Characterization of Cortical Bone Thickness Changes in the Human Ribs with Age and Sex

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Abstract

This study characterized age and sex-related changes in rib cortical thickness to study the effect on thoracic injury risk. A validated cortical density-based algorithm was used to measure rib cortical thicknesses from 108 males and 114 females aged 0-97 [1]. Point clouds of the inner and outer cortical bone surfaces were output for the entire ribcage. The points for individual ribs were transformed to a modified cylindrical coordinate system to make subject-to-subject comparisons of thicknesses at homologous rib regions. The average thickness for each rib sub-section was regressed with age and sex. From the compilation of the regressions, cortical thicknesses were set regionally for each rib and used to make age and sex-specific ribcage models with accurate cortical thicknesses. Cortical thickness measurements were collected from 5,568 ribs across 222 subjects and regionally assigned to homologous locations for comparative analysis with age and sex (38,760 sub-sections per ribcage per sex; 77,520 regressions total). Regression analysis showed maximum cortical thickness is achieved at a mean of age 45.40 (SD = 8.27 years) for females and a mean of age 54.64 (SD = 11.68 years) for males. Cortical thickness increases 22.27% for females (SD = 11.89%) and 30.43% for males (SD = 20.07%) from age 20 until the mean maximum age, then decreases 23.79% for females (SD = 10.42%) and 11.64% for males (SD = 9.19%) from the maximum age to age 90. Individual ribs generally increased in thickness until middle age and then cortical thinning occurred with aging. Rib 1-2 thicknesses increased 42.30% (SD = 26.13%) for females and 26.54% (SD = 14.44%) for males and then decreased 4.72% (SD = 9.64%) for females and 18.06% (SD = 13.88%) for males. Rib 3-7 thicknesses increased 31.87% (SD = 20.02%) for females and 25.26% (SD = 9.82%) for males and then decreased 9.20% (SD = 6.64%) for females and 20.51% (SD = 9.36%) for males. Rib 8-10 thicknesses increased 28.37% (SD = 11.61%) for females and 21.34% (SD = 7.70%) for males and then decreased 15.01% (SD = 7.65%) for females and 25.91% (SD = 7.92%) for males. Rib 11-12 thicknesses increased 29.05% (SD = 20.49%) for females and 20.81% (SD = 12.84%) for males and then decreased 12.56% (SD = 9.76%) for females and 25.24% (SD = 10.39%) for males. Cortical thickness changes also varied along the rib centerline (anterior to posterior) and within cross-sectional sub-regions (i.e. superior, exterior, inferior, interior).

A cortical density-based algorithm was used to estimate cortical thicknesses of the ribs from 222 subjects. Hundreds to thousands of thickness measurements were collected from each rib and the

measurements were grouped into angular sub-sections within cross-sectional rings defined along a rib centerline. The sub-sectioning methodology employed assigned cortical thicknesses collected from all subjects to homologous rib regions and age and sex-based comparisons were made. The rib cortical thicknesses were implemented into age and sex-specific finite element models and used to assess rib fracture risk in MVC simulations.

References: [1] Treece, G.M. Med Image Anal, 2012, 16, p. 952-65