INTRODUCTION

The introduction of passenger airbags has increased reports of injuries related to their deployment. While the majority of these injuries have been minor, the exposure of children to airbag deployment has resulted in more serious injuries (Winston). In many cases, adult occupants sustained little or no injury while child passenger injuries resulted in severe injury or death. The mechanism of the injuries has been primarily attributed to tensile loading as the airbag unfolds under the chin of the child.

Obtaining tolerance values for children of different age groups can help mitigate these injuries. Determination of these data for children is difficult because tissue for these tests is not readily available. Through the use of animal models, scaling factors determining the relationship between developmental age group strengths can be tested and related to human age group tolerance.

METHODS

The tensile neck strength and material characteristics of the pediatric cervical spine were studied using a caprine (goat) cadaveric animal model. The human age equivalent for one-year-old, three-year-old, six-year-old, twelve-year-old, and adult was determined using CT images to evaluate the skeletal equivalent maturation stage. Each specimen was initially tested under sub-failure loads in tension and load relaxation from the head to C6. The ligamentous spine was then sectioned into OC-C2, C3-C4, C5-C6, and C7-T1 motion segments. These segments were tested under several conditions including sub-failure in axial tension, load relaxation, pure moment bending in flexion-extension, lateral bending, and failure in axial tension.

The cervical sections were mounted by dissecting and embedding the desired vertebrae. Some muscle was left intact along with gauze soaked in Ringer’s solution to preserve the fluid in the specimen and the integrity of the intervertebral joints. The segments were mounted by passing wires over the vertebrae pedicles and through the vertebral bodies. The vertebrae and wire composite were mounted in PMMA (dental acrylic), creating an interface for the piston and load cells.

Axial testing of the cervical spine was done with an electro-hydraulic piston (MTS, Minneapolis, MN). The computer-controlled system was programmed under force and displacement control. A bottom six-axis load cell, an upper load cell, and an
LVDT provided measurements for all reactions of the system under quasi-static loading rates.

Pure moment testing used a four-camera, three-dimensional motion analysis system (Motion Analysis Corp., Santa Rosa, CA). A pure moment was created with masses hung from a pulley system. This system applied torque to the top of the specimen preparation through load arms. A bottom six-axis load cell measured the reaction forces and moments of the specimen.

RESULTS AND DISCUSSION

From the caprine models, several individual scaled relationships were developed. Measurements of linear and rotational stiffness, load relaxation rate, and destructive failure force in tension were taken for comparison. Figure 1 shows the average overall tolerances scaled to the adult strengths in comparison to other currently used scale factors.

Current tolerance levels for children and infants have been developed using several different methods. Most methods use the strength of lumbar ligaments, or different structure size and height comparisons (Yoganandan; Melvin). Very few tests have been done on young specimens to validate calculated tolerance factors.

The use of tolerance data in the configuration of child and infant crash test dummies can create a more realistic estimate of injury. Determination of injury probability can then lead to safer and stronger designs.

SUMMARY

Injuries induced in destructive testing such as endplate failure and ligament tears are consistent with clinical observations. Specimens demonstrated increased strength characteristics with age. Stiffness and tensile strength increase with cervical level and with age. Scaling relationships were developed with respect to the adult specimens. Results indicated that currently used scaling relationships may require more conservative strength limits for children of one and three years of age.

REFERENCES

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