Prevention of Fractures Caused by Falls in Elderly Persons

A tsushi HARADA
Chief, Department of Orthopedic Surgery, National Chubu Hospital

Abstract: Hip fracture usually occurs when the greater trochanter takes the impact of a fall. This was confirmed in our experimental study that simulated a fall onto the greater trochanter, since 75% of 24 femurs tested were fractured. Our experiment also showed that the fracture threshold for the hip of an elderly person was 2,166 N, while other researchers reported that the force exerted on the greater trochanter by the impact of a fall was 5,600 N. The large difference between these two values explains the high incidence of hip fractures in elderly individuals. To prevent such fractures, hip protectors were developed. We confirmed experimentally that a force-absorbing hip protector can reduce the impact force to 70%, and the load was further reduced to 54% when a force-dispersing device was added to it. A randomized clinical study was performed in 59 elderly persons living in nursing homes; no hip fractures occurred among the subjects wearing protectors, while four of the subjects without protectors suffered hip fractures. The incidence of hip fractures in the subjects not wearing protectors was higher than in those wearing protectors, although these two groups were equal to each other in terms of the frequency of falling, grip strength, thigh circumference, skinfold thickness in the upper arm, and ultrasonic bone assessment of the calcaneus. In conclusion, the hip protector is expected to prevent hip fractures in very elderly persons who have a higher risk of falling and decreased bone strength.

Key words: Hip fracture; Fall; Hip protector; Biomechanics; Osteoporosis

Introduction

In Japan, the orthopedic ward used to be full of patients with fractures caused by occupational and traffic accidents. Elderly patients with fracture of the spine or the hip were not noticed among the many other young patients. Because the elderly population has increased recently, however, orthopedic wards are now filled by elderly patients with fractures mostly caused by falls. Aging of the population will progress further in the future, so prevention of fractures caused by falls needs to be considered. We should not let the incidence of frac-
tures rise unchecked.

We have been searching for methods to prevent fractures by falls, particularly hip fractures. The purpose of this article is to describe the preventive measures that have been devised and the results of our investigations.

**Epidemiology of Hip Fractures**

Hip fracture is a major problem because of its high prevalence and severity. Epidemiological studies performed in the United States have shown that falls account for more than 90% of hip fractures. The treatment of this fracture was established long ago and many patients will recover the ability to walk if they can complete treatment uneventfully from operation to rehabilitation. A according to Kita-mura who performed a follow-up study of 1,169 patients in Japan, one year after injury, 67% of them had recovered the walking ability as before suffering the fracture. However, walking ability was deteriorated in the remaining 33% and a considerable number of very elderly persons became bedridden. He also reported that the mortality rate was 6% at 120 days after fracture and then increased to 11% at one year. These results indicate that hip fracture is associated with a high mortality. Consequently, a reduction of the incidence of hip fracture is considered important because of the coming predominance of the elderly among the total population.

**Mechanism of Hip Fractures**

In order to prevent hip fractures, the mechanism needs to be elucidated, but it is not well-known. If a hip fracture occurs spontaneously, for example, while a person is walking or standing up from a sitting position, a fall will occur subsequently. Many orthopedists still think that hip fractures mostly occur in this manner. Although the fracture precedes a fall in some cases, they are exceptional, and the most common cause of hip fracture is secondary to a fall.

1. **Site of impact**

   In brief, the majority of the hip fractures are produced when the great trochanter or the lateral aspect of the hip takes the impact of a fall. To investigate this mechanism, in collaboration with the Toyota Central R&D Labs., Inc., we developed a testing machine to simulate a fall onto the lateral aspect of the great trochanter. A fracture experiment was performed with this machine and 24 cadaver femurs. When a weight was dropped onto the greater trochanter, it produced a typical hip fracture in 75% of cases. This result showed that the femoral neck is fractured by an impact on the lateral aspect of the great trochanter.

2. **Magnitude of the impact force caused by a fall**

   The magnitude of the impact force on the greater trochanter during a fall has only been assessed in one experiment performed by Hayes et al. This group raised young volunteers with the body in the lateral position up to a level of 70 cm above the ground and suddenly released them. The force exerted on the greater trochanter by the resulting fall was measured with a force plate. This showed that the force acting on the great trochanter in a fall was 5,600 N when the subject was in a state of muscle relaxation. Interestingly, this force increased to 8,600 N when the fall occurred with muscle contraction. In the present study, the lower value (5,600 N) was defined as the impact force.

3. **Magnitude of the impact force that can cause the hip fracture in the elderly**

   According to another experiment performed by Hayes et al., this force was reported to be 2,100 N. In our fracture experiment, the fracture threshold was 2,166 N, which is well consistent with the reported value, confirming the validity of our experiment. This indicates that, in elderly persons, the femoral neck is likely to be fractured by a force that is less than half of that exerted on the greater trochanter in a fall (5,600 N). This fact is noteworthy when attempt-
solely on the basis of bone strength, it must be maintained at this level in the elderly, but this seems to be very difficult with current medical treatment. In other words, fractures cannot be prevented by only making efforts to maintain bone strength.

4. Incidence of hip fractures caused by falls

Tinetti et al. studied 336 persons living in the community\(^7\) and found that 108 fell during the one-year study period, with the incidence of hip fracture being 1%. This incidence is far lower than an estimate based on the difference between the impact force and the fracture threshold, as described above, which means that most elderly persons can avoid fracture in some way. Many factors may possibly be involved and precise knowledge of such factors could provide a key to preventing fractures caused by falls.

Factors Involved in Causing Hip Fractures after Falling

Factors that are presumed to influence the occurrence of fracture after falling include the ability to recognise the onset of a fall, the protective response of the upper extremities and trunk, attenuation of the impact on contact with the ground, and bone strength.

1. Recognition of a fall and protective response

If we notice that we are going to fall, we instinctively try to avoid it by holding onto something and taking a step forward, or we protect the head and trunk by breaking the fall with our arms and rotate the body to minimize damage. These events that occur before contact of the body with the ground still need to be studied further.

2. Bone strength

As described above, the force that can break the femoral neck in the elderly is much smaller than the force actually exerted on the hip in a fall. According to Courtney, the threshold load for femoral neck fractures at a mean age of 33 years was 7,200 N, indicating that persons of this age group are unlikely to sustain a hip fracture after a simple fall.\(^7\) To prevent fractures solely on the basis of bone strength, it must be maintained at this level in the elderly, but this seems to be very difficult with current medical treatment. In other words, fractures cannot be prevented by only making efforts to maintain bone strength.

3. Reduction of the impact on contact with the ground

We have studied methods for attenuation of the impact force that causes hip fracture during a fall. Atenation of the impact force by the floor covering is easy to understand. It is axiomatic that the severity of the injuries sustained in a fall varies widely depending on whether the floor is soft or hard. A fall on concrete, for example, may result in death or spinal cord injury, but the same fall on grass may cause no injury. Thus, the type of flooring often decides the outcome.

1) Soft tissue attenuation of the impact

The severity of the injury caused by a fall also depends on the properties of the soft tissues overlying the greater trochanter, which receives the impact. The physical properties of skin, fat, fascia, and muscle will vary with age, while a thicker layer of soft tissue has a greater ability to attenuate impact forces. An impact experiment carried out with human femurs and trochanteric soft tissues has actually demonstrated that thicker soft tissue absorbed more energy.\(^8\)

2) Soft tissue in patients sustaining hip fractures

We performed a clinical study to compare 45 patients with hip fractures and 51 age- and sex-matched patients without fractures. This study showed that the total body amount of soft tissue, as assessed by dual-energy X-ray absorptiometry (DEXA), was 6.9 kg less (a significant decrease), in the patients with fracture than in those without fractures. In addition, there was a strong correlation between the total body amount of soft tissue and the thickness of the trochanteric soft tissues assessed by CT scanning. When these results are considered together, it
seems that patients sustaining a hip fracture after falling have less trochanteric soft tissue and thus achieve less attenuation of the impact on the greater trochanter when they fall. In other words, the soft tissue may act as a pad that protects the bone from fracture. A lean physique is considered to be one of the risk factors for hip fracture, and decreased attenuation of the impact force may partly account for this association.

Prevention of Fractures by Using Hip Protectors

1. Concept of the hip protectors

The idea of wearing a hip protector to prevent fractures seems reasonable when attention is directed to the role of the soft tissues in reducing the force exerted on the hip in a fall. In brief, a device that attenuates impact force could be placed over the greater trochanter to prevent hip fractures. This idea was investigated in Europe in the 1970s. In 1988, Wortenberg actually used soft silicon pads as protectors in elderly persons. Since then, hip protectors of various types have been developed in Europe and the United States. Virtually all of these protectors belong to either one of two types, which are helmet-shaped protectors made of hard materials such as polypropylene to disperse impact forces and protectors made of soft materials such as silicon gel to absorb impact forces (Fig. 1). Most of these protectors are incorporated into an undergarment so that the greater trochanter is covered when the garment is worn (Fig. 2).

2. Pre-clinical evaluation of the effectiveness of hip protectors

Our weight-dropping experiment showed that
A soft silicon gel (force-absorbing) protector reduced the mean impact load on the greater trochanter from 3,117 N to 2,176 N (70%). When a hard (force-dispersing) protector made of resin was placed over the soft protector, the mean impact load was further reduced to 1,681 N (54%), a level below the hip fracture threshold in elderly persons (Fig. 3). In other words, the use of a soft protector plus a hard one can reduce the impact load by more than 40%. Therefore, the use of hip protectors could result in a considerable reduction in the occurrence of fractures.

3. Clinical studies on hip protectors

1) Study by Lauritzen

In 1993, an 11-month follow-up study was performed in Danish nursing homes, with 247 and 418 elderly persons randomized to use or not use hard hip protectors, respectively. During follow-up, eight (3.2%) and 31 (7.4%) subjects sustained hip fracture among those wearing and not wearing hip protectors, respectively, with a significant difference between these two groups. Thus, the effectiveness of hip protectors was demonstrated. In addition, all fractures in the hip protector group occurred while the subjects were not wearing their protectors. These results show that hip protectors can provide excellent mechanical protection of the hip, but that good compliance with wearing them is very important.

2) Studies in Japan

Only a few researchers have assessed hip protectors in Japan so far. Suzuki et al. performed a field survey to assess the wearing of hip protectors by elderly persons living in the community, and they found that only 44% of the elderly subjects continued to wear hip protectors after 6 months.

We performed a study to evaluate the effectiveness of hard hip protectors for preventing hip fractures in nursing homes. Among the elderly women living in these nursing homes, 35 and 24 were randomized to use or not use hip protectors, respectively. They were followed for 19 months, while falls and fractures caused by falls were assessed. During the follow-up period, 64 falls occurred among the subjects wearing protectors and 32 falls occurred in the control group, and there was no significant difference in incidence between the two groups. No hip fracture occurred among those wearing protectors, but four women sustained fractures in the control group, and the hip fracture rate of the protector group was significantly lower than that of the control group (Fisher’s exact test, \( p = 0.0336 \)) (Table 1).

Table 1 Study on the Prevention of Hip Fractures with Hip Protectors in Nursing Homes

<table>
<thead>
<tr>
<th></th>
<th>No hip fracture</th>
<th>Hip fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip protectors worn</td>
<td>30*</td>
<td>0</td>
</tr>
<tr>
<td>Hip protectors not worn</td>
<td>20</td>
<td>4</td>
</tr>
</tbody>
</table>

* Among the 35 elderly persons who wore protectors, five dropped out. Fisher’s exact test, \( p = 0.0336 \).
Prevention of Fractures Caused by Falls: A Three-Pronged Approach

As described above, the use of hip protectors is a typical method of preventing fractures based on attenuation of the impact of a fall. This method is practical and may be highly beneficial for very elderly individuals at high risk of falling who also have decreased bone strength. Today, it is also possible to increase bone strength with drugs such as bisphosphonates. Because drug therapy takes years to sufficiently increase bone mass, however, it alone may be unsuitable for very elderly persons who are already at high risk. By wearing hip protectors, they can immediately protect themselves against hip fractures, so protectors are also useful from the viewpoint of instant protection.

Finally, I would like to emphasise that the maintenance of bone mass and prevention of falls are the basis of preventing fractures. For the prevention of hip fractures, elderly persons over the age of 80 years, around which time the incidence of hip fractures increases exponentially with age, should also use hip protectors in addition to these other two protective elements. It is very important to prevent fractures after falling by employing all three methods in a coordinated manner.

REFERENCES