Fractured Femurs, Falls and Bone Disorders

P. J. COOK, MB, BSc, MRCP(UK)*
Medical Registrar, University College Hospital, London

A. N. EXTON-SMITH, CBE, MD, FRCP, Barlow Professor of Geriatric Medicine,
University College Hospital Medical School, London

J. C. BROCKLEHURST, MD, FRCP
Professor of Geriatric Medicine, University of Manchester

S. M. LEMPERT-BARBER, MB
Lecturer in Geriatric Medicine

After the age of 50 the incidence of femoral neck fracture increases exponentially with age, and the rates approximately double every five years in women and every seven years in men[1]. This age-related increase can be explained only by an increase in fall frequency, a change in the nature of falls, or by an increased liability of the bone to fracture. The last-named may be due to age-associated bone loss (osteoporosis), changes in the tensile strength of bone matrix, or excessive demineralisation of new bone (ostemalacia). Several studies have investigated the importance of falls[2,3] and of changes in bone[4-6], but little attempt has been made to examine the relationship between them.

Materials and Methods

The Patients

An examination was carried out on 384 patients (70 males and 314 females) with fracture of the proximal femur admitted to two hospitals in London and three in Manchester[3]. Their ages ranged from 50 to 100 years, with a mean of 76 years for the males and 79 years for the females.

The Controls

Information on fall frequency was obtained from a study of 968 people over the age of 65 (535 males and 433 females) who were living in their homes and who participated in a nutrition survey sponsored by the Department of Health and Social Security[7]. Their ages ranged from 65 to 95, with a mean of 76 years for males and 75 years for the females.

Hand Radiography

A standard hand X-ray can provide a useful estimate of cortical bone mass. The cortical width at the mid-point of the second metacarpal was measured using Vernier calipers and the value of the metacarpal cortical index (MCI) was calculated from the formula 

\[ D\frac{D^2 - d^2}{DL} \]

outside diameter, \( D \) the inside diameter and \( L \) the length of the bone[8].

Values for the MCI in the general population, based on measurements carried out by one of the authors (A.N.E.S.), were obtained from published figures[9,10].

Vitamin D Status

The London patients were given a detailed questionnaire on the intake of vitamin D-containing foods and vitamin D supplements. The results were used to calculate vitamin D intake from standard tables[11]. All patients were given a questionnaire on sunshine exposure, which was designed to give a score range of 0 to 30.

Iliac Crest Biopsy

Biopsy was carried out in 70 of the London fractured femur patients who underwent operation, and 50 specimens free from distortion of the bone architecture due to crushing were used in the final analysis. Control biopsies were obtained postmortem from an unselected group of 43 patients who had died from causes other than malignancy. The trabecular osteoid in the whole section was measured, using the Quantimet 720 image-analysing computer system, and the percentage trabecular osteoid area was calculated[6] using the formula:

\[ \frac{O}{O+B} \]

\( O = \) trabecular osteoid area; \( B = \) trabecular bone area.

Results

Falls (Fig. 1)

A history of falls during the preceding year was obtained from 41 per cent of the female control subjects and 21 per
percent of the male controls ($\chi^2 = 44$, $P < 0.001$, $\chi^2$ values corrected for continuity, $P$ value 2-tailed). There was a significant trend towards a higher incidence of falls with age in controls of both sexes ($\chi^2$ test for linear trend, $P < 0.05$). For those fracture cases aged over 65, 61 per cent of the 257 females and 41 per cent of the 53 males ($\chi^2 = 2.3$, N.S.) gave a history of falls in the previous year. The increase in the incidence of falls in the fracture cases was highly significant when compared with controls ($\chi^2 = 20$, $P < 0.001$, both sexes). For those subjects with a history of falls, female fracture cases tended to fall more often than controls ($\chi^2 = 9.9$, $P < 0.02$) whereas the fall frequency in the males was the same.

A detailed analysis of the relationship between fall frequency in the fractured femur patients and other variables was carried out. Significant associations were as follows: there was a three-way association between the inverse of the score on a mental status questionnaire (MSQ)[12], a history of falls and a history of taking daytime sedatives. For those patients with a low MSQ alone, daytime sedation was only weakly associated with falls, indicating that these two variables were principally correlated with mental status. There was no association between falls and a history of taking hypnotics. Falls were also significantly associated with poor physical state ($\chi^2 = 11.7$, $P < 0.001$) and with weak hand grip as measured by the Meridith dynamometer ($t$ test, $P < 0.05$) at the time of examination. No relationship was found between MCI and fall frequency.

**Vitamin D Status**

Of the 146 London patients 101 completed a detailed questionnaire on the intake of vitamin D-containing foods and vitamin D supplements. Forty-one per cent of the patients had intakes below the recommended minimum level of 100 IU/day, and 20 per cent took less than 50 IU/day. Answers to the questionnaire on sunshine exposure were obtained from 317 patients (mean age 78, range 50 to 100) and were compared with 41 controls (mean age 77, range 65 to 94). Sunlight exposure decreased significantly with increasing age in both groups. Patients aged under 75 had a mean score of 9.2, range 0 to 17, compared with 11.6, range 9 to 13, in the controls (Mann-Whitney U-Test, $P < 0.005$). For patients aged over 75 the mean scores were 6.8, range 0 to 13, compared with 8.1, range 0 to 13, for the controls (Mann-Whitney U-Test, $P < 0.05$).

**Metacarpal Cortical Bone**

The individual values for the MCI for fractured femur patients can be plotted on percentile ranking curves for the general population[9,10]. The regression of the mean MCI values against age are shown in Figs 2 and 3.

For female fracture patients the regression line lies between the 25th and 50th percentiles for the general population, and for male fracture patients between the 10th and 25th percentiles. ($t$ test showed no significant difference in the slopes of the regression lines.) In each sex the mean amount of bone in fractured femur cases is significantly less than that for the general population of similar age (for males $t = 6.3$, $P < 0.001$ and for females $t = 7.04$, $P < 0.001$). The absolute values of MCI in individual fractured femur cases can be expressed as percentiles of the values for the general population of corresponding ages, thereby eliminating the effect of age. The resultant frequency distributions are shown in Fig. 4.
The distributions are skewed towards the low p values, particularly in male patients.

Trabecular Osteoid Area

The mean proportion of iliac trabecular bone matrix area occupied by osteoid in a series of microscopic fields has been calculated. The values expressed as osteoid area percentages for fractured femur and control cases in each age group and in each sex are shown in Table 1.

Table 1 shows that the iliac trabecular osteoid area does not change with age in either the fractured femur or control series, but there is a significantly greater amount of osteoid in the fractured femur biopsy specimens than in those of the controls, particularly in the men. The mean osteoid area for the male fractured femur patients (5.60 per cent) was significantly higher (Mann-Whitney U-test, P<0.05) than that for female patients (2.54 per cent).

Inspection of the distribution of the trabecular osteoid areas in the control series shows an asymptotic curve tending towards zero cases at the 2.0 per cent trabecular osteoid level. This level of osteoid area was therefore
Table 1. Osteoid area percentages for fractured femur and controls grouped according to age and sex.

| Age Group and Sex | Fractured Femur | Controls | P*  |
|-------------------|----------------|----------|-----|
| Age               | %   | No. | %   | No. |       |
| 50-69 years       | 3.07 | 6  | 0.31 | 8   | 0.05   |
| 70-79 years       | 2.62 | 15 | 0.53 | 17  | NS     |
| 80-89 years       | 2.98 | 26 | 0.87 | 14  | NS     |
| 90-98 years       | 2.47 | 3  | 0.35 | 3   | NS     |

Sex

|        | Fractured Femur | Controls | P*  |
|--------|----------------|----------|-----|
| Males  | 5.60 | 7  | 0.71 | 24  | 0.002 |
| Females| 2.54 | 43 | 0.44 | 18  | 0.05  |
| All subjects | 2.96 | 50 | 0.59 | 42  | 0.004 |

*One-tailed Mann-Whitney U-Test

taken as the upper limit of normal. Of 7 male fractured femur patients, 5 had iliac crest biopsy, and 14 of 43 female patients had excessive osteoid according to this definition, and the differences compared with the numbers of controls were significant (Fisher’s exact test, P<0.01) for both males and females.

Metacarpal Cortical Bone and Trabecular Osteoid Area

Forty-one patients had measurements both of the MCI and of the percentage trabecular osteoid area in the iliac crest biopsy specimens. The MCI for each of the patients was calculated as a percentile of the values for the general population of corresponding age and sex.

The fractured femur patients with osteomalacia (trabecular osteoid area >2 per cent) had mean MCI percentile values of 45.8 for the males and 39.4 for the females; the corresponding values for patients without osteomalacia were 1.5 and 34.0. Thus, patients with osteomalacia tended to have higher MCI values for their age and sex although the differences were not quite significant (Mann-Whitney U-test, P<0.1).

Discussion

The frequency of falls increases with age and it is greater in the femoral neck fracture cases than in age-matched controls. The younger fractured femur cases have a high frequency of falls (see Fig. 1) and in these patients falls may make a relatively greater contribution to fracture than the bone factors, although even in patients of this age the amount of bone is significantly less and the trabecular osteoid area is significantly greater than in controls of similar age. The increased liability to fall in the fractured femur patients is in part due to associated pathology, especially in the central nervous system[3]. Patients with dementia have a higher incidence of falls compared with those who are mentally normal, as shown by the inverse linear correlation between the MSQ score and fall frequency. The prescription of daytime sedatives and tranquillisers for the control of restlessness and behaviour disorders in these patients adds a further increment to the frequency of falls. The type of fall leading to fracture changes with age[3]. Tripping is more common in younger patients, whereas loss of balance and drop attacks are more common with advancing age. Grip strength also falls with age and is lower in patients than in controls. Older patients may fall harder because of muscular weakness and diminished protective reactions which may partly be due to vitamin D deficiency and this, together with osteomalacia, could be prevented by simple dietary changes or by increased exposure to ultraviolet light. All these factors probably contribute to the high incidence of femoral neck fractures that has been reported in elderly patients in mental hospitals[13]. In general, however, the exponential increase with age in the femoral neck fracture rate cannot be attributed solely to a greater frequency of falling.

The quantity of cortical bone in the second metacarpal as measured by radiographic morphometry correlates well with the amount of bone in the proximal femur and at other sites[14,15]. In another study we have shown that the bone mineral ash content of the femoral head removed at operation from 57 patients with fracture of the femoral neck correlates significantly (r=0.45, P<0.001) with the MCI[16]. Thus, the MCI can be taken to be a reasonable indication of the amount of bone in the proximal femur.

Analysis of the data shown in Figs 2 and 3 shows that the mean MCI values for femoral neck fracture patients are significantly lower than those of the general population of corresponding age and sex. The reduction in the amount of bone in male fracture patients in relation to the controls is greater than in the females. This is clearly seen when the quantity of cortical bone for each fractured femur case is calculated as an MCI percentile in relation to the values for the general population of similar age (Fig. 4). The distribution of these MCI percentiles is skewed towards the lower values, particularly in male patients. Two-thirds of the male patients and slightly more than one-third of the female patients have MCI values below the 20th percentile for the general population. Osteoporosis can be considered to be an important factor in the pathogenesis of fracture in these cases. It will also be seen (see Figs 2 and 3) that at the age of 50 the mean value (0.092) for the MCI is similar in the two sexes. At this age, according to the data of Knowelden et al.[1], the incidence of fractures of the femoral neck is approximately the same in the male and female populations. After the age of 50 the decline in the mean MCI values with age in the fracture cases occurs at twice the rate in females compared with males; after this age the exponential increase with age in femoral neck fracture is also greater in the female sex.

Although osteoporosis is of major importance in the aetiology of this type of fracture, there are some individuals who sustain fractures with MCI values in the upper percentile ranges (see Fig. 4). It is difficult to interpret these findings on the basis of cross-sectional studies. It is possible that there has been a marked decline in the quantity of bone if their skeletal status was very good at maturity. We shall not know whether this is the explanation until we have information on the rate of bone loss derived from longitudinal studies. Such studies are also required to determine the cause of the greatly diminished bone quantity commonly found in fractured femur cases.

Osteomalacia is an additional factor in the pathogene-
sis of femoral neck fracture and there is evidence that it may play a more important role in those patients with relatively little osteoporosis. For the fracture series the mean trabecular osteoid area was significantly greater than that in the controls (see Table 1) and a significantly higher proportion of them had osteomalacia with an iliac trabecular osteoid area greater than 2.0 per cent. Nineteen of the 50 femoral neck fracture patients (38 per cent) from whom iliac crest biopsy specimens were obtained had osteomalacia, according to this definition. This incidence of osteomalacia in patients with fracture of the proximal femur is similar to that reported from Leeds by Aaron and her colleagues[5]. Examination of the relationship between osteomalacia and the quantity of cortical bone expressed as MCI percentiles indicates that patients whose iliac crest biopsy specimens show osteomalacia tend to have higher MCI values than fractured femur cases without osteomalacia. Thus, in patients with fracture of the femoral neck, there is a trend towards an inverse relationship between osteoporosis and osteomalacia; individuals who sustain fractures but have little or no osteoporosis may be more likely to have osteomalacia.

Acknowledgements

We are indebted to the DHSS for financial support and to Dr Hilary Summerfield for her help in collecting the data.

References

1. Knowelden, J., Buhr, A. J. and Dunbar, O. (1964) British Journal of Preventive and Social Medicine, 18, 130.
2. Clark, A. N. G. (1968) Gerontologia Clinica, 10, 257.
3. Brocklehurst, J. C., Exton-Smith, A. N., Lempert-Barrier, S. M., Hunt, L. P. and Palmer, M. K. (1978) Age and Ageing, 7, 7.
4. Jenkins, D. H. R., Roberts, J. G., Webster, D. and Williams, E. O. (1973) Journal of Bone and Joint Surgery, 556, 575.
5. Aaron, J. E., Gallagher, J. C., Anderson, J., Staia, L., Longton, E. B., Nordin, B. E. C. and Nicholson, M. (1974) Lancet, 2, 229.
6. Faccini, J. M., Exton-Smith, A. N. and Boyd, A. (1976) Lancet, 1, 1089.
7. Department of Health & Social Security (1981) Report of a Nutrition Survey of the Elderly. In preparation.
8. Exton-Smith, A. N., Millard, P. H., Payne, P. R. and Wheeler, E. F. (1969) Lancet, 2, 1133.
9. Exton-Smith, A. N., Millard, P. H., Payne, P. R. and Wheeler, E. F. (1969) Lancet, 2, 1154.
10. Gryfe, C. I., Exton-Smith, A. N., Payne, P. R. and Wheeler, E. F. (1971) Lancet, 1, 523.
11. McCance, R. A. and Widdowson, E. M. (1960) The composition of foods. 3rd edn. (ed. A. A. Paul and D. A. T. Southgate.) London: HMSO.
12. Denham, M. J. and Jefferys, P. M. (1972) Modern Geriatrics, 2, 275.
13. Leitch, J. H., Knowelden, J. and Seddon, H. J. (1964) British Journal of Preventive and Social Medicine, 18, 142.
14. Dequeker, J., Remans, J., Fransens, R. and Waes, J. (1971) Calcified Tissue Research, 7, 23.
15. Dequeker, J., Franssens, R. and Borremans, A. (1971) Clinical Radiology, 22, 74.
16. Stewart et al. (1981) In preparation.

Dedicated to the Queen

The timing of the publication of the first book in English on obstetrics in 1540 may well be significant. The death in childbirth of Queen Jane Seymour in 1537 would have drawn attention very sharply (if that were necessary) to the perils of parturition; and surgeons and midwives would have been led to seek a more trustworthy guide than those commonly known and in use. When Henry VIII married Anne of Cleves in 1540, it is conceivable that the work was to have been dedicated to her. The Byrth of Mankynde was a translation from the Latin of a book originally published in German in 1513—namely Eucharius Rösslin’s Der schwangeren Frauen und Hebammen Rosengarte—a book well-known in Germany and one which was dedicated to Princess Katherine of Saxony; it had been translated into Dutch, French, and Czech as well as into Latin. The identity of Richard Jonas, the translator, invites speculation. Justus Jonas of Wittenberg was a distinguished disciple of Luther, and Anne of Cleves was a sister-in-law of the Elector Frederick of Saxony, and had other family ties with the Lutheran princes of Germany. Could Richard have been related to Justus, and could he have come over from Germany in the train of Anne of Cleves? Be that as it may, Henry divorced Anne after only a few months and in July 1540 married Katherine Howard, and so it was she to whom the book was dedicated when it appeared. In his address to ‘the most excellent virtuous Lady Queen Katherine’ Jonas wrote: ‘For considering the manifold daily and imminent dangers and perils, the which all manner of women of what estate or degree so ever they be in their labour do sustain and abide . . . I thought it should be a very charitable and laudable deed, yea and thankfully to be accepted of all honourable and other honest matrons if this little treatise so fruitful and profitable for the same purpose were made English . . . I have done my simple endeavour for the love of all womanhood, and chiefly for the most bound service which I owe unto your most gracious highness.’

Apart from its subject matter, there are several bibliographical features worthy of comment. When it first appeared The Byrth of Mankynde was printed by T. R. who has been identified as Thomas Ray or Thomas Raynalde. He had a shop in St Paul’s Churchyard, and various works were issued from his press between 1540 and 1555. The second edition in 1545 was revised and considerably added to by Thomas Raynalde, physician, and thereafter the work was known by his name. There is nothing to connect him with the printer of the same name, since he tells us that he practised in London and Paris and visited Venice and Padua. Now one Thomas