Trabecular Bone Score (TBS) the new parameter of 2D texture analysis for the evaluation of 3D bone micro architecture status.

Poster No.:	C-1961
Congress:	ECR 2011
Type:	Scientific Exhibit
Authors:	T. Piveteau[1], R. winzenrieth[1], D. Hans[2]; [1]PESSAC/FR, [2]Lausanne/CH
Keywords:	Musculoskeletal bone, CT-High Resolution, Computer Applications-Detection, diagnosis, Technical aspects, Tissue characterisation
DOI:	10.1594/ecr2011/C-1961

Purpose

X-ray imaging is a technique used for many applications in the medical field. X-ray projection process provides a 2D gray levels texture which mainly reflects differences X-ray absorption properties of bone microarchitecture crossed through.

We find variations of gray levels in porous materials. X-rays are absorbed by the solid phase (mineralized) and transmitted by the porous phase. Therefore, for porous materials, gray levels texture changes in the projected images are related to the number of interfaces between solid and porous phases of the 3D structure.

Trabecular bone is not exactly a porous material, but can be considered as such. The trabecular tissue is actually composed of a solid part (mineralized bone) and of holes that are not empty but filled with bone marrow. Therefore, the analysis of gray levels variations that are present in the projected image should enable to assess indirectly the 3D microarchitecture of the tissue.

TBS is a new grayscale texture parameter based on the experimental variogram exploitation (derived approach from porous media analysis) from the 2D projection images. In addition, a beta version of TBS [1] has been previously published, major improvements have been made since and are explained in this study.

Objective:

The aim of this study was to evaluate the existing correlations between bone microarchitecture 3D parameters and TBS values, knowing that the 3D parameters were calculated from µCT 3D model reconstructions, and TBS was calculated from 2D projections of these models.

Methods and Materials

Study samples:

30 dried human vertebrae were obtained from the anatomy laboratory of the University Hospital of Bordeaux. This sample set is composed of lumbar and thoracic vertebrae.

3D Reconstruction and 3D microarchitecture parameters evaluation:

For each sample, a 3D reconstruction of the trabecular microarchitecture part of the vertebra was obtained from µCT image at an isotropic resolution of 93µm on a eXplorer Locus (GE Healthcare). The usual 3D microarchitecture parameters (ConnD, TbN, TbSp, TbTh and BV/TV) were obtained using Micro-View software (v.2.1.2, GE HealthCare).

2D projection model:

AP 2D projections were calculated using the Beer-Lambert law. Different X-ray energies were considered: 50, 100 and 150 keV. An example of X-ray energy effect on the 2D projected images is presented below:

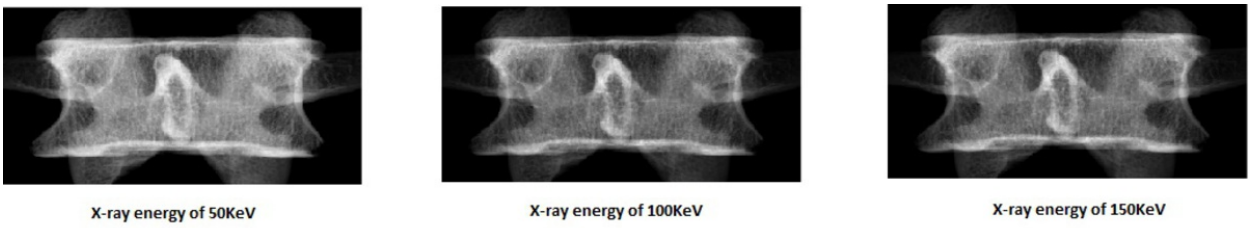

Fig.: X-ray energy effect on the 2D projected images
References: R. winzenrieth; Hôpital X. Arnozan, PESSAC, FRANCE

TBS Evaluation:

TBS was evaluated from 2D µCT projected images (TBSµCT). TBS is a black box based on the use of the experimental variogram. TBS is not an estimator of the Hurst coefficient (H). It is based on the evaluation of gray levels variations on an image in specific directions at specific distances.

Statistical Analysis:

Statistical analysis has been performed with MedCalc software (MedCalc ®, V 11.0.1). Descriptive statistics were used to characterize the samples set. A correlation analysis was performed between TBS values and the 3D microarchitecture parameters using Pearson's correlation test. The effect of X-ray energy on TBS and 3D microarchitecture parameters correlations was also avaluated. In addition, in order to evaluate the accuracy of these correlations, backward linear regressions were used coupled with a bootstrap approach (20 vertebrae picked-up randomly 10 times amongst the 30 vertebrae).

Results

Study samples:

The mean values, standard deviations (SD), and the values range for BV/TV, TbSp, TbTh and ConnD are presented (table below) for the 30 vertebrae. The study sample shows a large range of BV/TV values that vary from 0.185 to 0.376 (average: 0.288 ± 0.046).

Samples	BV/TV	TbTh	TbN	ConnD
Spine(n=30)	[1]	(mm)	(mm-1)	(mm-3)
Mean	0,288	0,228	1,457	4,652
SD	0,046	0,015	0,239	1,407
Interval	0,185-0,376	0,197-0,251	0,933-1,793	1,326-6,593

Fig.: Descriptive statistics of the 3D parameters
References: R. winzenrieth; Hôpital X. Arnozan, PESSAC, FRANCE

Descriptive statistics of the 30 vertebrae for TBS at 50, 100, 150 KeV are also presented (see table below).

Samples	TBS (50Kev)	TBS (100Kev)	TBS (150Kev)
Spine (n=30)	[1]	[1]	[1]
Mean	0,773	0,777	0,778
SD	0,184	0,186	0,187
Interval	0,413-1,091	0,419-1,102	0,419-1,104
Test for normality (*p*=)	0,442	0,464	0,468

Fig.: Descriptive statistics of TBS

References: R. winzenrieth; Hôpital X. Arnozan, PESSAC, FRANCE

Correlations between TBS and the 3D parametrs:

Correlations' analysis showed that TBS were strongly correlated with ConnD (0.856 # r # 0.862; p<0.001), with TbN (0.805 # r # 0.810; p<0.001) and negatively with TbSp (-0.714 # r # -0.726; p<0.001), regardless X-ray energy as presented in the table below.

	TBS (100Kev)	TBS (150Kev)	Bv/Tv	TbTh	TbSp	TbN	ConnD
TBS (50Kev)	0,999**	0,999**	0,68**	-0,354	-0,727**	0,812**	0,863**
TBS (100Kev)	1	0,9999**	0,676**	-0,359	-0,726**	0,81**	0,862**
TBS (150Kev)		1	0,676**	-0,36	-0,726**	0,81**	0,862**
Bv/Tv			1	0,179	-0,952**	0,906**	0,816**
TbTh				1	0,047	-0,253	-0,377*
TbSp					1	-0,959**	-0,865**
TbN						1	0,960**
ConnD							1

** Significant correlation p<0,001
* Significant correlation p<0,05

Fig.: Correlations between TBS and the 3D parametrs
References: R. winzenrieth; Hôpital X. Arnozan, PESSAC, FRANCE

TBS: a connectivity model

TBS has been expressed in terms of ConnD as **TBS = a1 + b1xConnD**. The two coefficients (a1, b1) were determined by linear regression analysis (incorporating a bootstrap approach) for each of the 10 subsets. Coefficients of the regression equation were calculated as the average of the coefficients obtained for the 10 subsets, leading to: **a1 = 0.237 ± 0.074** and **b1 = 0.116 ± 0.015.** The average **F-ratio** was **61.76 ± 16.11** with an average **r²** of **0.766 ± 0.044.**

Conclusion

In this study, we demonstrated that TBS was significantly correlated with 3D microarchitecture parameters ConnD and TbN, and negatively with TbSp, no matter what X-ray energy has been used.

Results obtained show that a lower TBS value is related to a "degraded" microarchitecture, with low ConnD, low TbN and a high TbSp. The opposite is also true.

References

[1] Laurent Pothuaud, Pascal Carceller, Didier Hans. CORRELATIONS BETWEEN GREY-LEVEL VARIATIONS IN 2D PROJECTION IMAGES(TBS) AND 3D MICROARCHITECTURE : APPLICATION IN THE STUDY OF HUMAN TRADECULAR BONE MICROARCHITECTURE. BONE (2008), 42, p775-787

Personal Information