Comparison between EOS imaging and CTscan for the femoral and tibial torsion measurements in children

Poster No.: C-0032
Congress: ECR 2014
Type: Scientific Exhibit
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Keywords: Dosimetric comparison, Radiation safety, Plain radiographic studies, CT, Pediatric, Musculoskeletal bone
DOI: 10.1594/ecr2014/C-0032

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Aims and objectives

Accurate evaluation of femoral and tibial torsion is essential for children or adult with legs deformity. An incorrect legs morphogenesis can lead to pathological situation. As soon as symptomatology appears orthopaedical care is needed(1). Objective radiologic measurements beside clinical examination greatly help choice of treatment(2). CT scan measurement is particularly accurate and considered the gold standard (3,4).

Still, using X-rays involves an optimization of radiation dose (5). Reducing patient irradiation thanks to low-dose biplanar radiographs is attractive. Based on Georges Charpak's research, 1992's French Nobel of physics, this system emits very low dose of radiation(6). Dosimetric evaluations shows a dose reduction with a nearly 20 ratio when compared with standard radiographs for scoliosis studies(7). Compared to CT scan this ratio is expected to be much higher. In adults, it was shown that biplanar radiography measurements of femoral and tibial torsion are interchangeable with standard CT measurements(8). Lower irradiation using this technique seems particularly appealing in children since tissue radiosensibility is higher among them(9). The purpose of this study was to evaluate in children the agreement between femoral and tibial torsion measurements obtained with low-dose biplanar radiography and CT scan and to investigate the dosimetric characteristics of both methods in vitro and in vivo.

Methods and materials

Study was conducted with the approval of our institutional review board and was compliant with Health Insurance Portability and Accountability Act regulations. The institutional review board waived the requirement for informed consent.

Our study was monocentric prospective. 30 children were included consecutively, all addressed from orthopaediatric consultation for lower limbs torsion evaluation from june 2012 to june 2013. There was 23 girls for 7 boys (sex ratio F/M = 3,3). Mean age on inclusion was 14 years for 8-18 years range.

The same day CT scan and low-dose biplanar radiographs were performed. Especially since biplanar radiographs were already used for radiomensuration purpose, so children in this study had no supplementary irradiation compared to others.

Scanning technique

A 32-slices CT scan (Lightspeed™ Pro 32, GE) was used. Topogram was centred on inferior limbs. Sequential acquisitions of hip joint knee joint and ankle joint were acquired without moving the patient. Axial images (tube voltage 120 kV, tube current, 200 mAs/
slice, matrix 512x512, reconstruction thickness 5 mm; reconstruction increment 5 mm). Images additions were used to measure femoral and tibial torsions.

Femoral torsion was defined as the angle between a line passing through the centre of the femoral head and parallel to the cortical bone of the femoral neck and a tangent line to posterior contour of the femoral condyles (3)(figure 1). Tibial torsion was defined as the angle between the tangent line to posterior contour of tibial head and the line passing through the midpoint of the articular surfaces of the medial and lateral malleoli (4)(figure 2). Senior radiologists with more than 5 years of experience performed measurements.

EOS imaging system from EOS Imaging was used for low-dose biplanar radiography. Perpendicular anteroposterior and lateral projections were acquired simultaneously (Anteroposterior parameters: tube voltage 85 kV, tube current 200 mA; Lateral parameters: tube voltage 110 kV, tube current 320 mA). These projection were used for 3D reconstruction of the lower extremity (figure 3) with sterEOS software (EOS Imaging) which automatically provided the measurement after a step by step fitting process on a 3D parametric model (figure 4). Two technicians who received a specific formation on sterEOS did perform the measurements.

**Dosimetric study**

For *in vitro* dosimetry, a pencil ionization chamber was used (8202041-c XI CT, UNFORS) inserted in standard tissue equivalent phantom (methyl polymethacrylate, diameter 32 cm) used for computed tomography dose index (CTDI) quality control. Two water cylinders were attached simulating the presence of thighs for diffusion rays. Measurements were taken in 5 different positions (central, anterior, posterior, left, right). Irradiation parameters were the same than those used on children. We used two sequential acquisitions of 5 cm length. One was on the phantom, one on the extremities of water cylinders, simulating acquisition of hip joint and knee joint. We did not simulate an acquisition of the ankle joint since diffusion irradiation is very low either for CT scan or biplanar radiography. Results were delivered in mGy.cm.

For *in vivo* dosimetry radiothermoluminescent detectors (TLD) with lithium fluorure were used. TLD were placed on 5 patients. They were positioned beside pubis and changed between exams. Two TLD were kept apart as control for natural radiations. Reading was executed by an automatic reader that delivered equivalent skin dose (Hp 0,07) estimation in mGy.

**Statistical analysis**

Every difference between CT scan and biplanar radiograph measurements use CT scan as reference. Negative value indicates that biplanar radiographs gave a lower measure. Positive value indicates a higher measure.
Comparison between measurement of femoral and tibial torsion for both modality was performed using Bland et Altman plots. Theses was preferred to correlation coefficients since high correlation does not imply good agreement between these two methods(10,11).

Correlation analysis was used to evaluate the relationship between the CT scan-biplanar radiography difference in absolute value and the age or the degree of deformity.

MedCalc software (version 12, MedCalc).

Images for this section:
**Fig. 1:** CT measurement of femoral torsion

**Fig. 2:** CT measurement of tibial torsion
Fig. 3: EOS 3D reconstruction

Fig. 4: EOS femoral torsion measurement
Results

For femoral torsion, the average differences between CT scan measurements and biplanar radiographs measurement were -0.97° (IC 95%, [-2.08;0.15]. Differences were between -10° and +8° (figure 5). There was no significant relationship between the CT scan-biplanar radiographs difference and the degree of femoral torsion (correlation coefficient, 0.18; p=0.17).

For tibial torsion, the average differences between CT scan measurements and biplanar radiographs measurement were -0.7° (IC 95%, [-2.1;0.6]. Differences were between -17° and +12° (figure 6). There was no significant relationship between the CT scan-biplanar radiographs difference and the degree of tibial torsion (correlation coefficient, -0.06; p=0.63).

We also looked for relationship between the CT scan-biplanar radiographs differences and the patients' age (figures 7, 8). No significant correlations were found either for femoral torsion (correlation coefficient, 0.22; p=0.09) or tibial torsion (correlation coefficient, 0.19; p=0.19).

Concerning in vitro dosimetry analysis of the irradiation dose, regardless position of the ionization chamber CT scan dose was higher than EOS (figure 9). Arithmetic mean of measurement was 69.01 mGy.cm for CT against 3.16 mGy.cm for biplanar radiographs (ratio, 22). Irradiation from the topogram represents less than 1% of total irradiation (0.55 mGy.cm).

Regarding in vivo dosimetry analysis with TLD, skin dose was 13.448 mGy (standard deviation = 6.76) for CT scan against 0.596 (standard deviation = 0.12) for biplanar radiographs. Natural radiation levels measured by controls were 0.17 mGy. CT scan irradiated more the children with a 31.9 ratio.

Images for this section:
Fig. 5: Bland-Altman plot of femoral torsion measurements

Fig. 6: Bland-Altman plot of tibial torsion measurements
**Fig. 7:** Absolute difference between low-dose radiographs (EOS) and CT scan femoral measurement according to age

**Fig. 8:** Absolute difference between low-dose radiographs (EOS) and CT scan tibial measurement according to age
**Fig. 9:** Ionization chamber measurements in vitro for low-dose radiographs (EOS) and CT scanner
Conclusion

Mean differences between CT scan and biplanar radiographs are -1° for femoral torsion and -0.7° for tibial torsion. In our study, 95% confidence interval are less than 3° in absolute value. The proportion of measurements strictly superior to 10° is 0% for femoral torsion and 5% for tibial torsion. In adults, Buck found similar results, respectively 0° and 3° differences for femoral and tibial torsion(8).

Low dose biplanar radiographs are attractive. There are more and more indications for using this system either for adult or children. Works on scoliosis are particularly interesting(12,13). A lot of data is obtained with less irradiation compared to standard radiographs or CT scan. The two projections simultaneously acquired gave an overall view of the limbs(14). In the particular case of inferior limbs torsion analysis, it gives an insight into lower limbs coronal statics and precise measurement of lower limbs segments useful for surgery(1).

Biplanar radiographs have no distortion and are used to produce 3D models of lower limbs skeleton. This needs identification of landmarks during a semi automatic step-by-step procedure. These landmarks are the great trochanter, the posterior contours of the femoral condyles, the posterior contours of medial and lateral aspect of the tibial head, and the malleoli of the ankle joint. This step is crucial for torsion measurement. In our paediatric population, presence of a cartilaginous skeleton did not alter the viability of these landmarks. Moreover the software copes with major deformations. Indeed there are no relationships between the CT scan-biplanar radiographs difference and the age.

In this study mean age was around 14 years old and is related with the end of inferior limbs growing which is the recommended time for therapeutic discussion(1).

Higher tissue radiosensibility among children(15) implies for us the seeking of lower dose of irradiation to acquire the data necessary for their treatment. The introduction of a new modality for femoral and tibial torsion measurement should not be at the expense of the quantity of X-Rays emission. Dosimetry data on low dose biplanar radiography essentially comes from comparison with standard radiography in scoliosis follow-up(16). Dose reduction data compared to CT scan seems to come from reckoning and not measurement. Especially it appears to compare the dose between 3D modelling from biplanar radiographs of rachis with 3D reconstruction from CT scan that is not used in standard scoliosis aftercare. It gave reduction dose ratio among 100 to 600 for absorbed dose by organs(6). A contrario CT scan is considered to be the reference in inferior limbs torsions study. Protocols have been optimised for minimal irradiation with sequential acquisitions centred on hip, knee and ankle joints.
Rigorous radiation dose comparison between two different modalities using X-Rays is quite difficult. Manufacturers only provide dose estimations. Computed tomography dose index (CTDI) and Dose-length product (DLP) from CT scan are calculated, same as Dose area product from radiographs. Furthermore we cannot compare them directly. Effective dose expressed in Sievert (Sv) is used in radiation protection to estimate the impact of irradiation on the whole organism. However International commission on radiological protection (ICRP) does not recommend its use for patients' exposition studies. They advise to consider absorbed or equivalent dose(17). These two can be measured and not calculated.

Limbs are considered to have low radio sensibility, but in our particular case we also irradiate the hip joint. Facing the femoral metaphysis and epiphysis are the gonads highly radio sensible organs. Therefore we targeted pelvis for our dosimetric analysis. In vitro measurements mean shows a 22 ratio of dose reduction from biplanar radiographs compared to CT scan. In vivo measurements indicate equivalent skin dose reduction with a 32 ratio. We think that the gap between the two ratios comes from the shape of the detectors. In the phantom the ionization chamber is a 10 centimetres long cylinder that integrates the dose on its whole length. On a patient, TLD can be assimilated to a point and was placed in the centre of acquisition window of the hip joint. Biplanar radiographs need continuous acquisition on the whole pelvis compared to the 5 cm window acquisition of CT scan protocol. In vitro measurements give probably a more accurate estimation of dose diminution ratio since they integrate data from smaller acquisition window.

Nevertheless, our study has shown that lower limb torsion measurements obtained with biplanar radiographs are interchangeable with CT scan measurements in children with a considerable radiation dose reduction. This could lead to changes in medical care of lower limb torsional abnormalities.

Personal information

References


