Contribution of Dual-Energy X-Ray Absorptiometry in Paediatrics, and Suggestions for the Analysis of the Exams

PM. Braillon* Phd, MD

Dept of Imaging, HFME, BD Pinel, 69677 Bron cedex (France)

*Corresponding Author: PM. Braillon, PhD, MD, Dept of Imaging, HFME, BD Pinel, 69677 Bron cedex (France).

The development of X-ray absorptiometry (DXA) has been an important contribution to quantitative radiological exploration of the spine and hip [1]. A second important step was the use of this new technique to make total-body measurements of the entire skeleton and soft tissues [2]. In more recent years, with the evolution of computers, whole body exams can be done fast enough to be used in Paediatrics, and DXA is now a very useful tool for monitoring growth as well as treatment in almost all paediatric specialties. The technique is indeed very reproducible. Moreover, the radiation dose delivered to the patient is low [3]. However, there are two aspects to consider: the reference values to be used to interpret the results and the possible differences in these values between devices of different brands or series. The most common reference values are generally given according to age. However, in children and adolescents significant differences in morphology can be seen at the same age. It is therefore better to refer to the size (H) and/or weight (W) of the patient to analyze the exams. To best solve the second point, phantom measurements are usually done. However, it is necessary to use phantoms whose shape and distribution of X-ray absorbing materials are as close as possible to anatomical reality [4].

We give here other correlations, unpublished for most of them, that can be useful in the analysis of lumbar spine, hip and whole body examinations.

Main Results

Lumbar spine

Fitting curves for spine bone mineral density (BMD) against age have the shape of growth curves [5]. Expressed against patient's height (H), spine BMD values are more accurately fitted by exponential curves in both sexes ($r^2 > 0.9$). Moreover the curve equations are easy to introduce in a computer table. The height (h) of the lumbar vertebrae is linearly correlated to H ($r^2 > 0.9$), as expected, while the projected surface area (A) of the lumbar vertebrae is better represented by exponential correlations ($r^2 > 0.9$). These two results could be of interest to follow particular bone diseases such as osteogenesis imperfecta.

Hip

In previous studies [6], it was found that the projected diameter (D) of the femoral neck was linearly correlated with H ($r^2 > 0.8$). The neck BMD was also linearly correlated with H ($r = 0.6$), but a better correlation was obtained by using power relationship against W ($r^2 > 0.6$). Finally, in controls a nice linear correlation was found between hip and spine BMD ($r^2 > 0.9$).

Whole body bone mineral content (BMCt) and body composition in lean tissue and fat masses (LTMt and FMt)

In the exploration of normal growth, we have shown that the BMC of the entire skeleton and limbs, as well as their lean mass and fat masses, were linearly correlated with the body weight of the control subjects [7]. These results were used to analyze data in overweight children and adolescents with mean weight higher than their ideal weight for height by more than 50% [8]. It was found that BMCt values were augmented by approximately 10% in both sexes while LTMt values were higher than normal values by 23% in females and

15% in males, and FMt values were close to 2.2 and 2.6 times the normal values, respectively. In this population the mean body weights that would be in accord with the measured BMCt values were less the actual weights by 22% in females and 24% in males [7,9].

Using H as variable parameter rather than W is another approach which leads again to high exponential correlations between BMCt, LTMt and FMt, and H values ($r^2 > 0.9$).

In neonates and infants weighing less than 12 kg the simplest solution is to use W as variable. This way, linear correlations between BMCt, LTMt, FMt and W can be used (Table 1).

BMCt	0.035 * W - 132
LTMt	0.767 * W - 120
FMt	W – BMCt - LTMt
BMCh	0.020 * W - 73

Table 1: Whole body results in neonates and infants (age < 24 mo) – Both sexes.

Hologic Discovery DXA system - Body weight (W), head BMC (BMCh), total bone mineral content (BMCt), lean tissue mass (LTMt), and fat mass (FMt) in grams – $r^2 > 0.9$.

Other DXA applications in paediatrics

The DXA technique can be useful in many paediatric specialties. For example, in the surgical correction of bone length discrepancy in a member, DXA allows a precise assessment of the amount of reconstructed bone in the distraction zone. This is of help to define the best time to remove the external fixer device (Ilizarov or Orthofix devices) with a low risk of fracture [10] (Figure 1).
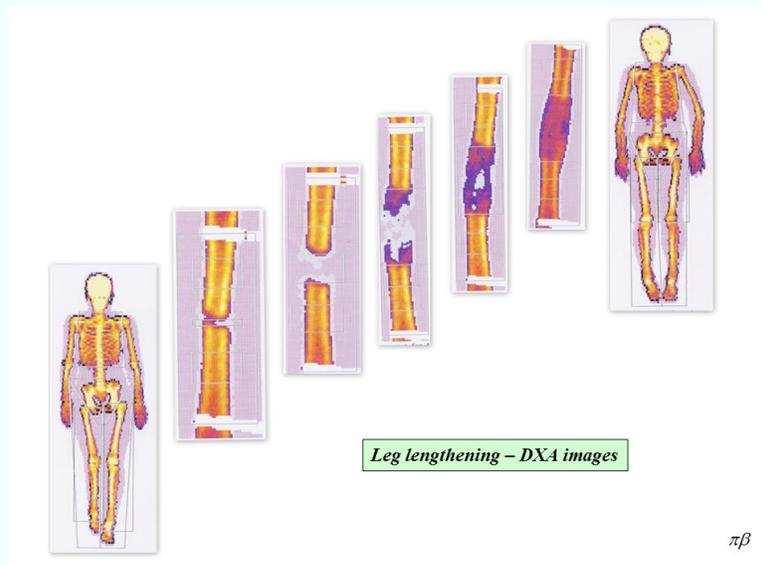

Leg lengthening – DXA images

πβ

Figure 1: Correction of a 7.5 cm femur length discrepancy in a 15 year-old girl (study performed on a Norland XR36 DXA system). The last image corresponded to 145 days of consolidation since the end of lengthening. At this point, the bone filling was close to 90%, a value that allowed the removal of the fixation device with a very low risk of fracture (surgical procedure: Pr J. Berard and Pr F. Chotel).

Another interesting application is the assessment of child's bone maturation from the measurement of the bone surface area of the hand. In this procedure which can be limited to the scanning of the wrist, the projected bone surface area of the carpal bones, corrected for the patient's height, is highly correlated with the so-called "bone age" defined by other usual methods such as the Greulich and Pyle one [11] (Figure 2). These DXA results are not operator dependent. Also another advantage would be the insertion of the program files in the DXA system software for an automated bone maturation calculation.
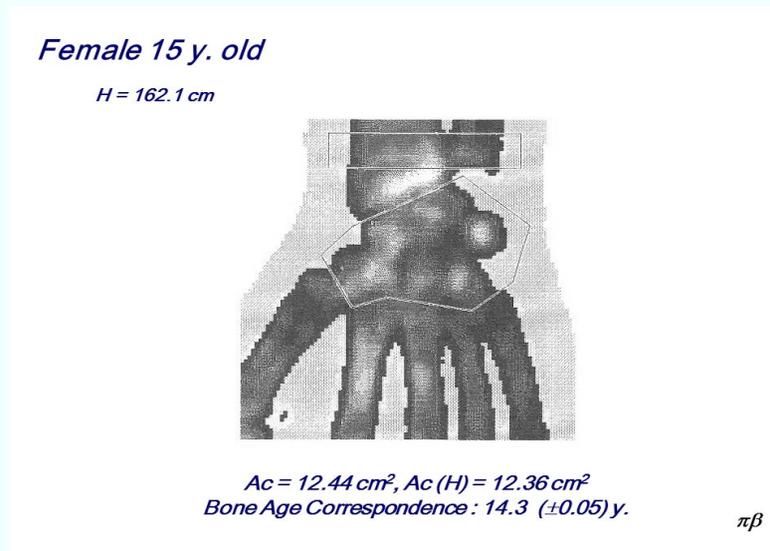

Figure 2: Measurement of the carpal bone surface area (Ac), and its corrected value for height (Ac (H)) in a girl of chronological age 15 years (Norland XR36 system). The bone age correspondence is obtained by using linear correlations established between bone maturation assessed by the method of Greulich and Pyle, and Ac (H). The standard deviation given was calculated from multiple measurements performed by two operators.

The follow-up of algodystrophy (Sudeck disease) is a third non-classical application of DXA. In this long healing and painful disease the patient is anxious, and reassured when she/he can see that her/his unhealthy bone BMC is increasing (Figure 3).
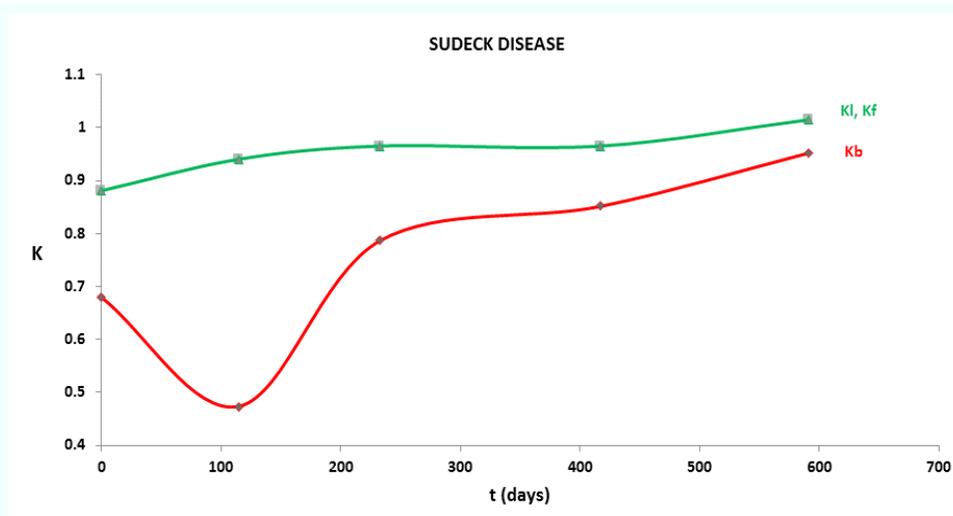

Figure 3: Algodystrophy of the left ankle in a girl (10-years and 8 month - old on first visit - t = 0).

K = ratio of the DXA value found in the traumatic member over the corresponding value measured in the healthy member

(K_b , K_l and Kf stand for the ratios of bone mineral contents, lean tissue masses, and fat masses, respectively).

While Kl and Kf remained close to 1, Kb reached a minimum value of less than 0.5 at about 4 months after the beginning of the disease and took about 20 months to regain a level of 0.95.

Conclusion

DXA is an excellent quantitative method that is now frequently used in pediatrics. This is not only a technique to assess the bone mineral content and density of the spine or hip and total body as well as the body composition in lean tissue mass and fat mass. It is also a versatile tool to study specific zones of the members or other parts of the skeleton. Adding its low level of radiation dose, and excellent precision make DXA a technique of interest in most pediatrics specialties.

Bibliography

1. Kelly TL., *et al.* "Quantitative digital radiography versus dual-photon absorptiometry of the lumbar spine". *Journal of Clinical Endocrinology and Metabolism* 67.4 (1988): 839-844.

2. Mazess RB., *et al.* "Dual energy X-Ray absorptiometry for total-body and regional bone mineral and soft tissue composition". *American Journal of Clinical Nutrition* 51.6 (1990): 1106-1112.

3. Njeh CF., *et al.* "Radiation dose and in vitro precision in paediatric bone mineral density measurement using dual energy X-Ray absorptiometry". *British Journal of Radiology* 70.835 (1997): 719-727.

4. Braillon PM. "Cross-calibration of dual energy X-Ray absorptiometry systems with a new anthropomorphic whole body phantom". RSNA annual meeting, Chicago IL (2007).

5. Glastre C., *et al.* "Measurement of bone mineral content of the lumbar spine by dual energy X-Ray absorptiometry in normal children: correlations with growth parameters". *Journal of Clinical Endocrinology and Metabolism* 70.5 (1990): 1330-1333.

6. Braillon P. "Femoral neck diameter and bone mineral density in youths and young adults: a new approach". RSNA annual meeting, Chicago IL (2005).

7. Braillon PM., *et al.* "Contenu minéral osseux et composition corporelle au cours de la croissance : quantification par absorptiométrie à rayons X". *Journal de Radiologie* 83.5 (2002): 627-633.

8. Braillon PM and Serban A. "Bone mineral content and body composition in overweight children and adolescents". *Pediatric Research* 62.4 (2007): 462-467.

9. Braillon PM and Pracros-Deffrenne P. «Whole-body dual energy X-ray absorptiometry in overweight and obese youths. Most useful results in clinical practice". RSNA annual meeting, Chicago IL (2011).

10. Braillon PM., *et al.* "Limb lengthening by Ilizarov or Orthofix techniques. Contribution of dual energy X-ray absorptiometry". RSNA annual meeting, Chicago IL (2007).

11. Braillon P., *et al.* "Bone age and projected surface area of the carpal bones". *Pediatric Radiology* 32 (2002): S1.