Spinal fractures resulting from the 1995 Great Hanshin Earthquake of the Kobe–Osaka area of Japan

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One of the worst earthquakes hit the Hanshin area between Kobe and Osaka, in the early morning at 5:46 AM on January 17th 1995. The destructive force with MG 7.2 severely damaged buildings, houses, roads and railways, leaving 6500 dead, and 34 900 injured. Hyogo College of Medicine located in this area was also severely damaged, thus there was a major challenge to provide post-quake medical support.

A post-quake investigation in this area was done by 50 affiliated hospitals. More than 15 000 victim-patients were treated at these hospitals during the first 3 days after the quake. Major injuries were spinal fractures, and other trunk fractures, including rib or pelvis fractures, but fractures of long bones were uncommon, because the quake hit this area in the early morning when most people were asleep.

In this study, the mechanisms of these major injuries were analysed by direct interview soon after the quake, with 230 victim-patients who had 140 spinal fractures, and 100 with rib or pelvis fractures. Most of those who had a spinal fracture had either sat up or stood up on their 'Futon' mattresses without bed frames and were struck on their backs by falling furniture or ceilings. On the other hand, patients who had fractures of the ribs or the pelvis had been lying in the supine or lateral position and were hit on their chest or pelvis. This characteristic lifestyle pattern of the Japanese people to lie down on the floor directly beside furniture, resulted in these injuries.

From these results, we will emphasize the following precautions:- If an earthquake occurs during sleeping hours at home, do not stand up or sit up. The best position is to crouch on the 'Futon' mattress.

Keywords: spinal fracture; earthquake; disaster; rib fracture; pelvis fracture; Kobe–Japan

Introduction

It was just like a nightmare. The Hanshin area of Japan, located between the cities of Kobe and Osaka, was hit by one of the worst earthquakes in history, named the Great Hanshin Earthquake, in the early morning of January 17 1995. I (SM) also had a terrible experience as one of the victims of Kobe city where I live and as a victim-doctor who treated the victim-patients in our damaged hospital, located in Nishinomiya city near Osaka (Figure 1). We doctors at the Hyogo College of Medicine hospital and its affiliated hospitals were greatly challenged to provide after-quake medical support despite the severe damage suffered by our hospital facilities.

During these medical activities, investigations were made with reference to how many victim-patients were treated, what kind of major injuries were found and

what were the characteristic bone injuries caused by this special urban earthquake which occurred in the early morning, especially affecting those people who live in traditional Japanese style.

This Great Hanshin Earthquake occurred in the early morning, 5:46 AM on January 17 1995. The destructive force of the quake was measured at 7.2 magnitude on the Richter scale. It caused many buildings and houses to collapse and destroyed the railways. The Western part of Kobe was mostly damaged by post-quake fire, but the Eastern part where our hospital is located was mainly damaged by the quake collapsing houses and buildings. Many victims were rescued from collapsed wooden houses or buildings (Figure 2).

Resulting from this terrible earthquake disaster, the final death toll was 6500 and 34 900 were injured. Among the damaged houses or buildings, 92 877 completely collapsed, and 99 829 were partially destroyed, and 71 119 were completely burned down.

Figure 1 Hanshin area and major cities damaged by this earthquake

Figure 2 Many wooden houses collapsed in the quake and victims were rescued at the eastern part of Kobe city (Photo by Kobe Shinbun)

Materials and methods

A post-quake investigation in the area was done by the staff of 50 affiliated hospitals. The number of quake victims at these hospitals was about 15 773 during the first 3 days following the quake. But it might have been more, because of the large number of victims who came to these hospitals just after the disaster for medical care before there was time to make medical records.

Out of 757 major bone injuries, spinal fracture ($n=222$) were the most common, followed by ribs ($n=170$) and pelvic fractures ($n=74$), with few long bone fractures, as shown in Table 1.

In this study, the mechanisms of these major injuries were analysed through direct interview of 230 victim-patients who suffered 140 spinal fractures, 100 other trunk fractures including 45 rib and 34 pubic fractures and others, 10 both fractures, a total of 240 fractures.

Table 1 Major bone injuries treated at 50 affiliated hospitals

1	Spinal fractures	222
2	Rib fractures	170
3	Pelvis fractures	74
4	Crush syndrome	37
5	Burns	28
6	Finger fractures	27
7	Others	199
	Total	757

Table 2 The major fractures occurring in 230 patients who had agreed to a direct interview

Spinal fractures	140
spinal cord injuries (Frankel A:3, D:3)	6
Other trunk bone fractures	100
Fractures of ribs	45
Fractures of clavicle	6
Fractures of pubis	34
Fracture of ischium	15
Total	240

One of the reasons why the three major injuries were spinal fractures and other trunk fractures, with fewer long bone fractures occurring, was the timing of the quake, which occurred while most of the victims were still sleeping, and also because of the traditional custom in Japan of sleeping on grass-mat floors 'Tatami', on cotton mattresses 'Futon', without bed frames. The number of victims was greater than might have been had the earthquake happened during waking hours, except for those hours when commuting is heavy.

We can easily understand why the victims sleeping on cotton mattresses, 'Tatami', in the supine or lateral position, were hit on their chest or pelvis by falling objects, at the time of disaster. But why were spinal fractures so common? The victims must have been sitting in an upright position, or be in the standing position with their back facing the falling objects which struck them. Posture at the time of the disaster and the severity of the damaged houses are important factors. Thus direct interviews were done.

Results

The number of victim-patients (by direct interview)

The number of victim-patients who agreed to the direct interview were 230 out of 466. The classification of 240 fractures on these 230 victim-patients is shown in Table 2.

Fortunately, there were only six patients (0.5%) with a spinal cord injury out of the 140 with a spinal fracture, and the severity in these six patients was classified as either Frankel A:3 or D:3.

The sex and age distribution

The sex and age distribution of 230 victim-patients suffering from spinal or other trunk fractures are shown in Figure 3. The average age was 62.9 years old. As to the sex distribution, females 162, males 68, 70% of them were aged females.

The site of spinal fracture

The site of 169 affected vertebrae on 130 victim-patients, including double lesions, are shown in Figure 4.

The 'victims' home and the extent of damage at the time of the disaster (Figure 5A–E)

Comparison between the spinal fracture groups (Group-S) and the other trunk fracture groups (Group-T) was done to analyse the factors resulting in these different types of fractures. We used only the data from the replies of the victim-patients, because some did not remember exactly the situation at the time of the quake. Wooden houses were the most common denominator in both groups. Group-S: 83 (75%) out of 111, and Group-T: 61 (65%) out of 94. Apartment houses or deluxe apartments followed (Figure 5A).

The severity of damage of these houses or buildings is shown in Figure 5B. Totally collapsed houses were 32 (34%), and partially collapsed were 41 (43%) out of 95 in group-S, and 36 (47%) total and 15 (20%) partial, out of 76 in group-T. There were no significant differences between these two groups.

Types of falling objects, and the way of escape (Figure 5C and D)

Regarding the way to escape, no significant differences were found (Figure 5D).

The posture of the patients

The posture of victims at the time of the quake revealed significant differences. (Figure 5E).

In Group-S, the victims were in the posture of either sitting up 31 (29%), or standing up 28 (26%), or in the prone position 22 (20%), with a total of 81 (75%) out of 108, lying on their mattresses (Futon) during the quake. This implies that many people stood upright, or were in a prone or a crouched position surprised by the strong tremor, and tried to escape with their backs facing the falling objects and were then struck on their back.

In group-T, the victims who were supine position 26 (30%), lateral position 28 (33%), with a total 54 (62%) out of 86 lying on their mattress 'Futon' during the quake.

Falling objects hit the chest or the upper part of the body resulting in rib fractures and the lower part of the body resulting in pelvis fractures, especially pubic fractures, with a total of 140 trunk fractures.

Discussion

The conditions of this earthquake were very similar to that of the Tangshan earthquake in China, which also

Figure 3 Sex and age distribution

Figure 4 The site of affected vertebrae

occurred in the early morning, at 3:43 AM on January 28th 1995. The destructive force measured 7.8 magnitude on the Richter Scale, and resulted in very severe damage to the city resulting in a death toll of 242 769, with 164 851 injured.¹ According to the post-quake investigation, the three major injuries in the quake were the crush syndrome, fracture of the pelvis and of the spine. Most of the patients who suffered from spinal fractures, were aroused by the strong tremors and as soon as they sat up in their beds, they were hit on their backs by falling ceilings. 70% sustained injuries of the thoraco-lumbar spine, and unfortunately more than 34% became paraplegic. This may be due to the difference between the stone houses in China, and wooden houses in Japan.

Conversely, are the conditions of Armenian earthquake in the former Soviet Union which occurred later

in the day, on December 7th, 1988, with 6.9 magnitude on the Richter scale, with a death toll of 25 000 with 30 000 injured.² The types of major bone injuries were head, face, upper and lower extremities, with few spinal or other trunk fractures.

In the Hanshin area quake the number of bone injuries were 1675 (14%) out of the total (11 975) of all of the injured victim-patients. Fracture of the spine or other trunk bones was 995 (59%) out of 1675. But fortunately only 21 (2.1%) had a spinal cord injury.

Post-mortem examination by legal medical examiners after the quake showed that 2761 (76%) out of the 3651 cadavers' deaths were mainly caused by traumatic asphyxia from chest or abdominal compression.

From these results, the timing of the quake and the victim's posture at the time of the quake are seen to be important factors determining the location of fracture. Another important factor is the traditional custom in Japan of sleeping on grass-mat floors 'Tatami', on cotton mattresses 'Futon', without bed frames along with the nearby furniture such as drawers, console cases or book cases which hit the victims directly.

From this analysis, we observe the mechanisms of these injuries as follows: (Figure 6). The earthquake occurred during sleeping hours in the early morning in Japan. Regarding fractures, were those who were either sitting up or standing up on their Futon mattresses during the quake, and thus suffered from spinal fractures. On the other hand, the victims lying in the supine or lateral position suffered rib or pelvic fractures.

We emphasize the following precautions: If the earthquake occurs during sleeping hours at home, 'Don't stand up! Don't sit up! Don't walk!' The Crouch position on cotton mattresses 'Futon' might be the safest option.

Figure 5 The situation of damage at the time of disaster. (A) Type of houses or buildings. (B) Degree of damage to houses or buildings. (C) The sort of falling objects. (D) The way to escape. (E) Posture at the time of injury

Figure 6 Mechanisms of each fracture. The victims sitting or standing suffered from spinal fractures and the victims lying in the supine or the lateral position suffered from rib or pelvic fractures

Conclusion

One of the worst earthquakes hit the Hanshin area, resulting in 6500 deaths and 34 900 injuries. The earthquake occurred in the early morning, resulting in more trunk injuries like spinal, rib and pelvic fractures, than long bone fractures. Posture at the time of earthquake was important also. Upright position resulted in more spinal fracture. Probably, the crouch position would have been the safest.

References

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