## VPHOP: the Osteoporotic Virtual Physiological Human

The fight with Osteoporosis now has a new ally. The VPHOP research project will develop, validate and deploy to pilot clinical studies the next generation of technology for predicting the risk of fracture in patients with low bone mass and assisting clinicians in prognosis and treatment planning (both pharmacological and interventional). The most advanced multiscale modelling technologies will be used to predict the patient-specific risk of fracture, and how it would change as a result of the various potential treatment options.
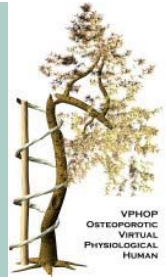
Objectives of the project

Context: Nearly four million osteoporotic bone fractures cost the European health system more than € 30 billion per year. This figure could double by 2050. After the first fracture, the chances of having another one increase by 86%. We need to prevent osteoporotic fractures. The first step is an accurate assessment of the patient-specific risk of fracture that considers not only the skeletal determinants but also the neuromuscular condition.

Osteoporotic fractures cost the European health system is more than €30 billion per year

Project: The aim of VPHOP is to develop multiscale modelling technology based on conventional diagnostic imaging methods that makes it possible, in a clinical setting, to assess *for each patient individually*, the strength of his/her bones, how this strength is likely to change over time, and the probability that the he/she will overload his/her bones during daily life.

With these three assessments, the evaluation of the risk of bone fracture will be much more accurate than any estimation based on external and indirect determinants, as happens in current clinical practice. These assessments will be used to improve the diagnostic accuracy of current clinical standards, and to provide the foundation for an evidence-based prognosis with respect to the natural evolution of the disease, to pharmacological treatments, and/or to preventive interventional treatments aimed at strengthening particularly weak regions of the skeleton selectively.

For patients at high risk of fracture, and for whom the pharmacological treatment appears insufficient, the VPHOP system will also assist the interventional radiologist in planning the augmentation procedure.

The various modelling technologies developed during the project will be validated not only *in vitro*, on animal models, or against retrospective clinical outcomes, but will also be assessed in term of clinical impact and safety on small cohorts of patients enrolled at four different clinical sites, providing the factual basis for effective clinical and industrial exploitation.

Project Description *(from DoW)*

Project Description: Currently, the risk of fracture is estimated empirically, i.e. based on observations of past cases. However, in theory we could imagine developing a patient-specific computer model that is capable of assessing the risk of fracture in a deterministic way, with much higher accuracy. The problem is that the occurrence of an osteoporotic fracture is a multiscale event:

– the daily loading spectrum, which includes para-physiological overloading events is defined at the Body level;

– the fracture event occurs at Organ level;

– the bone elasticity is due to the tissue, which is defined at the Tissue level;

– the composition and the morphology of the bone tissue changes over time due to the metabolic activity, which is defined at the Cell activity level;

– the strength of the tissue is due to the molecular composition of the bone matrix, which is defined at the Constituents level.

By creating a patient-specific hypermodel – a model composed by many sub-models, each describing the relevant phenomena taking place at one of the many dimensional scales involved – we will be able to solve this incredibly complex problem.

This modelling technology will be specialised to solve four clinically relevant problems:

a. Screening (level 1): to supplement the conventional Dual X-ray Absorptiometry (DXA) screening of subjects at risk, in order to include in the diagnosis also the propensity to fall, and possibly 3D densitometric information.

b. Diagnosis (level 2): In osteoporotic subjects, use 3D densitometry information to develop a personalised assessment of the risk of fracture at the hip and the lower spine that clinicians can use to better modulate the life-style recommendations and the treatment options.

c. Prognosis (level 3): for patients at high risk of fracture, develop a predictive model based on tissue-level imaging that estimates the variation

of such risk over time due to bone remodelling with, and without, pharmacological treatment.

d. Interventional treatment planning: simulation-based pre-operative planning to decide which vertebral body is at higher risk, in which region of that vertebrae the augmentation would be more effective, and to estimate the reduction of the risk of fracture that the treatment would produce.

Expected Results & Impact

Clinical innovations:

– prognosis

  o predicting the risk of femoral or vertebral fracture under low energy loading

  o predicting, at the tissue level, the probability of developing micro-fractures

– pharmacological treatment planning

  o predicting changes over time due to the evolution of the disease and to the pharmacological treatment

– interventional treatment planning

  o Predicting the location within each bone that is most susceptible to fracture

  o Predicting the changes in risk due to interventional augmentation

Industrial innovations:

– Imaging technology to generate whole bone patient-specific models with very low radiation dose

– Wearable activity monitor capable of capturing the patient's life style for one week including para-physiological events

– Hypermodelling technology for the creation of massive multiscale models using heterogeneous codes

– Tissue level imaging in vivo at the spine and hip with clinically acceptable radiation doses

– Cellular activity models, capable of predicting the functional outcome of different pharmacological modulations of bone metabolism

– Software technology for patient-specific deterministic prediction of fracture risk

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