PATIENT-SPECIFIC DYNAMIC STRESS ANALYSIS OF OSTEOPOROSIS VERTEBRAE

[1]Daisuke Tawara, [1]Jiro Sakamoto, [2]Serina Awamori, [2]Hideki Murakami,
[2]Norio Kawahara, [1]Juhachi Oda and [2]Katsuro Tomita
[1]Graduate School of Natural Science and Technology, Kanazawa University, Ishikawa, Japan,
[2]Graduate School of Medical Science, Kanazawa University, Ishikawa, Japan,
email: datawara@nihonkai.kanazawa-u.ac.jp, web: http://www.hm.t.kanazawa-u.ac.jp/bionic

INTRODUCTION

Mechanical strength analysis using finite-element (FE) method is effective to predict a risk of compression fracture of osteoporosis vertebrae. Bone fracture in clinical case of osteoporosis sometimes occurs under the dynamic load condition during transition process from sitting down position to standing position. Patient-specific dynamic FE analysis is necessary to evaluate mechanical strength of osteoporosis for the clinical condition. In this study, dynamic FE analyses of osteoporosis vertebrae were performed considering individual shape and material property based on CT images of patients. Differences of fracture risk depending on patient's case and availability of dynamic analysis was discussed comparing with the results of the static analysis.

METHODS

Finer finite-element meshing is required for patient-specific analysis to reflect individual bone shape and material properties. We used finite-element code "NEXST_Impact (FSIS, Japan)" [1], which can solve large-scale dynamic problem by using parallel processing. Analysis target was L1 vertebra because it was located near the inflection point of spine and favorite site of osteoporosis fracture. X ray CT images were taken at 1mm intervals from 4 Japanese female osteoporosis patients whose age was 60, 53, 71 and 72 years old. Patient-specific FE model of L1 based on CT images were obtained by "Mechanical Finder (RCCM Co.)" that was software to make FE models considering individual bone shape and density distribution. Young's modulus of each element was given one by one calculating from bone density and CT value. Relationship between the mechanical properties and bone density proposed by Keyak [2] was used. An example of FE model and its density distribution of whole model and central section are shown in figure 1. Simple dynamic compressive loading was considered in the analyses, that is, bottom surface was fixed and uniform step pressure was applied to upper surface of vertebra [3]. Dynamic analysis was done in the t=0.0(ms) to t=5.0(ms) range by setting time of loading as t=0.0(ms) and analysis time step was 2.0(μs).

RESULTS AND DISCUSSION

Figure 2 shows Mises stress distribution by time steps in dynamic analysis. Stress wave propagated along high-density region. Peak of stress in dynamic analysis occurred slightly delay after loading. High stress widely occurred at the anterior surface of cortical bone. It is reasonable because load seems to concentrate at cortical bone by low load sharing at cancellous bone in osteoporosis vertebrae. Table 1 shows maximum Mises stress value of dynamic analysis and static analysis of the 4 models. Results of dynamic analysis exceeded that of static analysis in 3 models. It was suggested that static analysis solution give us underestimation of bone fracture risk of vertebrae in comparison with clinical condition that involves dynamic loading.

CONCLUSIONS

Stress wave propagation process of osteoporosis vertebra was shown precisely by patient-specific dynamic FE analysis.

REFERENCES

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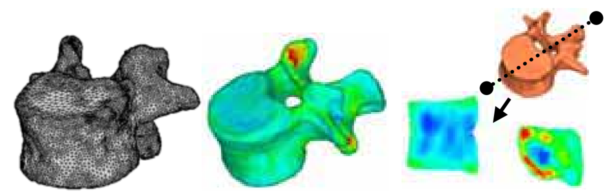
2. Keyak JH, et al., *J Biomech* **31**, 125-133, 1998.
3. Nachemson A, et al., *Spine* **6**, 93-97, 1981.



FE model Bone density distribution

Figure 1: FE model and density distribution of whole model and central section view

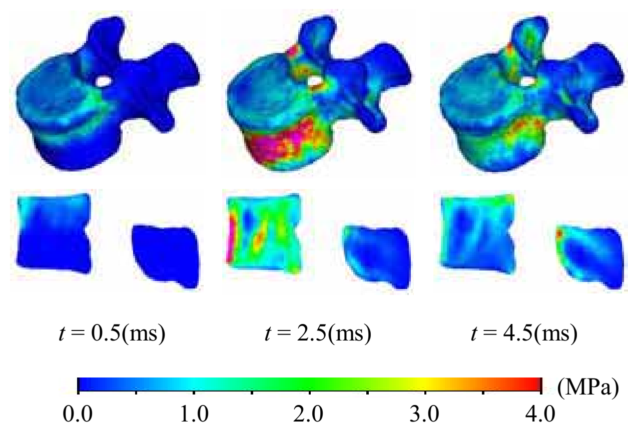


Figure 2: Mises stress distribution of dynamic analysis in model and central section

Table 1: Maximum Mises stress value of dynamic analysis and static analysis of the 4 models

Model	A	B	C	D
Dynamic analysis (MPa)	7.25	12.4	34.3	24.4
Static analysis (MPa)	3.61	13.8	23.5	16.8