SPINAL HEMIEPIPHYSIODESIS INDUCES PHYSEAL HISTOMORPHOMETRIC GRADIENTS

INTRODUCTION

Unilateral growth inhibition of the spine by stapling has been shown to induce spine curvatures in a porcine model of deformity progression and treatment. The mechanism is presumed to be an increasing pressure differential. Excessive physeal compression has been shown to correlate with changes in growth plate structure and function. Therefore, staple efficacy may be determined in part by the extent of changes in chondrocyte morphology across the vertebra. The purpose of this study was to test the hypothesis that the heights of the physeal hypertrophic zones and chondrocytes were directly related to the distance from the staple. Differences in disc width were also determined.

METHODS

Custom spine staples were implanted into the left side of the mid-thoracic vertebrae of 7 live, skeletally immature domestic pigs. Using endoscopic procedures approved by an IACUC, six staples were implanted per pig from T6-7 to T11-12. Each staple spanned an intervertebral disc and two growth plates. After surgery, the animals were maintained in individual cages for 8 weeks. The spines were then harvested for routine histology. Coronal sections were cut, photographed, fixed in formalin, and decalcified. Half vertebra sections (Fig. 1) were embedded in paraffin, cut (4 μm), and stained (H&E).

Histological and gross measures were determined for stapled level T8: unstapled level T4 served as the paired control. Variables included the height of hypertrophic cells (Hz), the height of the hypertrophic zone (Hz), and intervertebral disc width. Images were acquired via light transmission microscopy (Olympus AX80, 10x objective) and digital photography (MagnaFire S99800). Variables were measured (Photoshop) over approximately 50% of the physeal area in 4 regions: directly under the staple (~15%), and at 40%, 60%, and 80% of the distance from the stapled edge to the opposite cortex. The hypertrophic zone boundaries (Fig. 2) were identified by the first chondrocytes with an increased size relative to those of the proliferative zone, and the terminal intact chondrocytes on the metaphyseal side. A minimum of 320 Hz and 80 Hz were measured per vertebra (i.e., 80 cell heights and 20 zone heights per quartile region). Height direction was defined as perpendicular to the local epiphyseal and metaphyseal boundaries (Fig. 2, far right). Disc widths were measured from T4 to T13 at 25%, 50%, and 75% of the distance across the plane. Statistical analyses included ANOVA (SAS, Cary NC); Tukey’s studentized range test was used if a difference (α=0.05) was found in the overall models.

RESULTS

Five of the seven animals were followed for the entire 8-week period; these gained 142% of their initial weight. Two were eliminated due to complications (hemorrhage, gastric ulcers).

For the stapled vertebrae, both hypertrophic cell height (Fig. 3) and zone height (Fig. 4) decreased across the coronal plane of the growth plate, with the lowest values under the staple. The mean cell height under the staple was 85% of its contralateral side and 78% of control. For the unstapled side, Hz remained 9% below controls. Zone height under the staple was 80% of its contralateral side and 70% of control. The Hz of the contralateral side remained 13% below control. Under the staple, both cell and zone heights were significantly less than controls. No statistically significant differences were found across the control vertebrae in either variable.

The disc width of stapled vertebrae was significantly less than controls across the entire section. Disc width under the staple was 83% of contralateral and 48% of control; the unstapled side remained 44% less than control.

DISCUSSION:

Spinal hemiepiphysiodesis decreased growth plate hypertrophic zone and cell heights under the implant in a scoliosis treatment model. Physeal parameters showed a graduated response that did not dissipate completely on the contralateral side. The results, while not direct measures of cell function or absolute cell size, may be used to improve implant efficacy. While implant effects on intervertebral disc structure and function require further study, the methods may bear the clinical promise of surgical treatment of scoliosis without fusion.

REFERENCES:

ACKNOWLEDGMENTS: Support from DePuy/AcroMed and laboratory support from Ethicon Endo-Surgery is gratefully acknowledged.

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