Early Detection Of Growth Plate Change Using MR Images After Growth Plate Injury

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Introduction: Fifteen to thirty percent of children’s fractures include growth plate injuries, which can lead to different degrees of limb deformity and length discrepancy. Early detection of growth plate injury may contribute to early treatment which can prevent from limb deformity and length discrepancy. Recently, magnetic resonance imaging (MRI) studies have demonstrated changes after growth plate injuries and effects of growth plate treatments. They demonstrated premature closure not only at injured parts but also at uninjured parts of growth plates. The purpose of this study was, by using MRI, 1) to reveal the relationship between size of growth plate injury and start time of premature closure, and 2) to reveal the relationship between limb length discrepancy and start time of premature closure.

Methods: Sixteen 5-week-old Japanese White rabbits were operated. A 3.0 mm drill-hole (3.0-mm group, n=8) and a 1.2 mm drill-hole (1.2-mm group, n=8) was made in the central part of growth plate of right proximal tibia. Left tibia was untreated as control. MR images were obtained 1, 4, 8, 10, and 12 weeks after operation by a 7.04 T MRI system. Coronal, sagittal, and transverse plane of gradient echo (GRE) images and proton density weighted images (PDWI) were obtained. Ratio of injured area of growth plate was measured at transverse plane of GRE image one week after operation. Growth plate height of medial and lateral uninjured part was measured on MR images at sagittal plane of PDWI. Animals were sacrificed at twelve weeks after operation. Tibial length was measured and micro-CT images of proximal tibia were obtained. All data were shown by mean ± standard deviation. The statistical difference of growth plate height and tibial length were determined by two-sided paired t test. Difference with P<0.05 was considered significant.

Results: Ratio of injured area of growth plate one week after injury of 3.0-mm and 1.2-mm group was 4.61±0.86 % and 2.31±0.80 %, respectively. Growth plate height of uninjured part of 3.0-mm group did not decrease significantly until eight weeks after injury but decreased significantly from ten weeks after injury both at medial and lateral side of growth plate (Fig.1 and 2). Medial growth plate height was 0.30±0.11 mm at injured tibia and 0.43±0.08 mm at control in ten weeks after injury, and 0.22±0.05 mm at injured tibia and 0.36±0.06 mm at control in twelve weeks after injury. Lateral growth plate height was 0.25±0.04 mm at injured tibia and 0.39±0.09 mm at control in ten weeks after injury, and 0.20±0.01 mm at injured tibia and 0.31±0.06 mm at control in twelve weeks after injury (Fig. 1a and 2a). In contrast, growth plate height of uninjured part of 1.2-mm group did not decrease significantly until ten weeks after injury but decreased significantly at twelve weeks after injury both at medial and lateral side of growth plate (Fig.1 and 2). Medial growth plate height was 0.23±0.03 mm at injured tibia and 0.38±0.06 mm at control in twelve weeks after injury. Lateral growth plate height was 0.22±0.03 mm at
injured tibia and 0.30±0.04 mm at control in twelve weeks after injury (Fig. 1b and 2b). Micro-CT images demonstrated bone bridges across the central part of all injured growth plates of 3.0-mm group but of five injured growth plates of 1.2-mm group. The remaining three injured growth plates of 1.2-mm group did not show any bone bridges. Tibial length of 3.0-mm group was 98.49±3.12 mm at injured tibia and 100.16±3.07 mm at control, which demonstrated 1.67 mm significant difference (Fig. 3a). In contrast, tibial length of 1.2-mm group was 100.50±2.34 mm at injured tibia and 101.15±2.50 mm at control, which demonstrated 0.65 mm significant difference (Fig. 3b).

**Discussion:** The present study demonstrates that size of growth plate injury determines start time of premature closure and that start of premature closure results in limb length discrepancy. It is clear that large injury of growth plate induces premature closure. However, it was difficult to detect early growth plate change after small injury using conventional imaging methods. MRI has advantage to detect growth plate changes after relatively small injury. PDWI can provide anatomical structure. We demonstrated clear images with PDWI using high resonance MRI device of 7.04 T and surface coil. Clear images made it possible to evaluate growth plate height quantitatively.

It is suggested that growth plate can tolerate a certain amount of injury, which is termed ‘threshold of injury’, before provoking premature closure. Several prior studies have demonstrated that threshold of injury is 7 to 9% of femur and more than 4% of tibia in rabbits. Our data showed that a 3.0-mm drill made larger injury and a 1.2-mm drill made smaller injury than 4%. It suggests that even small injury once induces premature closure of growth plate but growth plate recovers its normal activity in some way.

**Significance:** Chronological measurement of growth plate height of uninjured part can help to detect early signs of premature closure.

**Figure 1**

*Medial growth plate height of uninjured part of 3.0-mm group (a) and 1.2-mm group (b). Growth plate height of injured tibia decreases significantly at 10 and 12 weeks after injury in 3.0-mm group (a, *: P<0.05) and at 12 weeks after injury in 1.2-mm group (b, *: P<0.05).*
Figure 2

Lateral growth plate height of uninjured part of 3.0-mm group (a) and 1.2-mm group (b). Growth plate height of injured tibia decreases significantly at 10 and 12 weeks after injury in 3.0-mm group (a, *: P<0.05) and at 12 weeks after injury in 1.2-mm group (b, *: P<0.05).

Figure 3

Tibial length of 3.0-mm group (a) and 1.2-mm group (b). Injured tibial length decreases significantly by 1.5 mm in 3.0-mm group (a, *: P<0.05) and by 0.6 mm in 1.2-mm group (b, *: P<0.05).