Available online at www.sciencedirect.com

ScienceDirect

Biomedical Journal

journal homepage: www.elsevier.com/locate/bj

Original Article

Characterization of a novel caudal vertebral interbody fusion in a rat tail model: An implication for future material and mechanical testing

Yu-Cheng Yeh [a], Cheng-Chun Yang [b], Ching-Lung Tai [c], Tsung-Ting Tsai [a,*], Po-Liang Lai [a], Tsai-Sheng Fu [a], Chi-Chien Niu [a], Lih-Huei Chen [a], Wen-Jer Chen [a]

[a] Department of Orthopaedic Surgery, Spine Section, Musculoskeletal Research Center, Chang Gung Memorial Hospital at Linkou, Chang Gung University College of Medicine, Taoyuan, Taiwan
[b] Department of Medical Education, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan
[c] Graduate Institute of Medical Mechatronics, Department of Mechanical Engineering, Chang Gung University, Taoyuan, Taiwan

ARTICLE INFO

Article history:
Received 20 December 2015
Accepted 12 July 2016
Available online 15 March 2017

Keywords:
Interbody fusion
Rat caudal discs
Animal interbody fusion model
Mechanical testing

ABSTRACT

Background: Of the proposed animal interbody fusion models, rat caudal discs have gained popularity in disc research due to their strong resemblance to human discs with respect to geometry, composition and mechanical properties. The purpose of this study is to demonstrate an efficient, repeatable and easily accessible animal model of interbody fusion for future research into mechanical testing and graft materials.

Methods: Twelve 12-week-old female Sprague–Dawley (SD) rats underwent caudal interbody fusion of the third and fourth coccygeal vertebrae of the tail. Serial radiological evaluation, and histological evaluation and manual palpation after sacrifice were performed to assess the fusion quality. Mechanical testing of functional units (FUs) of non-operated and operated segments was compared using a three-point bending test.

Results: At postoperative 12 weeks, callus formation was observed at the fusion sites in all rats, with the mean radiological evaluations of 2.75/3 according to the Bransford classification. Newly formed bone tissue was also observed in all rats with the mean histological score of 5.85/7, according to the Emery grading system. No palpable gaps and obvious change of bending stiffness was observed in the operated segments. The mean bending stiffness of the FUs was statistically higher than that of the control FUs (26.57 ± 6.71 N/mm vs. 12.45 ± 3.21 N/mm, $p < 0.01$).

Conclusion: The rat caudal disc interbody fusion model proved to be an efficient, repeatable and easily accessible model. Future research into adjuvant treatments like growth factor injection and alternative fusion materials under conditions of osteoporosis using this model would be worthwhile.

* *Corresponding author*. Department of Orthopaedic Surgery, Spine Section, Chang Gung Memorial Hospital at Linkou, 5, Fusing St., Gueishan, Taoyuan 333, Taiwan.
E-mail address: tsai1129@gmail.com (T.-T. Tsai).
Peer review under responsibility of Chang Gung University.
http://dx.doi.org/10.1016/j.bj.2016.07.002

At a glance commentary

Scientific background on the subject

Rat caudal discs have gained popularity in disc research due to their strong resemblance to human discs.

What this study adds to the field

This study has demonstrated a rat caudal disc interbody fusion model, which is efficient, repeatable and easily accessible.

Interbody spinal fusion is currently the most commonly performed surgical procedure for a number of spinal conditions, including degenerative disc disease (DDD), spondylolisthesis, and spinal deformity. All can potentially cause compression, stretching or angulation of the nerve roots, and lead to radiculopathy or myelopathy [1–3].

Spinal stability is restored by fusing two or more vertebrae together with interbody spacers, consisting of bone autografts, allografts or synthetic materials. Then, pedicle screw fixation provides supplemental stabilization, and dynamically restores lumbar lordosis in which interbody spacers serve as a cantilever [4]. Also, interbody fusion with the use of pedicle screw fixation has been reported to significantly improve fusion rates [5,6].

Previous studies have proposed several animal models to study interbody fusion with adjuvant treatment; for example, anterior lumbar interbody fusion with platelet-rich plasma (PRP) in a porcine model, lumbar interspinous process fusion with beta-tricalcium phosphate and recombinant human bone morphogenetic protein-2 (rhBMP-2) in a rabbit model, and posterior lumbar fusion with hyperbaric oxygen (HBO) therapy in a rabbit model [7–9]. In addition, the effects of anti-resorptive agents, including alendronate and zoledronic acid, in interbody fusion have also been investigated [9,10].

In spinal fusion animal models, lumbar discs have been the most commonly studied; however, rat caudal discs have recently become an attractive model in disc research due to their strong resemblance to human discs, with regard to geometry, composition and mechanical properties [11,12]. The purpose of this study is to demonstrate an efficient, repeatable and easily accessible animal model of interbody fusion for future research into mechanical testing and graft materials.

Methods

Study design

This study was approved by the Animal Care and Ethics Committee of our institute. 12-week-old female Sprague–Dawley (SD) rats were obtained from the Laboratory Animal Center of our institute, and were housed in environmentally controlled cages. The study protocol was designed in accordance with the guidelines of the National Research Council for the Care and Use of Laboratory Animals.

All the rats underwent caudal interbody fusion of the third and fourth coccygeal vertebrae of the tail, and an X-ray assessment of each rat tail was conducted. Radiological evaluation, manual manipulation and histological evaluation were performed to assess fusion quality.

Operative technique

Inhalational general anesthesia with 2% isoflurane was administered before the operation. The rat was placed in a lateral recumbent position, and an approximately 2.5 cm dorsal skin incision was made. In order to obtain full exposure of the caudal vertebrae, the underlying tendons were partially removed. The caudal disc between the third and fourth coccygeal vertebrae was completely removed with a rongeur. Grafton DMB®, a commercial bone allograft containing demineralized bone matrix, was placed in the disc space as fusion material. Finally, the wound was closed in layers with sutures. In addition, to stabilize the surgical site, a sterile silicon drainage tube was attached to the rat tail. The tube was cut in half horizontally, glued to the rat tail by super glue, and further fixed with surgical suture. An intramuscular injection of 80-mg cefazolin and a local neomycin application on the surgical site were used to prevent postoperative infection. Each rat was housed individually in a cage to prevent other rats from inadvertently contacting the wound [Fig. 1].

Radiological evaluation

Anteroposterior and lateral plain films of the fused caudal vertebrae were taken at 0, 4, 8, and 12 weeks postoperatively. All the radiographs were taken under the same radiographic exposure factors (penetration power: 42 kV, output current: 320 mA, distance: 120 cm, and exposure time: 8 mA).

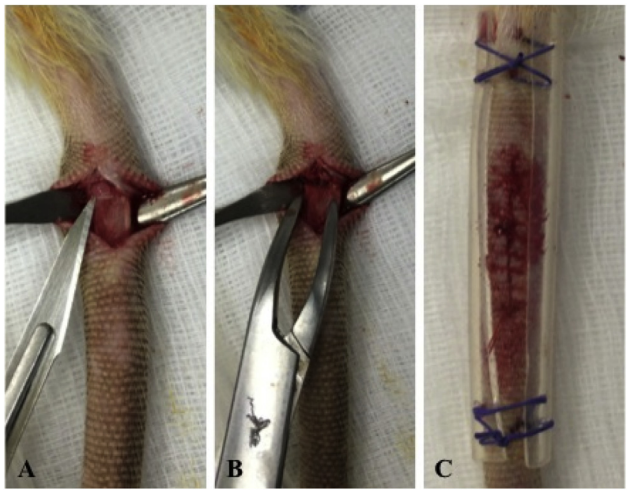

Fig. 1 Photographs showing the surgical procedure for interbody fusion at the rat tail. (A) An approximately 2.5 cm dorsal skin incision was made, and underlying tendons were partially removed. (B) The caudal disc between the 3rd and 4th coccygeal vertebrae was removed using a rongeur. (C) The wound was closed in layers with an additional sterile silicon drainage tube as protection.