Biomechanical study of patients with spinal tumors by means of CT image analysis and finite element simulation

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BACKGROUND

- Cancer is one of the most relevant disease worldwide, due to its incidence, prevalence and mortality, being the second cause of death in Spain.
- Most of cancer patients will present metastasis. The skeleton is the most common organ to be affected by metastatic cancer and the spine the most frequent location, causing a severe morbidity in patients.

OBJECTIVES

- To provide an **indicator of vertebrae fracture risk** in oncological patients because of bone degeneration by means of Computed Tomography (CT) image analysis.
- A **vertebrae segmentation** is proposed, quantifying and classifying the bone into healthy bone, osteolytic metastases, osteoblastic metastases or osteoporotic bone induced by the cancer treatment.
- To perform a **biomechanical analysis** by means of finite element analysis in order to determine the vertebrae fracture risk when subjected to compression loads under normal conditions.

MAIN STAGES

1. Development of algorithms for quantifying the tumor burden and bone quality in metastasized vertebra.
2. Construction of a finite element model of the healthy, metastatic and osteoporotic vertebra.
3. Biomechanical analysis by finite elements of the vertebrae with metastatic tissues or osteoporosis.
4. Analysis of results and determination of fracture risk.

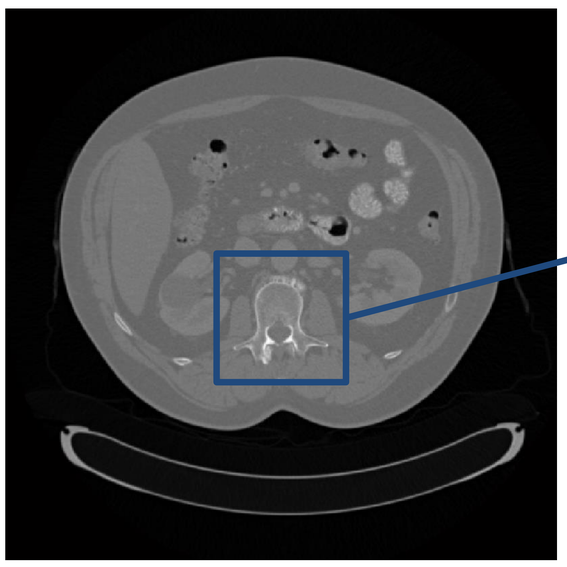

Figure 1. Raw image of axial CT image.

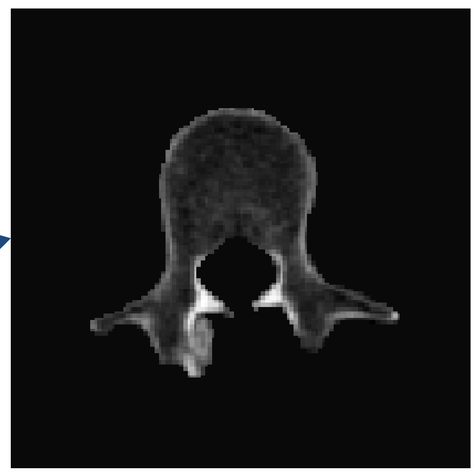

Figure 2. Vertebral segmentation from a single CT image. From vertebral segmentation, three-dimensional model of the spine is constructed.

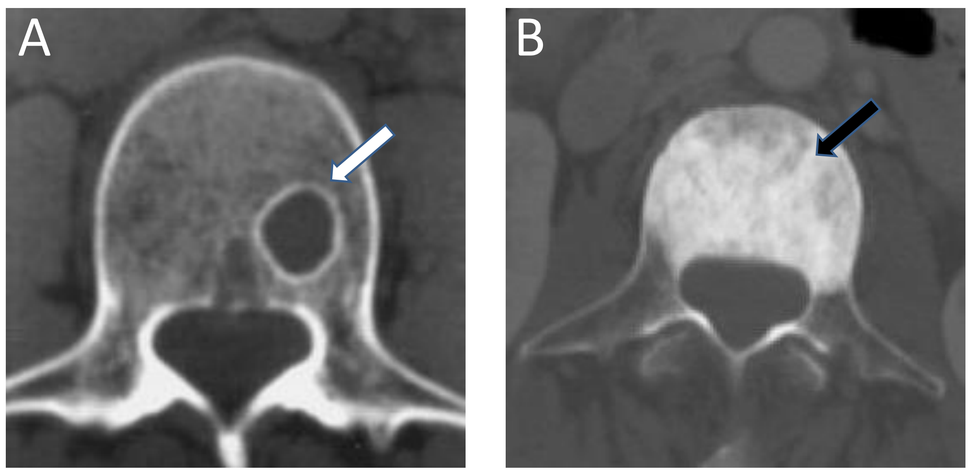

Figure 3. (A) Osteolytic metastases (white arrow). (B) Osteoblastic metastases (black arrow). The first step in this work is to develop algorithms to quantify tumor burden and quality of the vertebrae with bone metastasis.

Figure 4. 3D Vertebrae model (from C3 to L5) reconstructed from segmentated CT images.

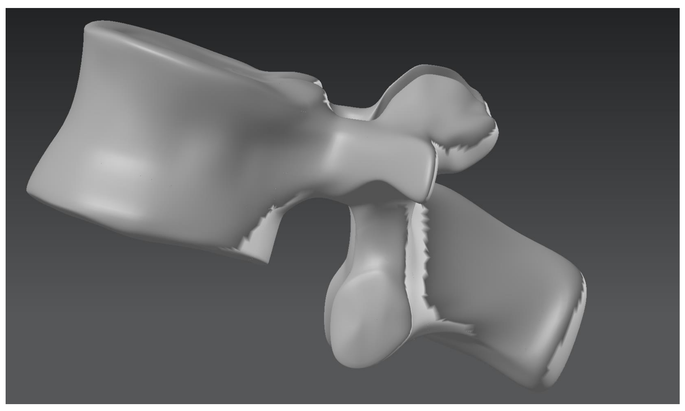

Figure 5. Three-dimensional normal lumbar vertebra model reconstructed from segmentation CT images (L1 vertebra). Biomechanical analysis of a single vertebra will be performed before whole spine analysis. Three-dimensional vertebrae model with metastases, osteoporosis and healthy bone from CT images segmentation will be performed.

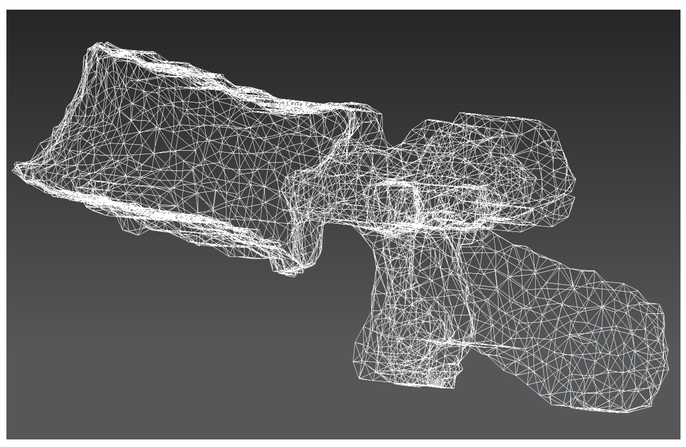

Figure 6. Meshing of one vertebra (L1 vertebra) from its three-dimensional geometry. The mesh is three-dimensional with tetrahedral 8-nodded elements. After the meshing is obtained, material properties (bone) will be assigned to model, and an analysis based on finite element from a single vertebra will be performed as a first approximation.

EXPECTED RESULTS

- Three-dimensional vertebrae model with metastases, osteoporosis and healthy bone from CT images segmentation.
- Three-dimensional mesh consisting of hexahedral 8-node of whole spine and pathologic lesions.
- Biomechanical analysis of vertebrae under normal load conditions.
- Prognostic model for fracture risk based on biomechanical analysis of their vertebrae.

KEY POINT

To determine whether the biomechanical finite element analysis is a good predictor of fracture risk in cancer patients.

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