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<원저>

Quantitative Analysis of Bone Mineral Measurements in Different Types of Dual-energy Absorptiometry Systems: Comparison of CT vs DEXA

- 이중 에너지 조사 방식의 장비별 골밀도 측정의 정량적 비교 분석: CT vs DEXA 비교 -

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— Abstract —

Generally assessing bone mineral density (BMD) were performed on dual energy X-ray absorptiometry (DEXA) the same as dual energy CT (DECT) with a rapid-kVp switching. The purpose of this study is to compare the different of BMD value between DEXA and DECT method, and evaluate usefulness of DECT method. Using scanner for BMD measurements were GE, Healthcare Discovery 750 HD for DECT and Hologic QDR 4500W for DEXA. For compare BMD value in each method, scanned lumbar spine phantom and subjects visiting Korean National Cancer Center from April 2015 to December 2015, records of 50 patients. This study was approved by the Institutional Review Board. The mean BMD value measures for spine phantom and for subjects in each scanners presented strong correlation (r=0.948 with $p<0.05$ for phantom; r=0.635 with $p<0.05$ and Kendall's tau (τ)=0.46 with $p<0.05$ for subjects) and linear relationship between DECT and conventional DEXA. DECT technique for BMD measurement will provide a very useful methodology without additional radiation dose.

Key Words: DEXA, CT, BMD, DECT, osteoporosis

Ⅰ. INTRODUCTION

Since implemented in the late 1970s, CT (computed tomography) scanner has rapidly developed with higher rates of clinical use[1]. CT scanner has developed from detector to recently varied X-ray energy system. Dual energy CT (DECT) allows simultaneous obtained data from two different energies without imposed by the polychromatic energy spectrum of single-tube X-ray[2]. DECT systems have integrated two X-ray source-detector aggregates into one rotating gantry, using dual 80 and 140 kVp energies. DECT system has two types to make DECT images at different energies [2]. One is dual-source CT scanner used in equipped with sets of two different X-ray energy (80 and 140 kVp) and two corresponding detector pairs. Another uses a single X-ray tube (rapid kVp switching 80 kVp to 140 kVp) to make DECT images.

Generally to measured properties of bone mineral density (BMD) in medical fields, assessed by dual-energy X-ray absorptiometry (DEXA), which evaluation of the density in terms of bone mineral (Hydroxyapatite;

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HAp) used as marker for bone health[3]. DECT systems could decompose the information from each scanned voxel into the intensity of two defined materials due to using two different kVp energy level that is materials decomposition (MD)[3–5].

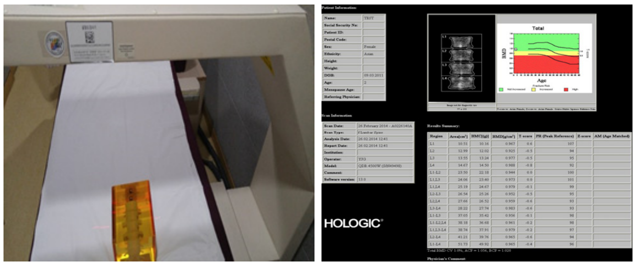
There are a few studies that have been published on measuring BMD using DECT[4,5]. Therefore the aim of this study was to compare the different of BMD value that conventional DEXA and the using in rapid kVp switching a dual energy CT technique and assess the feasibility of measuring BMD by DECT technique as new technique.

Ⅱ. MATERIALS AND METHODS

1. Equipment

Measurements of BMD in the baseline study were performed on Hologic anthropomorphic lumbar(L)–spine phantom (calibration phantom), to know absolute evaluation of BMD value between a fan beam QDR 4500W bone densitometer (Hologic, Waltham, MA) as conventional (Fig. 1(a)) and DECT equipped with a source that can fast kV–switching (GE, Healthcare Discovery 750 HD) method. Fast kV–switching scanning with dual energy method is used to same acquire method in both scanners, except for using X–ray energy level (DEXA scanning is switching between 100 and 140 kVp). DECT (80 and 140 kVp) data were acquired with the GSI–36 preset protocol (Large body bowtie filter; rotation time, 0.8 sec; beam width, 40mm; helical pitch, 0.984) (Fig. 2(a)). The phantom was scanned while placed horizontally on each top of the table of scanner (Fig. 1(a)). To minimize the measurement error, BMD values measures for spine phantom both scanners were repeated 3 times. The average of the each measurement was calculated to yield on value. The DEXA scanner was calibrated daily for validity.

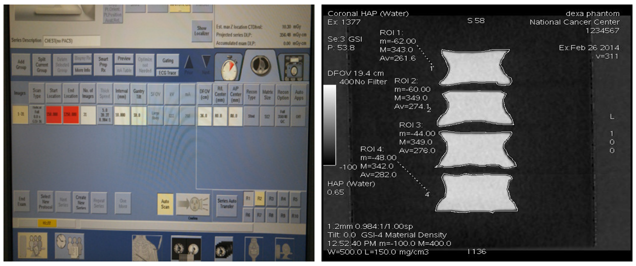
In subjects, compare the different BMD value depending on evaluation of BMD scanners and from April 2015 to December 2015, records of 50 patients



(a) (b)

Fig. 1 Scanning lumbar spine phantom for BMD value and result in DEXA scanner

(a) L-spine phantom was scanned on the table of DEXA scanner, (b) Report of BMD after DEXA scanned



(a) (b)

Fig. 2 Scanning monitor and evaluation for BMD value in DECT scanner

(a) Scanning parameter in DECT scanner, (b) Measuring BMD using AW workstation

(28 men and 22 women, age range 38–68, mean age 55.6 years) visiting Korean National Cancer Center. In subjects, measurements of BMD were performed on only lumbar spine because subjects received an additional CT radiation dose. That is subjects were CT scanned that match the subjects' visiting NCC goal, but additional not performed CT scan for this study. That reason excludes neck of femur.

All subjects underwent were scanned using both scanners (DEXA and DECT) to evaluate the BMD, which measurements of BMD on lumbar spine (first to fourth lumbar vertebra) in total subjects. Each scanners scanned within one month and does not one month difference from each measurements method. And it was not used contrast medium when CT scanned with patients to reduce the influence the BMD value. Scanned DECT images were monochromatic images from Gemstone Spectral Imaging (GSI) reconstruction, base MD were made choosing HAp and water as the base materials. HAp is the most biocompatible material and the most suitable. The results of measured conventional DEXA images were automatically displayed after scan (Fig. 1(b) but the DECT BMD value was performed using a commercially available system (Advantage Windows [AW] workstation 4.6, GE Healthcare, USA) after DECT images were transferred to AW system.

The evaluation of DECT images were using GSI Viewer in AW system with ROI (region of interest) drawn fitted for outer line of coronal cross-section of the mid line vertebral body, respectively (Fig. 2(b)).

This study was approved by the Institutional Review Board (NCC2014-0124) of the National Cancer Center.

2. Statistical Analysis

BMD measurements value obtained from DECT (phantom and subjects) were compared with conventional DEXA method to know a value using linear regression model, and their Pearson correlation coefficient was computed. Statistically a paired t test between measurements from DECT and conventional DEXA, and a p value of 0.05 was considered to indicate a significant difference. A Bland-Altman plot was applied to assess the average difference between the two scanners. All statistical analysis was carried out using IBM SPSS.

Ⅲ. RESULTS

Table 1 contains both descriptive data for the included number of population and the mean of age and body mass index (BMI) for all subjects. There were 28 male and 22 female subjects who had mean age of 50.2 years and mean BMI of 25.8 kg/㎡.

The average of BMD value for spine phantom with DECT and DEXA method is summarized in Table 2. All the mean BMD value measures for spine phantom both scanners (DECT and DEXA) demonstrated strong correlation with statistically significant (r=0.93, $p<0.05$), as shown in Table 2.

Also in subjects, results of correlation was show strong with statistically significant (r=0.635, $p<0.05$) (Table 3). Kendall's tau (τ) correlation coefficient were computed to measure the correlation of the continuous DEXA with DECT for BMD value, and the results point to each scanners with statistically significant tau (τ) values at 0.46, $p<0.05$ (Table 3). The linear relationship and coefficient of slope for mean BMD value between DECT and DEXA scanners are presented linearly correlated (Fig. 3). Equation for regression is y=1.252x + 120.25.

Table 1 Descriptive data of the included subjections and the mean age and BMI

Subject group	Age (y), mean±S.D	BMI (kg/㎡), mean±S.D
All (*N*=50)	50.2±13.5	25.8±6.4
Male (*N*=28)	50.9±12.8	25.3±6.2
Female (*N*=22)	49.2±14.3	26.5±6.6

Table 2 Mean BMD value comparison for L-spine phantom in two different scanners

L-spine number	DEXA (g/㎤), mean±S.D	DECT HAP(water)(g/㎤), mean±S.D
L1	97.1±3.9	25.9±5.6
L2	97.8±3.8	27.1±5.2
L3	98.1±.4.1	27.8±5.4
L4	98.3±4.2	28.4±5.7

r: 0.93, $P<0.05$

Table 3 Mean BMD value comparison for human in two different scanners

L-spine number	DEXA (g/㎤)	DECT HAP(water) (g/㎤)
L1	78.5	20.2
L2	85.8	21.9
L3	89.1	23.0
L4	92.8	24.6

r: 0.635, $P<0.05$; tau (τ): 0.46, $P<0.05$

Ⅳ. DISCUSSION

Our study indicates that the quantitative BMD values of DECT images were well correlated and

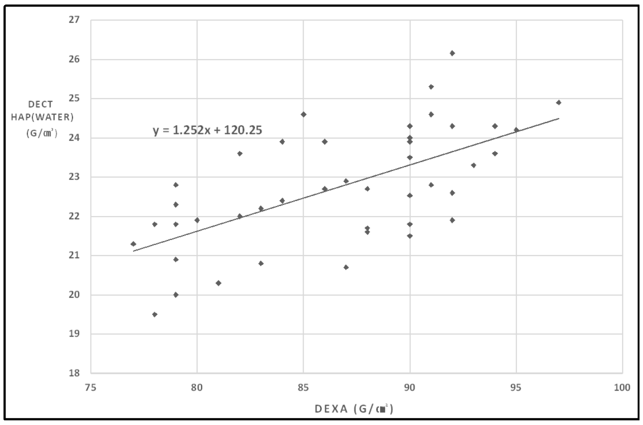


Fig. 3 Linear regression of DECT with DEXA

positive linearly with DEXA BMD values. Although there are systematic differences and inconsistencies in unit value between DECT and DEXA scanner[5], our results presented linear equations that can be used as conversion equations.

The application of BMD value from conventional DEXA is a method for fast kVp switching dual energy, which also approach to DECT material density is the same method based on GSI[4,6].

DECT has the potential to acquire different materials from two different energy level scans even when they have identical attenuation in a single kVp energy scan[5,6].

DEXA have several points to related drawbacks that considered as the following lists. DEXA is the estimates only area of density (2D) due to method for measured the BMD based on the attenuation expose simple one way X–ray through the body. That reason it is able to inappropriate estimate in cases differences in related growth of bone size in young people and degenerative changes that have a variation of densities in local area[7,8]. On the other hand DECT is measure the BMD based on the tissue volume, which cross section as it passes through the body. Thus DECT were considered as useful technique for evaluation of BMD, especially in local area[7–9].

Recent technological advances in radiology fields have markedly promoted the clinical applications so that concerning awareness level of radiation dose and possible radiation risks related diagnostic radiology examination. However the advantage of DECT measurement is that it is possible to use BMD measurement analysis while CT scan for patient's own study, without an additional radiation dose[5]. Another advantage in addition to DECT measurement is more flexible regarding CT scan images. On the other hand, DEXA is can only evaluate for BMD value in body part of L1~L4 and neck of the femur compared with reference value.

Although the DEXA method have been considered to be the gold standard to measure BMD, but this study has shown that DECT densitometry is a useful for the DEXA method as supplementary method[7]. There are so many researches about measured BMD by generating CT. However many previous studies of measuring BMD by CT have dealth with QCT (Quantitative CT) or densitometry data based on the Hounsfield units[8]. Due to its simplicity and low correlation value with DEXA method, using single type energy CT has been not allowed employed for measurement of BMD in clinics. On the contrary, DECT is performed with the same method of DEXA scanner, Which allows differentiation of bone and soft–tissues in accordance with CT density values derived from two different kVp energy[9].

This study was able to show which DECT measurements were correlated with DEXA measurements value as a reference[5]. Therefore DECT imaging should be used to promise accurate measure values in clinics. However one limitation of this study for BMD value was its inability to determine which system's measurements were correlated with other cross–sectional imaging, such as quantitative computed tomography (QCT).

Ⅴ. CONCLUSION

The value of BMD from DECT materials density are well correlated with conventional DEXA scanner, but the indicating unit value is volume unit different from area unit by DEXA. A DECT measurement will provide a methodology for extending BMD measurements for clinical implementation with quantitative analyses also without additional scan for BMD value.

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•국문초록

이중 에너지 조사 방식의 장비별 골밀도 측정의 정량적 비교 분석: CT vs DEXA 비교

김명성

국립암센터 영상의학과

골다공증 검사의 표준검사법은 이중 에너지 X선 흡수율(DEXA) 차이를 이용한 방식이고, 임상에서는 유사한 방식의 이중 에너지 X선 전산화단층영상장치(DECT)가 사용되고 있다. 본 논문의 목적은 기존 방식의 DEXA와 DECT 장비를 활용하였을 때 골밀도 차이를 확인하고 DECT 활용의 유용성을 알아보고자 한다. 기존 방식의 DEXA (QDR 4500W, Hologic)와 DECT (750 HD, GE Healthcare system) 장비를 이용하여 동일한 부위의 허리척추 팬텀 대상으로 검사 시행과 측정을 하였고, 1개월 내 기존 DEXA와 DECT 검사를 동일하게 허리 척추 검사를 시행한 환자 50명을 대상으로 골밀도를 측정·분석하였다. 허리척추 팬텀 대상 골밀도 측정 결과 두 영상장비 간에 통계적으로 높은 상관성(r=0.93, $p<0.05$)을 나타냈고, 사람을 대상으로 하였을 때도 비교적 높은 상관성(r=0.635, $p<0.05$; τ=0.46, $p<0.05$)을 나타냈다. DECT를 이용한 골다공증 검사는 일반적으로 시행한 CT 영상 정보를 추가로 분석하여 골밀도 값을 얻는 것으로 추가적인 방사선 노출 없이 유용한 골밀도 정보를 제공해줄 수 있다는 유용성이 있다.

중심 단어: 이중 X선 흡수계수, 이중 에너지 전산화단층영상, 골밀도, 골다공증