

## Toward Patient-Specific Finite Element Mesh Development of the Cervical Spine

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**INTRODUCTION:** Patient-specific hexahedral mesh generation is highly desired, yet poses a challenge for the field of finite element (FE) analyses of anatomical structures. The cervical spine is a complex component of the skeletal system, which heightens the need for accurate geometrical representations in order to extract clinically relevant data. Traditional meshing techniques are time consuming and tedious, and lack remeshing capabilities<sup>1</sup>. Most meshes created using these techniques are relatively coarse and use simplified or idealized geometry<sup>2</sup>. The ability to automate cervical spine meshing methods is critical to the development of patient-specific models that can be used for clinical assessment; our methods improve upon existing multi-block meshing methods to make this possible.

**METHODS:** CT scans were acquired of a cadaveric specimen; the cervical spine was segmented and surface definitions of each vertebra were created. The vertebral body mesh for C5 was created by manually tracing the bounds of the superior and inferior vertebral endplate periphery, in addition to the location of the nucleus. A butterfly building block (BB) pattern was automatically generated to subdivide and mesh the vertebral body (Figure 1A).

A system of BBs was created which surrounded the entire posterior region of the C5 vertebral surface. At the pedicle, the vertices of the BBs were defined to directly coincide with nodes on the predefined vertebral body mesh, allowing for direct attachment of the posterior mesh to the vertebral body (Figure 1B). Mesh seeding was automatically generated for the BBs based on a user specified average element length, but could be manually modified. After the mesh was created, laplacian smoothing was performed on the surface nodes and interpolation methods were employed to calculate the interior nodes (Figure 1C). The quality of the resulting mesh was improved using MESQUITE<sup>3</sup>, a mesh improvement software library.

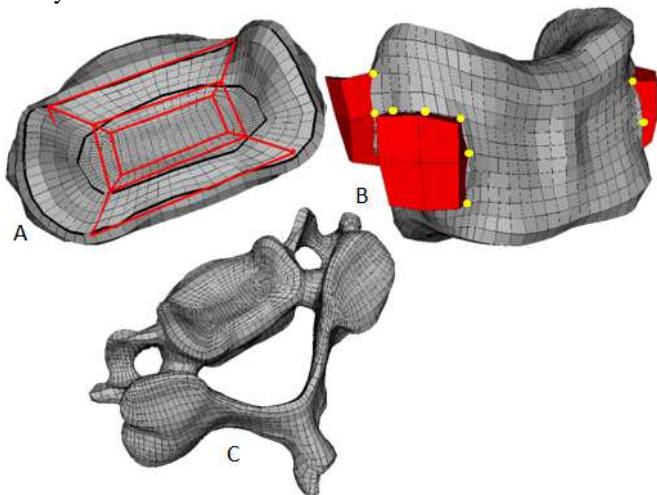


Figure 1. (A) Vertebral body BB definition and final mesh. (B) BB attachment at the pedicles. (C) Final C5 mesh.

**RESULTS:** The BBs for the posterior region can be created on the order of a few hours. Once the BBs are created, the actual meshing process takes only a few minutes. The mesh quality was improved by untangling the mesh and improving the shape of the internal elements (Figure 2). The number of elements with zero Jacobian decreased from 214 to 0 after using the methods described.

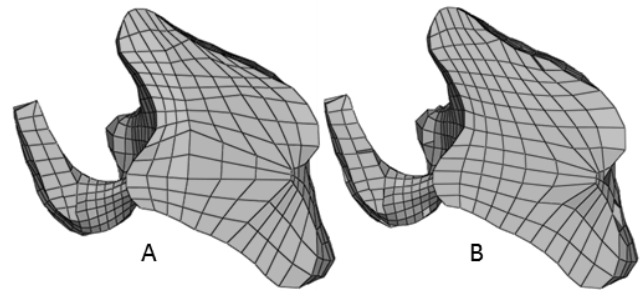


Figure 2. A portion of a C5 cervical mesh before (A) and after (B) improvement with MESQUITE.

**CONCLUSIONS:** The novel meshing techniques described here help pave the way for patient-specific FE model development. Traditional meshing techniques are time consuming, making patient-specific modeling impractical. Our methods substantially decrease the amount of time to create cervical spine FE models, in addition to providing feedback on the quality of the meshes created, allowing us to improve the overall mesh quality. We are currently working on determining the optimal number of BBs required for the posterior region. Using the remeshing capabilities inherent to our methods, convergence studies can be done relatively quickly. In addition, the BBs that are created for one particular spinal level may be used for other levels with small modifications, making the process amenable to multi-patient studies. Because the meshes are created on a specimen-specific basis, direct validation of our methods can be performed via comparison to experimental data obtained from the same specimen.

### REFERENCES:

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