribution of the patients who fall on each criterion.

		All (n=78)	Female (n=59)	Male (n=19)
Lumbar X-ray	SQ grade ≥1	74 (94)	56 (95)	18 (95)
	SQ grade ≥2	30 (39)	27 (46)	3 (16)
BMD decline (YAM <70%)	Hip neck	31 (39)	28 (48)	3 (16)
	Lumbar	10 (13)	10 (17)	0 (0)
	Whole body	2 (3)	2 (3)	0 (0)

Data are expressed as number (%). SQ – semiquantitative; BMD – bone mineral density; YAM – young adult mean.

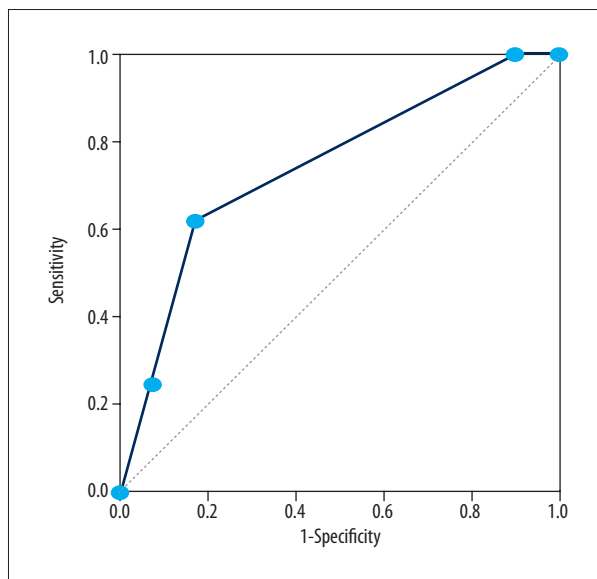


Figure 3. Prediction of bone mineral density (BMD) decline using the receiver operating characteristic curve. Grading using the subquantitative (SQ) method shows moderate certainty (area under the curve, 0.742). The cutoff at grade 2 best distinguishes participants with lower BMD from those with higher BMD in the femoral neck (accuracy, 0.713). The 45-degree diagonal line represents the reference line of nondiscrimination.

simple, easy-to-use diagnostic modality will provide better understanding of the importance of screening for osteoporosis among general practitioners in geriatric medicine.

Among osteoporotic fractures, proximal femoral neck fractures are the most harmful because they severely limit the ability of an individual to perform activities of daily living. In this study, we found that radiographically detected lumbar fracture correlated with BMD decline observed on DXA. This means that individuals with spine deformation tend to have weaker femoral necks and are at a high risk of hip fracture, consistent

Table 4. Predicted rate of decreased femur neck BMD (YAM of <70%) measured by DXA by ROC curves of each SQ grade.

	Cutoff	Specificity (95% CI)	Sensitivity (95% CI)	Accuracy
SQ grade	3	0.93 (0.80–0.99)	0.24 (0.12–0.41)	0.526
	2	0.83 (0.68–0.93)	0.62 (0.45–0.78)	0.731
	1	0.10 (0.03–0.23)	1.00 (0.91–1.00)	0.603

AUC – area under the receiver operating characteristics (ROC) curve; BMD – bone mineral density; CI – confidence interval; DXA – dual-energy X-ray absorptiometry; ROC – receiver operating characteristic curve; SQ – semiquantitative; YAM – young adult mean.

with those of previous studies [17,18]. In real-world settings, patients who have sudden back pain would receive a lumbar X-ray. However, a certain number of patients with lumbar fractures are missed by medical check-up because they have no symptoms. Our results show that subjects with silent lumbar fracture may have decreased BMD in the femur neck. In a previous report, a decrease of 1 SD in femur neck BMD raised the risk of fracture by 2.6 times in femur neck and 1.6 times in the whole body [19]. Therefore, our results could consistently fill the gap between previous studies. Moreover, our results suggest that SQ grade 2, rather than grade 1, is the better cutoff for predicting decreased BMD in the femoral neck, with high specificity (82.9%).

Osteoporotic fractures can increase the risks of comorbidity and shortened life expectancy. Vertebral fracture, the most common osteoporotic fracture, causes chronic pain, kyphosis, height loss, and psychological damage such as negatively affecting self-esteem, body image, and mood [20–22]. Moreover, vertebral fractures are strongly predictive of future fractures and are associated with an increased risk of death [17,23]. Hip fractures can worsen quality of life, necessitate dependent living, and increase the risk of death [5]. After a hip fracture, approximately one-third of the patients become totally dependent, and the need for permanent placement in a nursing facility increases [24,25].

Despite current participation of general practitioners in the diagnosis of osteoporosis and care of affected patients, the availability of DXA equipment remains limited to medium- to large-sized general hospitals and orthopedists' offices. Radiography, however, is more common in general clinics, but is not frequently used for diagnosing osteoporosis. In this context, the radiograph-based SQ method of fracture assessment may prove to be a valuable screening tool.

Besides the morbidity and mortality, rising expenditures for fracture treatment and care have become a problem in almost every country [26]. For patients with osteoporosis who have concurrent fracture, health care expenditures are more than twice as high as those for patients with osteoporosis but without fractures, and 3 times higher than those for patients without osteoporosis [27]. Therefore, early detection of osteoporosis and prevention of fractures are mandatory. Jonsson et al. [28] reported that pharmacological treatment of patients at high risk of fractures is cost effective; however, such drugs are expensive, making widespread use of fracture-preventive drugs difficult in many countries. Therefore, physicians should identify patients at high risk of fracture and offer effective treatments. We believe that screening using the SQ method would help identify patients who are prone to additional fractures.

This study has several potential limitations. First, we had only hospital-based data, not community data; thus, the possibility of a selection bias cannot be excluded. This data includes outpatients who are suspected to have osteoporosis, as well as inpatients with dementia or medical disease. Therefore, the participants of this study tend to be more vulnerable than the general population. This was a preliminary study; thus, the external validity of the results needs to be discussed. Second, we did not gather data on occurrences of fracture, being bedridden, or death. The BMD measured using DXA cannot always help predict the likelihood of fracture because BMD does not reflect the quality of bone trabeculae or balancing ability; it only helps show one of the aspects of osteoporotic deterioration. Third, we used the YAM score for the diagnosis of osteoporosis. WHO guidelines use T score compared to the young female average. In contrast, YAM score refers to the average of young adults of the same sex. Although YAM 70% is equal to T score -2.5 for the calculation, YAM can sensitively reflect the loss in BMD among male patients. Finally, 2 radiologists interpreted lumbar X-rays in this study, and this would be different from the real-world setting. However, interpretations by general practitioners could deviate more compared to these of radiologists if the general practitioners are not experienced in this method. Therefore, in this setting it would be beneficial to describe the ideal and less-biased condition. Indeed, plain radiography is useful for assessing bone structure, although it cannot be used to measure BMD. Nonetheless, our results sufficiently demonstrated the value of the SQ method in assessing osteoporotic changes on radiographs and distinguishing patients at high risk of fracture. Longitudinal studies with larger population are needed to assess the effect of screening using the SQ method on patients' lives.

Conclusions

Our data suggest that the SQ method using lumbar radiographs can help predict decreased BMD. The severity of vertebral bone deformity is associated with low BMD in the femoral neck. The SQ method may prove to be an accessible screening tool for osteoporosis and an indicator of the severity of BMD decline.

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Conflicts of interest

None.

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