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Basic Science

A rabbit model of lumbar distraction spinal cord injury

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Abstract

BACKGROUND CONTEXT: Excessive spinal distraction is a major cause of distraction spinal cord injury (SCI) during spinal deformity correction surgery. However, the lack of animal models of gradable and replicable distraction SCI has hampered research about how it occurs and how it can be prevented. The rabbit is a suitable choice for a model because it is more similar to humans than the rat, the most often used for studies of distraction SCI. The rabbit is readily acquired and reasonably affordable to maintain.

PURPOSE: The study aims to develop a gradable and replicable animal model of human lumbar distraction SCI.

STUDY DESIGN: This is an animal laboratory study.

METHODS: We built a spine distractor designed to vary the percentage of spine distraction by changing the movement between the bony landmarks of the spine. Anesthetized rabbits underwent surgery to expose the vertebral segments from T12 through L4. The distractor was mounted onto the T12 and L4 vertebral segments, and distraction was effected by turning the distractor's central screw to 0% (control), 10%, 20%, or 30% of the length from the L1 to the L4 vertebral segments, with eight rabbits in each group. Cortical somatosensory evoked potentials were recorded, and neurologic function was evaluated before the distractor was mounted and after the distractor was dismounted. The rabbits were killed, and spinal cord samples were taken for biochemical, histopathologic, and stereologic studies.

RESULTS: With increasing percentage distraction, the extent of distraction SCI increased as measured by recordings of cortical somatosensory evoked potentials, neurologic function, and biochemical, histopathologic, and stereologic studies.

CONCLUSIONS: Our model can be widely applied to studies of the causes of and treatment for distraction SCI.

Keywords: Animal model; Biochemical study; Cortical somatosensory evoked potentials; Distraction; Histopathologic study; Spinal cord injury; Stereologic study

Introduction

As reported as early as the 1960s, excessive spinal distraction can lead to spinal cord injury (SCI) [1], and as reported in the 1970s [2,3] SCI can occur during skeletal traction procedures. Particularly with the invention of representative spine fixation devices applied to correct spinal deformity [4–6], the danger of complications of treating SCI also increases spontaneously.

A survey conducted by the Scoliosis Research Society [3] found that about 0.7% of about 7,900 patients had acute neurologic complications resulting from the treatment of scoliosis in 1965 to 1971. In 2011, the society reported [7] that of about 5,000 cases of adult scoliosis submitted in 2004 to 2007, acute neurologic defects occurred in 1% of cases, and delayed neurologic deficits occurred in 0.5%. The incidence of complications of treating adult scoliosis did not decline accordingly during these years [7] despite the development of surgical techniques and instruments.

Neurologic deficits are inherently potential complications of spine surgery even when performed by surgeons skilled

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in treating spinal deformity [8]. It is agreed [8–11] that excessive distraction is a major cause of SCI during spinal deformity correction procedures, and that distraction SCI is common, not unusual, in such procedures.

Most studies [12,13] of SCI have used transection and contusion injuries in a rat model, even though human SCIs occur by a spectrum of primary injury mechanisms, such as spinal cord contusion from vertebral burst fracture, shearing from fracture dislocation, and stretching from distraction injuries [14]. The lack of animal models of distraction SCI has hampered research about how it occurs and how it can be prevented. Recently, a few reports described studies of traction SCI, but mostly emphasizing pathophysiological changes in rat [15–17] and cat models [18]. Thus, how distraction SCI occurs is still an underexplored field, and better animal models and methods are needed to better understand it.

To better understand how distraction SCI occurs in humans, we designed and built a spine distractor for use in a rabbit model to investigate the primary mechanism of distraction SCI. Using up-to-date technologies, including recording of cortical somatosensory evoked potentials (CSEPs), neurologic function testing, biochemical studies, and histopathologic studies by light and transmission electron microscopy, we systematically explored spinal cord changes resulting from various percentages of distraction SCI. The National Acute Spinal Cord Injury Study 2 and 3 clinical trials demonstrated that treatment within 8 hours of acute SCI is critical, and that after 8 hours have elapsed the injury is secondary [19]. Both experimental and clinical results have already shown that the mechanisms of secondary injury are consistent with those of primary injury [20]. We were not aware of a comparable critical time point after SCI in rabbits, and so we chose 8 hours after the completion of distraction as the time point for neurologic function testing.

Materials and methods

Description of the spine distractor

We designed a spine distractor (Fig. 1) built to vary the percentage of spine distraction. During distraction, the movement between the bony landmarks of the spine and the corresponding markings on the spine distractor was monitored in real time, further assuring that the percentage of distraction was accurate. A digital vernier micrometer was used to double-check the accuracy of the distance measurements. The use of clamps avoided a situation in which distraction could have occurred in a line that curved from side to side instead of along a straight line. Turning the central screw resulted in the distraction force being applied both cranially and caudally.

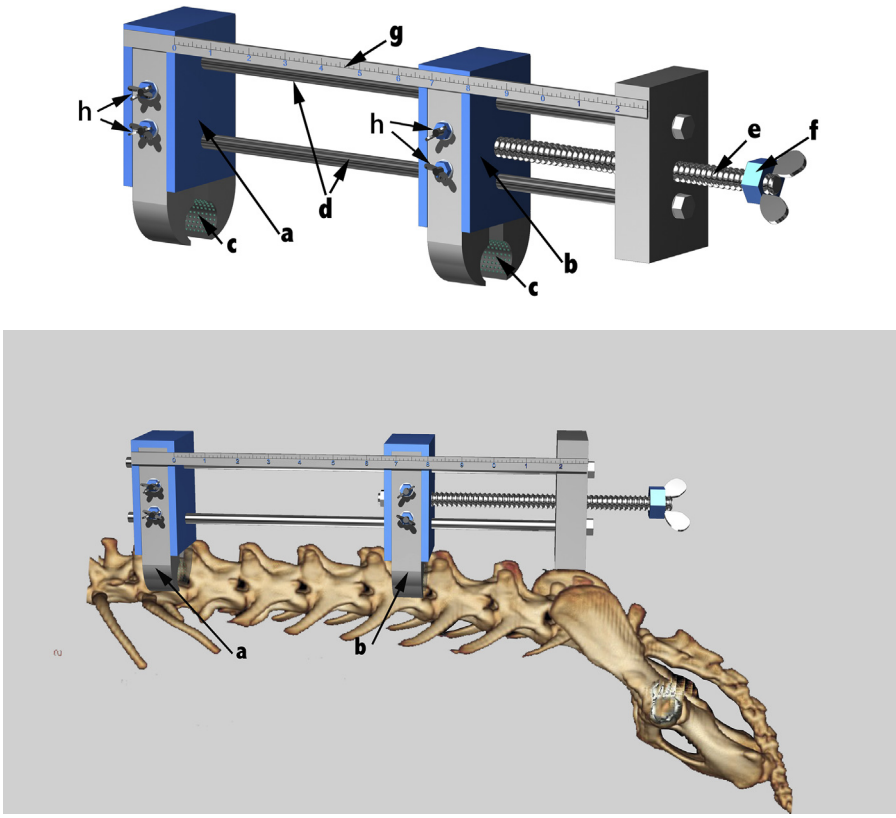

Fig. 1. Schematic view of the spine distractor. (Top) Fixed (a) and adjustable (b) clamp arms with skid-resistant, burr-like protrusions (c) at the gripping ends were attached to two sliding rods (d). The adjustable clamp arm was positioned into place by turning a central screw (e), and the distance in millimeters between the arms was set by adjusting a hexagonal screw (f) and displayed on a ruler (g). A pair of nuts (h) on each clamp arm secured the clamp arms into place on the vertebrae. (Bottom) The distractor was mounted onto a spine from the T12 vertebral segment (a) through the L4 vertebral segment (b).