Osteoporosis and bone densitometry: an overview

Osteoporosis is a major problem in healthcare and the role of bone densitometry in the assessment and measurement of this metabolic bone disease is being recognised. **Professor Sobhan Vinjamuri** and **Dr Robert Higgins** discuss the merits and pitfalls of bone densitometry reporting as well as the impact osteoporosis and its management is having on the NHS, and speculate on what lies in the future for assessment and monitoring.

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Over the past decade, osteoporotic fractures have become recognised as one of the most serious problems in public health. For a 50-year-old Caucasian woman, the lifetime risk of suffering a fragility fracture of the spine, hip, or forearm is estimated to be 30-40 per cent (which compares with the percentages of breast cancer and cardiovascular disease of nine to 12 per cent and 30-40 per cent, respectively). For men, the risk of an osteoporotic fracture is about one-third of that in women. The effects of osteoporosis not only include minimal trauma fractures of the spine, hip or wrist, but also deformities such as kyphosis or abdominal protrusion. It is estimated that three million people in the UK suffer from osteoporosis and it accounts for 300,000 fractures each year. It costs the NHS an estimated £1.7bn per year[1-4].

The increased recognition of the scale of morbidity and mortality attributed to osteoporosis has led to the development of new therapeutic strategies for the prevention of fractures by the pharmaceutical industry such as hormone replacement therapy (HRT) and bisphosphonates. Associated with this growing awareness and development of treatments for its prevention has been the evolution of radiological techniques for the non-invasive assessment of skeletal integrity[1]. Prior to the 1960s bone mineral density (BMD) assessment to predict the risk of osteoporosis was based upon plain radiographs. However, radiographs are an insensitive method to accurately quantify BMD changes and require a 30-50 per cent loss of BMD before changes become apparent. Due to the limitations of plain radiographs to assess BMD, specialised measurement equipment was developed to accurately assess and measure BMD. The best known technique for measuring bone density is dual energy x-ray absorptiometry (DXA) scanning[1].

Bone densitometry and osteoporosis measurement

The internationally agreed definition of osteoporosis is 'a progressive systemic disease

characterised by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture'. DXA scanning of the hip and lumbar spine, according to the World Health Organisation (WHO) is considered to be the 'gold standard' for assessing a patients' bone density status. DXA measurements of the spine and proximal femur have been shown to have a high precision, which makes it particularly effective in follow-up measurements, and is the most widely used technique for assessing bone density[5].

When the BMD is measured by DXA, the results are quoted in g/cm2 of calcium in the skeleton, this can then be statistically compared with a group of normal, young adults (T-Score) and to an age, weight and ethnically matched group (Z-Score). These scores are then used to indicate (or exclude) osteoporosis in the patient[6]. The WHO defines these scores as:

- Normal: T-Score >-1 standard deviation (SD)
- Osteopenia: -2.5SD< T-Score <1SD
- Osteoporosis: T-Score<-2.5 SD
- Severe osteoporosis: T-Score <-2.5SD with fragility fracture/s.

The T-score is calculated by taking the difference between a patient's measured BMD and the mean BMD of healthy young adults, matched for gender and ethnic group, and expressing the difference relative to the young adult population SD. Therefore, a T-score result indicates the difference between the patients' BMD and the ideal peak bone mass achieved by a young adult. In addition to the T-score, the Z-score is another useful way of expressing a patient's BMD. Like the T-score, the Z-score is expressed in units of the population SD. However, instead of comparing the patient's BMD with the young adult mean, it is compared with the mean expected for the patients' peers. Although the Z-score is not as widely used as T-scores, they remain a useful concept because they express the patient's risk of sustaining an osteoporotic fracture relative to his or her peers[1].

DXA is not only effective in identifying patients at risk of osteoporotic fractures, but is particularly effective in follow-up examinations due to its high precision. DXA can be used in the sequential examination of patients being treated for osteoporosis or those at increased risk due to factors such as medication or amenorrhoea[5].

The design of DXA scanners has become increasingly complex, with the use of fan-beam rather than pencil-beam technology[5]. Fan-beam technology DXA scanners use a fan-beam of x-rays and multiple detectors to acquire the scan in a series of steps. Pencil-beam technology DXA scanners use only a single narrow (pencil-beam) of x-rays with a single detector, which acquires the scan in rectilinear motion. Fan-beam DXA scanners have much shorter scan times (30 sec per scan) compared to pencil-beam scanners (10 min per scan), which permits more rapid scanning (and therefore higher patient throughput) at the expense of a small increase in radiation exposure.

Bone densitometry reporting

The reporting of DXA scans can be undertaken by a range of different medical staff including radiologists, radiographers, medical physicists and clinical nurse specialists. There are four types of report that can be issued depending on knowledge and expertise and these include[6]:

- No report: BMD values quoted in g/cm2 and a statement that the result is average or below average for age
- Technical: issue BMD value in g/cm2 and provide a reference graph with the patients' BMD shown by an asterisk (this can be confusing if no interpretation is available)
- Clinical: a clinical report where BMD is quoted and related to a T-score; Z-score is shown and reference curve and results are categorised as WHO criteria dictates
- Informed: provide an individual report taking into account the results, the patient's risk factors, both T and Z scores. It makes a note of any abnormal anatomy and any excluded vertebrae. The report should then explain the need for treatment, and if the reporter is competent to do so, treatment options should be outlined.

However, it should be borne in mind that it would be inappropriate to report, without a caveat, T-scores in persons not at an age in which peak bone mass might be reached (age 18 in girls and age 20 in boys) or in non-white persons. While T-scores might be corrected for men, it is not certain if the negative T scores have the same predictive power for identifying fracture risk as in women[5]. It has also been suggested that there is a need for a more defined system of interpretation rather than just T-scores as defined by WHO, as many women over the age of 80 will have a T-score <2.5, but will not necessarily succumb to an osteoporotic fracture[6].

It should also be noted that there are a number of confounding variables, which can artefactually increase BMD. These include the presence of osteophytes, aortic calcifications and degenerative disc disease of the lumbar spine region. These variables are important to consider especially in elderly patients, as DXA measures the calcific density projected in the area of interest defined by the software (or by the operator). Similarly, fractures reduce the projected area of a vertebra and may result in an apparent increase in density. By carefully examining the individual vertebral levels, it is possible to identify density measurements that may be artefactually increased due to fracture.

There is usually a small but steady increase in density moving distally from L1 to L4. A measurement out of step with this can be eliminated[5]. Another confounding factor is the consistency of reproducibility of scans. Changes in BMD over time are small, therefore any changes due to the precision of the scanner and operator need to be kept as low as possible to allow confidence in the accuracy of any follow-up scans. The previous scans should be used as a template to ensure consistent analysis and positioning of the regions of interest[6]. Other artifacts to be aware of include zips on patient clothing, body piercing (particularly navel rings) on the lumbar spine scan and plastic materials such as credit cards in trouser pockets on the femur scan.

The images on a DXA report have a note indicating that the images are not for diagnosis. Nonetheless, recognition of and reference to positioning errors or artifacts in the report and the choice of regions of interest (vertebrae analysed) can help to improve the quality of a DXA study. It should also be noted that the fewer the vertebrae analysed, the greater the potential for errors in accuracy and precision; therefore, any diagnostic inference based on one or two vertebral segments is not advised. Referring clinicians should also be made aware of the limitations of BMD in obese patients, as BMD measured with DXA positively correlates with total body mass. A DXA measurement of the spine will be underestimated if the amount of fat overlying the spinal column is greater than that on either side of the lumbar spine[5].

Osteoporosis and the NHS

As stated earlier, around three million people suffer from osteoporosis and its complications, costing around 1.7bn to treat the resulting fractures each year. This therefore has a major cost and resource implications to the NHS[7,8].

In 2004, an All Party Parliamentary Osteoporosis Group study identified that there was a lack of priority, and even understanding, among healthcare providers of osteoporotic patients. It found that many PCTs had made progress with initiatives to prevent falls, but not in the treatment and prevention of osteoporosis. The National Osteoporosis Society (NOS) and National Service Framework (NSF) voiced their concerns that the NHS was failing to meet the needs of patients with osteoporosis and that until the NHS started to act these patients would continue to fracture bones needlessly[8].

The Department of Health responded to this criticism in 2005, by announcing an investment of £10m by the government to improve the amount of scanning equipment and service improvements in the NHS. Of this investment, £3m was used in 2005 to increase NHS capacity to provide a key diagnostic service, with the remaining £7m to be made available over three years to bolster NHS capacity to help improve access and reduce waiting times for diagnostic scans and treatment. The National Institute for Health and Clinical Excellence (NICE) has also issued clinical guidelines for the NHS in England and Wales for the targeted prevention, assessment and treatment of osteoporosis, in association with the NOS and NSF to identify areas where DXA scanners were needed and to establish a programme of action and reforms to address the problem of osteoporosis within the elderly to enable high quality services to be delivered to this group of patients[9].

Discussion

Osteoporosis was not recognised as a disease by WHO until 1994, after which there has been a major effort by governments and healthcare providers to assess the impact of osteoporosis in society[10]. Greater awareness of the morbidity and mortality associated with osteoporosis has also led to a large number of international clinical trials to develop effective new treatments for the prevention of osteoporosis. Along with these developments, the need for the rapid technological development of equipment to assess a patients' bone density status non-invasively has led to the rapid innovation of bone densitometry equipment[1,2].

Key points

- Osteoporosis has become recognised as one of the most serious problems in public health in the UK and accounts for approximately 300,000 fractures per year.
- DXA is the best known technique for the identification and assessment of patients at risk of sustaining osteoporotic fractures.
- When reporting DXA scans, there are a number of potential pitfalls, which may artefactually affect the results; these include fractures in the lumbar spine or metal zips on patient clothing.
- Greater awareness of the morbidity and mortality associated with osteoporotic fractures has led to the introduction of guidelines and Government investment to increase the amount of DXA scanners and improve services within the NHS.

References

1. Fogelman I, Blake GM. Different approaches to bone densitometry. *Journal of Nuclear Medicine* 2000; **41**(12): 2015–25
2. Blake GM, Gluer CC, Fogelman I. Bone densitometry: current and future prospects. *Br J Radiol* 1997; **70**: S177-S186
3. Anonymous. Consensus development conference. Diagnosis, prophylaxis and treatment of osteoporosis. *Am J Med* 1991;**90**: 170–210
4. Kanis JA, Delmas P, Burckardt P, *et al*. Guidelines for diagnosis and management of osteoporosis. *Osteoporosis Int* 1997; **7**: 390–406
5. Lentle BC, Prior JC. Osteoporosis: what a clinician expects to learn from a patients's bone density examination. *Radiology* 2003; **228**: 620–28
6. Barlow S. The diversity of reporting methods in bone densitometry. *Synergy* 2007; : 18–20
7. National Institute for Clinical Excellence. Osteoporosis: assessment of fracture risk and the prevention of fracture risk. 2002. London
8. BBC News. NHS not geared for osteoporosis. 2004. Available from http://news.bbc.co.uk/. Accessed 21 April 2007
9. Department of Health. Press release: £20m investment in osteoporosis services. 2005. Available from http://www.dh.gov.uk/en. Accessed 21st April 2007
10. Kermani F. Osteoporosis: the silent threat. 2004. Available from http://www.touchbriefings.com. Accessed 21st April 2007
11. Compston J. Guidelines for the management of osteoporosis: the present and future. *Osteoporosis International* 2005; June: 1173–76

The interpretation of DXA scans is not difficult, but there are number of factors, which have been described earlier, that should be borne in mind when reporting scans, such as the artefactual effect on the BMD result by fractures or zips on a patient's clothing[5]. Once a patient has been diagnosed with a high risk of fracture, a treatment and management pathway needs to be identified and in some cases (GP referrals, for example) investigation by means of a blood bone profile may be suggested to ensure that the bone loss is not secondary to any underlying secondary conditions such as hyperparathyroidism[6].

For the immediate future, it is thought to be desirable that if a patients' fracture risk estimation is to be made, that this should be based on patient history and any physical, radiological and biochemical examination results, which are then synthesised into a comprehensive index of risk. This index can then used to deduce the magnitude of fracture risk and serve as guide to advising the patient about life style modification or treatment interventions if necessary[5].

Evidence-based guidelines issued by NICE and other organisations such as the NOS are increasingly being used in the management and diagnosis of osteoporosis. These have the potential to produce uniformity and high standards of care across a range of sectors within the NHS[11].

However, demand on hospital-based osteoporosis clinics is set to increase and there is doubt as to whether the NHS healthcare centres equipped with DXA equipment can meet this demand. The alternative is heel measurements by quantitative ultrasound (QUS) technology.

QUS is a cheap, portable, radiation-free method to assess bone density. Its use in the elderly to predict hip fracture risk has been proven (although there are still doubts of how to interpret the results in younger women). At the present time, most experts do not advocate mass screening of the population for osteoporosis, and instead guidelines recommend a case finding strategy that is based upon identifying patients with generally accepted clinical risk factors[1,2].

Conclusion

Advances in healthcare management in the NHS are likely to focus on improving the diagnostic process and pathway for conditions such as osteoporosis. Professionals looking after an increasingly older and more morbid elderly population should be aware of the implications of doing a bone densitometry scan and the range and scope of interpretation of these tests to guide further management.

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