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Development of Osteopenia in the Hemiplegic Finger in Patients with Stroke

Key Words

Stroke
Hemiplegia
Osteopenia
Hip fracture

Abstract

Previous studies have demonstrated that hip fractures in stroke patients occurred almost exclusively on the hemiplegic side. We examined the bone changes in the second metacarpal of the hemiplegic side in terms of microden-sitometric indices in 93 stroke patients with hemiplegia. All six indices indicated a significant decrease in bone mass on the hemiplegic side compared with the contralateral side. Differences in the indices between the hemiplegic and contralateral sides were correlated well with the duration of the illness and Brunstrom's stage for finger, arm, and leg. The same degree of osteopenia occurred in both small capsular and large hemispheric lesions. The same osteopenia was demonstrated in paralyzed and immobilized patients with myopathy. Thus a combination of weakness and immobilization is thought to be responsible for the osteopenia in the hemiplegic metacarpal bone. The osteopenia noted in the second metacarpal in the affected limb may account for the fact that hip fractures in stroke patients occur almost exclusively on the hemiplegic side.

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Introduction

It has been reported that 4-15% of patients with hip fractures have had previous cerebrovascular disorders and that 79-100% of the fractures occurred on the hemiplegic side [1-3]. This was explained by the development of disuse osteoporosis on the hemiplegic side that makes the bone more likely to break and the fact that hemiplegic patients with a stroke are prone to falls [4]. However, the pathogenesis of bone abnormalities on the hemiplegic side in patients with a previous stroke has not been fully elucidated [5, 6].

We examined microdensitometrically [7] the bone changes on the hemiplegic side in patients with a stroke and compared them to the contralateral side.

Materials and Methods

From 1991 to 1992, 141 patients with hemiplegia due to stroke of more than 1 month's duration were admitted to our hospital. Of these, 48 were excluded because of an association with the shoulder hand syndrome (n = 15), a previous history of stroke (n = 2), or difficulty in taking finger radiographs due to impaired consciousness (n = 31). Of the 93 patients studied, 57 were men and 36 were women, with ages ranging from 35 to 90 years (average: 69.8 ± 7.2, and 69.7 ± 11.7 years, respectively). The interval between the onset of stroke and the bone evaluation ranged from 32 to 8,156 days, with an average of 1,394 ± 1,863 days. None of the patients had a history of hip fracture. A diagnosis of stroke was made on the basis of computed tomography (CT) in both the acute and chronic phases, as well as the clinical evaluation. In 8 patients whose duration of illness was greater than 5,475 days, however, a CT scan was performed only in the chronic phase, which revealed decreased attenuation. The decreased attenuation corresponded to the territory of the cerebral arteries in 3 of these patients. The strokes were classified as brain infarction (n = 67), brain hemorrhage (n = 21), or unclassified (n = 5) according to

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Cross section of the metacarpal bone

- 1) $MCI = (d_1 + d_2) / D$
- 2) d (bone marrow width)
- 3) $GS_{max} = (GS_{max1} + GS_{max2}) / 2$
- 4) GS_{min}
- 5) GS / D
- 6) densitometer pattern index (1-9)

Fig. 1. Schematic of the MD method. Ranking the bone cortex width ($d_1 + d_2$) and the bone density, nine bone models (1-9) were determined. Each index was ranked by severity with a score of 0, 1, 2, or 3. From the sum of the scores of these six indices, the MD score was calculated. MCI = Ratio of the combined thickness of cortical bone (d_1 and d_2) to D ;
 $GS_{max1} + GS_{max2} / GS_{max} = \dots$
 Optical density of metacarpal bone pattern Aluminium step wedge

NINDS III. In the brain infarction group, a pure motor hemiparesis was due to a pontine lesion in 2 patients, and a capsular lacunar lesion in 21 patients. Cardioembolic stroke involving more than one cortical branch of the cerebral artery was present in 7 patients. A large hemispheric hemorrhage was present in 3 patients. Clinical severity of the hemiplegia was evaluated using Brunstrom's staging classification [8]. Stage 1 is defined by no voluntary movement of the affected limb, while stage 6 is characterized by near-normal strength in the arm, leg and each finger. In the fingers, an awkward weak hand grip is defined as stage 2, whereas the inability to release the hand grip is defined as stage 3. Grasping of a small object between the thumb and the radial side of the index finger defines stage 4, whereas spherical grasping ability is defined as stage 5. In the arm, weak basic limb synergies are defined as stage 2, whereas sufficient development of the synergies to show definite joint movement is defined as stage 3. In stage 4, an increasing number of movement combinations such as placing the dorsum of the hand in the lumbar region becomes possible. More difficult movement combinations such as raising the arm to a side-horizontal position with the elbow extended can be performed in stage 5. In the leg,

slight voluntary movement, and mass hip-knee-ankle flexion are defined as stage 2 and 3, respectively. Voluntary flexion of the knee beyond 90° is defined as stage 4, whereas stage 5 is characterized by isolated knee flexion in the standing position with the hip fully extended. Overall, in the finger, hand, and leg, the average stages were 3.38 ± 1.92 , 3.77 ± 1.34 , and 3.45 ± 1.75 , respectively. 37 patients suffered from right-sided and 56 from left-sided hemiplegia. Diabetes mellitus, which is known to result in osteopenia, was present in 19 patients. None of the patients had received drugs known to alter bone metabolism, including corticosteroids, thyroxin, or anticonvulsants.

For the determination of the bone changes on the hemiplegic side, plain radiographs of both hands were taken with an aluminum step scale, and were analyzed by a microdensitometer. The optical density at the center of the second metacarpal bone was read according to the method of Joue et al. [7] (fig. 1). The bone width (D), bone marrow width (d), cortical width on the radial side (dl), cortical width on the ulnar side (d2), density at the center of the bone marrow (GSmin), peak density on the radial side (GSmax1), and peak of density on the ulnar side (GSmax2) were measured. The cross section of the metacarpal bone was assumed to be a circle, and the cortical bone width (dl and d2) was classified into three grades (1, 2/3 and 1/3). The optical density of dl and d2, was also graded (1, 1/2, and 0). Nine bone models were prepared by drawing the metacarpal bone pattern according to the above parameters. These values were used to determine the following six indices: (1) the metacarpal index (MCI), (2) the bone marrow width index (d), (3) the center density index (GSmin), (4) the side density index, mean of the GSmax1 and GSmax2, (GSmax), (5) the index corresponding to the mineral content of the bone (2 GS/D, 2 GS = the integrated value of the density area), and (6) the densitometer pattern index (1-9). There were 388 male and 315 female controls aged 30-90 years (matched for age and sex). Changes in these indices in each sex and age group were defined as follows: changes of less than 1 standard deviation (SD) from the regression line of 703 healthy controls were expressed as a change of one point, less than 2 SD as two points, and greater than 2 SD as three points. From the sum of the scores of the six indices, the degree of bone loss was expressed as the microdensitometric (MD) score. Thus,

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Table 1. Laterality of the bone changes in hemiplegic patients (n = 93)
Table 2. Comparison of the right and left hands of healthy controls (n= 55)

	Hemiplegic side	Contralateral side		Right	Left
MCI	0.386±0.094*	0.431 ±0.084	MCI	0.477 ±0.089 [#]	0.469 ±0.079
d	5.524 ±1.033*	5.045 ±0.874	d	4.474 ±0.842 [#]	4.439±0.791
GSmax	3.446 ±0.699*	3.790±0.550	GSmax	3.930±0.441 [#]	3.781 ±0.397
GSmin	1.965±0.767*	2.399±0.643	GSmin	2.599±0.627 [#]	2.639±0.623
2GS/D	2.450±0.651*	2.801 ±0.506	2 GS/D	2.889 ±0.422 [#]	2.846±0.414
Bone pattern	3.925 ±2.789*	2.656±2.238	Bone pattern	2.145±1.779 [#]	2.056±1.522
MD score	5.957±5.529*	2.630±3.340	MS score	1.782±2.158 [#]	1.889 + 2.195
*p<0.001.			[#] Not significant.		

the lowered estimated values of MCI, GSmin, GSmax, and 2 GS/D, and conversely the elevated values of d and densitometer pattern index indicated the development and progression of osteopenia. The microdensitometric method permits the assessment of the degree of bone loss as indirect evidence of osteoporosis. The term osteopenia is used instead of osteoporosis in the text. To confirm the lack of laterality of abnormal values of the microdensitometric indices in healthy individuals, a total of 55 persons (25 males and 30 females) with an average age of 58.2 ± 14.3 years served as controls. To evaluate differences in bone abnormalities between stroke and paralyzed and immobilized patients without brain lesions, 6 patients with various types of myopathy (not on corticosteroids) were evaluated only by using the unilateral MD score (2 males and 4 females). They had a hand grip of less than 10 kg, an average age of 35.2 ± 11.3 years, and a mean duration of illness of 7.5 ± 6.4 years.

In all of the patients, the six indices and the MD score were compared between the second metacarpals of the left and right sides. The six indices and MD score on the hemiplegic sides were compared between the 21 patients with pure motor hemiparesis due to lacunar infarction at the capsula interna and 10 patients with cardioembolic stroke or large hemispheric hemorrhage. The same comparison was made on the hemiplegic side between 19 diabetic and 74 nondiabetic patients.

The results were expressed as the mean ± standard deviation. For statistical analysis, means were compared using the t test for paired or unpaired samples. Fisher’s exact test was used when appropriate. To examine between each index and the duration of illness and severity of the palsy, Spearman’s rank correlation coefficients were calculated, p values of less than 0.05 were accepted as statistically significant.

Results

Table 3. Correlation between the hemi-plegic-nonhemiplegic differences and the duration of illness (n = 93)

	Spearman’s rank correlation coefficient	p value
MCI	0.413	0.0001
d	0.352	0.0008
GSmax	0.162	0.1211
GSmin	0.288	0.0058
2 GS/D	0.272	0.0092
Bone pattern	0.269	0.0218
MD score	0.338	0.0014

Spearman’s rank correlation coefficacy was used to examine the relationship between the left-right difference in the index and the duration of illness.

healthy controls (table 2). The MD score and the six indices on the intact side in the stroke patients were intermediate between those on the hemiplegic side and those in the controls (tables 1, 2).

MD Score in Patients with Myopathy All 6 patients with myopathy had an MD score greater than 4, with a mean of 6.17 ± 1.31.

Laterality of Abnormal Values of Bone Changes
(tables 1,2)

All of the estimated values of the six indices and the MD score on the hemiplegic side differed significantly from those on the contralateral intact side (table 1), while the values were not different in the two hands of the

Relationship between the Hemiplegic-Nonhemiplegic Differences and the Duration of Illness (table 3) A strongly positive correlation was found between the left-right difference in the indices and MD score (except GSmax) and the duration of illness, suggesting continuous progression of osteopenia on the hemiplegic side.

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Table 4. Correlation between the hemiplegic-nonhemiplegic differences and Brunstrom’s stage (n = 93)
Table 5. Comparison of bone changes due to small lesions of the capsula interna with those due to large hemispheric lesions

	Finger	Upper limb	Lower li
MCI	-0.236 (0.0133)	-0.248 (0.0105)	-0.199 (0.0307)
d	-0.281 (0.0036)	-0.287 (0.0033)	-0.196 (0.0328)
GSmax	-0.464 (0.0001)	-0.494 (0.0001)	-0.260 (0.0058)
GSmin	-0.424 (0.0001)	-0.468 (0.0001)	-0.260 (0.0058)
SGS/D	-0.427 (0.0001)	-0.464 (0.0001)	-0.285 (0.0027)
Bone pattern	-0.371 (0.0001)	-0.424 (0.0001)	-0.267 (0.0009)
MD score	-0.482 (0.0001)	-0.499 (0.0001)	-0.293 (0.0015)
Small lesion (n = 21)			Large lesion (n=10)
Age, years	68.6±8.5		64.4±10.0 ^a
Male/female	15/6		6/4 ^a
Duration of illness, days	1,697 + 1,787		1,458±2,418 ^a
Brunstrom’s scale			
Finger	3.571 ±1.886		2.200 ±1.874 ^a
Arm	1.650±0.745		2.000 ±0.943 ^a
Leg	4.095 ±1.221		2.800 ±1.619**
MCI	0.376±0.103		0.416±0.098 ^a
d	5.694±1.186		5.166±0.991 ^a
GSmax	3.589±0.806		3.346 ±0.643 ^a
GSmin	2.076 ±0.859		2.009±0.614 ^a
2GS/D	2.581 + 0.718		2.437 ±0.524 ^a
Bone pattern	4.095 ±3.192		4.400 ±2.459 ^a
MD score	6.476 ±5.980		5.900±4.383 ^a

Values represent Spearman’s rank correlation coefficacy (SRCC) with the p value in parentheses. SRCC was used to examine the relationship between the left-right difference in the index and Brunstrom’s stage.

**p<0.05. Not significant.

Relationship between the Hemiplegic-Nonhemiplegic Differences and Brunstrom 's Stage (table 4) A close correlation was demonstrated between the severity of palsy based on Brunstrom's stage and the left-right differences in the six indices and MD score calculated for the fingers, the upper and lower limbs.

Comparison of Bone Changes due to Pure Motor Hemiparesis with Those due to a Large Hemispheric Lesion (table 5)

There were no significant differences between the two patient groups with respect to age, sex, duration of illness, or Brunstrom's stage in the finger and arm. Musclar weakness of the leg (based on Brunstrom's stage) was significantly worse in the patients with large hemispheric lesions than in those with capsular lesions. There were no significant differences in any of the indices or the MD score between the two patient groups on the hemiplegic side.

Comparison of Bone Changes in Diabetic and Nondiabetic Patients (table 6)

There were no significant differences with respect to age, sex, duration of illness, or Brunstrom's stage between the two patient groups. There were no significant differences in any of the indices or the MD score between the two patient groups in the hemiplegic side.

Table 6. Comparison of bone changes in diabetic and nondiabetic patients

DM (n = 19)		Non-DM (n = 74)	
Male/female	14/5	42/32	
Duration of illness, days	1,116+ 1,591	1,468 ±1.940	"
Brunstrom's scale			
Finger	4.111 +1.367	3.288+ 1.989	a
Arm	3.778 + 1.629	3.425 ±1.779	a
Leg	4.000 ±1.188	3.712±1.380	a
MCI	0.399±0.075	0.383±0.098	a
d	5.406±0.959	5.554±1.067	a
GSmax	3.782±0.596	3.383±0.703	a
GSmin	2.327±0.714	1.895±0.755	a
SGS/D	2.739±0.562	2.394±0.656	a
Bone pattern	3.056±2.363	4.055 ±2.847	a
MS score	4.389±4.828	6.164±5.540	a

DM = Diabetes mellitus. Not significant.

Discussion

There are few reports of bone changes on the hemiplegic side in small numbers of patients with a stroke [5, 6], despite the fact that hip fractures almost exclusively occur in this location [1-3]. The present study, using the MD method of analysis of radiographs, confirmed a reduction of bone mass on the hemiplegic side when compared with the contralateral side. As the normal values of each index vary according to sex and age, we used the contralateral intact side as a control to detect abnormalities in the hemiplegic side. The MD method is based on a principle similar to that used in the photon absorption technique using X-rays instead of y-rays. The validity of this simple method has been reported by Inoue et al. [7]. They demonstrated, using iliac bone, a positive correlation between the five indices estimated by the MD method and the severity of osteoporosis as evaluated by photon absorptiometry and confirmed by pathologic examination. It is noteworthy that a positive correlation was observed between the duration of illness and the differences between the hemiplegic and nonhemiplegic side. Moreover, a close correlation was found between the severity of the palsy, not only in the finger but also in the lower and upper limbs, and the differences between the hemiplegic and normal sides. It was

also found that the same degree of osteopenia occurred in association with both small capsular and large hemispheric lesions. This indicates that size or site of the cerebral lesion is unrelated to the degree of osteopenia. Several studies have demonstrated a loss of bone tissue during immobilization such as prolonged bed rest or spinal cord injury [9-11]. Biering-Sorensen et al. [11] demonstrated decreased bone mineral content of the lower extremities, and an unchanged bone mineral content in the distal forearm in patients with spinal cord injuries manifested as paraplegia. In the present study, a close correlation was found between the severity of the palsy and the degree of bone changes, which is in agreement with the findings in the patients with paraplegia. Decreased voluntary muscle power may account for a significant proportion of the osteopenia on the hemiplegic side since the existence of osteopenia was confirmed in patients with myopathy. It is concluded that the pathogenesis of the osteopenia on the hemiplegic side is a combination of muscular weakness and immobilization. Similar bone abnormalities may develop in the hemiplegic femoral neck as well as the finger, as evidenced by the positive correlation between Brunstrom's stage in the leg and the observed differences in the indices in the finger. The reason why hip fractures occur almost exclusively in the femoral neck on the affected side may be explained by osteopenia. The fact that the values of the contralateral side were intermediate between the hemiplegic side and those in the control subjects is not explained by differences in age and sex between the two groups because the MD score is absolute. In the hemiplegic state after a stroke, the dependence on professional care for the activities of daily living may result in a decrease in mobility of the intact limb. Therefore, mild contralateral osteopenia may exist parallel to the degree of immobilization of the intact limb. Diabetes mellitus has been shown to be an important factor in the development of osteopenia [12] and is known to be a significant risk factor for stroke [13, 14]. In the present study, however, there were no significant differences in any of the indices or the MD score between the two patient groups in the hemiplegic side. The reason is not known at present, and cannot be explained simply by differences in age, sex, or duration of the illness. A more detailed clinical investigation of a large number of patients is necessary to elucidate the relationship between diabetes mellitus and osteopenia on the hemiplegic side in stroke patients.

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