Temporary Segmental Distraction in a Dog with Degenerative Lumbosacral Stenosis

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Abstract

Objectives Degenerative lumbosacral stenosis (DLSS) is characterized by intervertebral disc degeneration and causes lower back pain in dogs. Temporary distraction in rabbit models with induced intervertebral disc degeneration showed signs of intervertebral disc repair. In the present study, we assessed safety and efficacy of temporary segmental distraction in a dog with clinical signs of DLSS.

Methods Distraction of the lumbosacral junction by pedicle screw–rod fixation was applied in a 5-year-old Greyhound with DLSS and evaluated by radiography, magnetic resonance imaging, and force plate analysis before and after distraction.

Results Safe distraction of the lumbosacral junction was demonstrated, with improvement of clinical signs after removal of the distraction device. Signal intensity of the intervertebral disc showed no changes over time. T2 value was highest directly after removal of the distraction device but decreased by 10% of the preoperative value at 9 months of follow-up. Disc height decreased (8%) immediately after removal of the distraction device, but recovered to the initial value. A decrease in the pelvic/thoracic propulsive force during pedicle screw–rod fixation and distraction was demonstrated, which slowly increased by 4% compared with the initial value.

Clinical significance Temporary pedicle screw–rod fixation in combination with distraction in a dog with DLSS was safe, improved clinical signs and retained disc height at 9 months of follow-up.

Keywords
- degenerative lumbosacral stenosis
- dog
- intervertebral disc
- lower back pain
- distraction

Introduction

Degenerative lumbosacral stenosis (DLSS) is a well-described disorder in medium and large breed dogs which can manifest in patients as signs of lower back pain, lameness and neurological deficits.[1] It is a disorder of multifactorial origin, in which intervertebral disc degeneration and herniation (Hansen type II) play an important role.[1] A loss of physiological tension within the intervertebral disc may lead to segmental instability and proliferation of osseous

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and soft tissues, resulting in spinal stenosis and compression of the cauda equina. Surgical treatment consists of decompression of neural tissue, and in cases with instability, fixation and fusion of the lumbosacral junction can be performed.[1–3] Nevertheless, none of the current treatments restore the functional integrity of the intervertebral disc.

A relatively new approach to cartilage regeneration of osteoarthritic joints is temporary distraction, which originates from the field of osteoarthritis in the human ankle and knee.[4–6] Although the exact underlying mechanism is not known yet, distraction reduces the mechanical stresses on the cartilage, prevents further wear and tear of the cartilage surfaces and allows chondrocytes to initiate repair. Because of the similarities between articular cartilage and the intervertebral disc, several experimental studies have focused on segmental distraction of the intervertebral disc to provide optimal conditions for regeneration.[7] Distraction of both the intervertebral disc and facet joints can be achieved by using a pedicle screw–rod fixation device.[2,8] Nevertheless, fixation of a spinal segment alters the biomechanics of the spinal column, and secondary pathology such as adjacent segment disease and facet joint pathology are possible complications if the constructs remains in situ for a longer period.[9] Placing a fixation and distraction device temporarily could allow biological repair of the affected intervertebral disc and might prevent adjacent segment changes. In several in vivo rabbit intervertebral disc degeneration models, distraction of the intervertebral disc showed signs of tissue repair at a biological, cellular and biomechanical level.[10] To our knowledge, the effect of temporary intervertebral disc distraction in animals with spontaneous intervertebral disc degeneration has not been evaluated before. Therefore, we assessed the safety and efficiency of temporary distraction in a dog with clinical signs of spontaneous intervertebral disc degeneration.

Clinical Case

A 5-year-old, 31 kg, intact male Greyhound was presented because of signs of lower back pain. The dog showed a slight kyphosis of the vertebral column, a shortened and stiff stride of the pelvic limbs, signs of pain on palpation of the lumbosacral junction and a painful response to the lumbosacral extension test. Orthogonal radiographs of the lumbosacral area were obtained under sedation (t_{-1}) and showed minimal mineralization of the sixth lumbar (L6) to seventh lumbar (L7) intervertebral disc. Magnetic resonance (MR) images (T1-weighted [T1W], T2W, T2 maps) of the lumbosacral area were obtained under general anaesthesia (t_{-1}) using a 1.5-Tesla scanner and a Sense NeuroVascular 16 top-off coil (Phillips Healthcare, Best, The Netherlands) according to the protocol previously described.[11] On the sagittal planes, a mild protrusion at the L7–first sacral (S1) disc space was seen, and slight degeneration of the fourth lumbar (L4)–fifth lumbar (L5) and L7–S1 intervertebral discs was noted. The dog was treated with carprofen (2 mg/kg PO every 12 hours). As the dog showed no signs of improvement on medical treatment, temporary distraction of the lumbosacral segment was performed (t_0). All procedures were approved and conducted in accordance with the guidelines set by the Animal Experiments Committee of Utrecht University (experimental number: 2012.III.03.029), as required by the Dutch regulation.

Methods

Temporary distraction of the lumbosacral junction by pedicle screw–rod fixation under general anaesthesia was applied by a board-certified veterinary surgeon (BPM) and orthopaedic surgeon (FCÖ). The surgical procedure and insertion of the pedicle screws are described in detail by Smolders and colleagues.[12] Four 25-mm long, 4-mm wide titanium pedicle screws (USS Small Stature; DePuy Synthes, Zeist, The Netherlands) were inserted into the pedicles and vertebral bodies of L7 and S1 under fluoroscopy. Two 5-cm long, 6-mm wide titanium rods (USS Small Stature) connected the L7 pedicle screws with the two ipsilateral S1 pedicle screws. The rod was slightly adjusted with a rod bender (USS Small Stature) to acquire optimal alignment with both screw heads. Prior to tightening of the sleeves and nuts on the screw heads, 5-mm distraction[4] was applied with a Gelpi distractor to the pedicle screws over the L7–S1 junction. A part of the cauda equina was exposed due to partial rupture of the ligamentum flavum; hence, a splash block of morphine (Morphine; Centrafarm, Etten-Leur, The Netherlands; 0.1 mg/kg in 2 mL of 0.9% NaCl) was given and a small epidural autologous free fat graft was placed.

Distraction was applied for 3 months, based on studies in humans with severe osteoarthritis of the ankle.[6] After 3 months, the pedicle screw–rod formation was removed in a second surgery (t_3). During removal of the four pedicle screws, it was noticed that the L7 pedicle screws were more firmly seated in the bone than the S1 pedicle screws. A swab was obtained from a screw hole in the sacrum and submitted for bacteriology. Follow-up times for radiography, force plate analysis, disc height index (DHI) and MR images are depicted in ►**Table 1**. Disc height index was calculated for L7– S1 on radiographs.[13] The surface area of the intervertebral disc was measured at all-time points on lateral radiographs using Adobe Photoshop CS6 (Adobe Systems; San Jose, California, United States) thereby using the length of the vertebral body L7 as a reference. Intervertebral disc degeneration grades were evaluated on mid-sagittal slices of T2W images according to the Pfirrmann classification.[14] T2 mapping values were calculated and analysed according to a previously described method.[11] Force plate analysis was performed by measuring ground reaction forces (peak vertical force [Fz^+], peak braking forces [Fy^+] and peak propulsive forces [Fy^-]).[15]

Results

Placement of Pedicle Screw–Rod Fixation and Distraction (t_0)

After placement of the pedicle screw–rod fixation device, the dog was admitted to the surgical ward and treated intravenously (IV) with fentanyl (Fentanyl; Bipharma, Hameln

Table 1 Follow-up schedule

Time	Time point (t_{month})	Radiographs	Force plate analysis	MRI
Preoperatively	t_{-1}	Yes	Yes	Yes
At placement of distraction device	t_0	Yes	No	No
At removal after 3 months of distraction	t_3	Yes	Yes	Yes
3 months	t_6	Yes	Yes	No
9 months	t_9	Yes	Yes	Yes

Abbreviation: MRI, magnetic resonance imaging.

Pharmaceuticals, GmbH, Gloucester, United Kingdom; 4 µg/kg/h IV), ketamine (Ketamine; Vétoquinol, Lure Cedex, France; 4 µg/kg/min IV), carprofen (Carprofen; AST Farma, Oudewater, The Netherlands; 4 mg/kg IV) and amoxicillin/clavulanic acid (Amoxicillin/clavulanic acid; Sandoz GmbH, Kundl, Austria; 20 mg/kg every 8 hours). The fentanyl/ketamine was tapered down the next day and after methadone (Methadone; Eurovet Animal Health B.V., Bladel, The Netherlands; 0.2 mg/kg IV) was given once, oral tramadol (Tramadol; Centrafarm, Etten-Leur, The Netherlands; 3 mg/kg PO every 8 hours) was started. The dog was clinically evaluated daily by a veterinarian (NW), and pain was assessed according to the short form of the Glasgow composite pain scale. One day after surgery, swelling at the level of the popliteal lymph nodes of both stifles was noticed, most likely associated with congestion or local bleeding. Four weeks after insertion of the pedicle screw–rod fixation distraction device, the dog showed mild kyphosis and stiffness of the caudal lumbar area, less severe than at the initial clinical examination (t_{-1}). Radiographs of the lumbosacral area showed no abnormalities. The dog was treated with carprofen (4 mg/kg PO every 24 hours) for 14 days. The dog's activity was restricted for 6 weeks and was only allowed to walk on a leash for 10 to 15 minutes four times a day.

Removal of Pedicle Screw–Rod Fixation (t_3)

After removal of the pedicle screw–rod fixation device, the dog was admitted to the surgical ward and was treated IV with dexmedetomidine (Dexmedetomidine; Vétoquinol, Lure Cedex, France; 1 µg/kg/h IV for 24 hours, buprenorphine Buprenorphine; AST Farma, Oudewater, The Netherlands; 20 µg/kg IV every 6 hours) for 2 days, and orally with carprofen (4 mg/kg PO every 24 hours) for 10 days. After the buprenorphine was stopped, tramadol (3 mg/kg PO every 8 hours) was started and given orally for 14 days. Again, the dog's activity was restricted for 6 weeks, and was only allowed to walk on a leash for 10 to 15 minutes four times a day. Recovery after implant removal was uneventful. The bacteriology swab tested negative. Clinical examinations during the follow-up period showed no pain response to superficial palpation and only a mild response to deep palpation of the lumbosacral joint. Rescue analgesic intervention was not needed.

Radiographs

Radiographs obtained during or after distraction showed no evidence of implant failure or migration. Disc height index in L7–S1 remained unchanged after distraction (t_{-1} vs t_0) (►**Fig. 1**). At 3 months of distraction, immediately after removal of the device (t_3), and at 6 months (t_6), DHI decreased by 8%. At 9 months (t_9), the DHI returned to the initial value (t_0). Although the DHI was not different before and after distraction (t_{-1} vs. t_0), assessment of the complete intervertebral disc revealed distraction of the dorsal part of the intervertebral disc and compression of the ventral part (►**Fig. 1**). The intervertebral disc surface area on lateral radiographs increased by 15% and 20% at t_0 and t_3, respectively, compared with t_{-1}. At 6 (t_6) and 9 (t_9) months, the intervertebral disc surface area decreased to values slightly higher, that is 1% and 2%, respectively, than the initial value at t_{-1}.

Magnetic Resonance Imaging

At 9 months (t_9), that is 6 months after the removal of the distraction device, fibrous tissue with a low signal intensity on both T1W and T2W images surrounding both facet joints of L7–S1 was noticed. Furthermore, tissue was noted surrounding the facet joints of L6–L7 with a high signal intensity on T1W images and a low signal intensity on T2W images, consistent with either fibrous or fat tissue. Pfirrmann scores of the L7–S1 intervertebral disc remained grade II at all-time points. The T2 mapping value was highest (208.7 ± 46.3) directly after the removal of the distraction device (t_3) but decreased to a value at 6 months after removal (t_9, 148.8 ± 58.9) which was lower than preoperative value (t_{-1}, 165.9 ± 46.4) (►**Fig. 1**).

Force Plate Analysis

Before distraction, the pelvic/thoracic (P/T) peak vertical force (Fz^+) and P/T peak braking force (Fy^+) were slightly higher than reference values in control animals, whereas the P/T peak propulsive force (Fy^-) ratio was comparable with that in dogs with DLSS as described by Suwankong and colleagues (►**Fig. 2**).[16] A decrease of 16% of the P/T Fy^- was noticed after 3 months of distraction. The P/T Fy^- slowly increased after the distraction device was removed and resulted in a value at 9 months follow-up that was 4% higher than the initial preoperative P/T Fy^- value.

Discussion

Safe temporary fixation and distraction of the lumbosacral intervertebral disc and facet joints by using pedicle screw–rod fixation was demonstrated in a dog with clinical signs due to DLSS with early intervertebral disc degeneration.

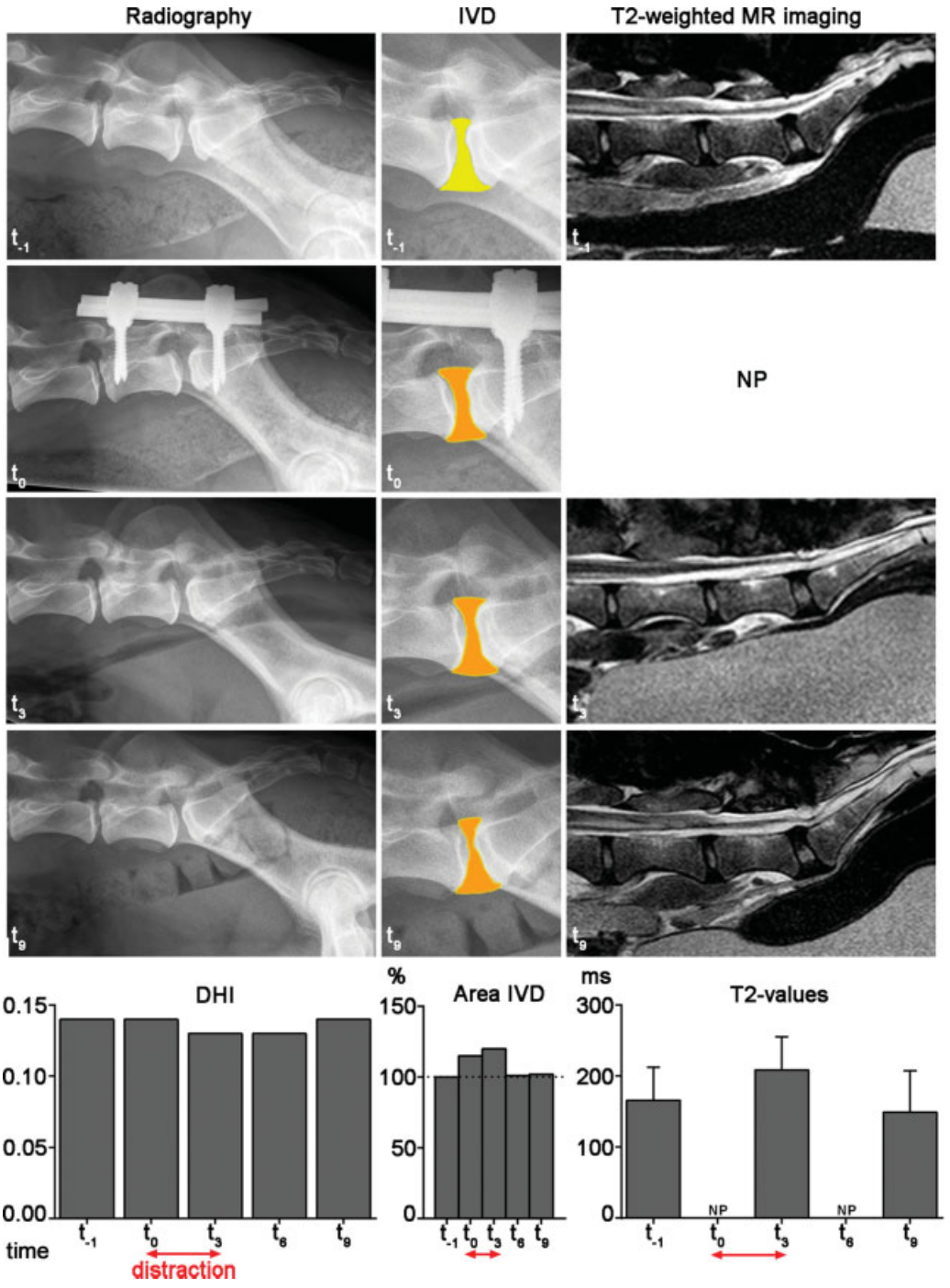

Fig. 1 Lateral radiographs and lateral T2W magnetic resonance images of the lumbosacral junction of a dog with degenerative lumbosacral stenosis exhibiting lower back pain and concurrent mild degeneration of the L7–S1 IVD. Temporary distraction of the lumbosacral junction was applied with the aid of pedicle screw-rod fixation. The dog was evaluated at the following time points: before (t_{-1}), directly after application of the distraction device (t_0), after 3 months of distraction at removal of the device (t_3), and again at 6 (t_6) and 9 months (t_9) of follow-up. DHI and area of the IVD were measured on lateral radiographs, with t_{-1} set at 100%. *T2* values are mean (±SD) *T2* mapping values in the NP, obtained at the same time as the T2W images. DHI, disc height index; IVD, intervertebral disc; NP, not performed; SD, standard deviation; T2W, T2-weighted.

Signal intensity of the intervertebral disc on T2W MR images during and after temporary static distraction remained unchanged. Furthermore, the T2 mapping value, a quantitative MR imaging parameter shown to be more sensitive in detection of qualitative changes over the course of intervertebral disc degeneration, was highest directly after removal of the distraction device, indicative of an increase in water content,[17] but decreased by 10% at 9 months follow-up compared with the preoperative value. Despite the initial increase in the T2 mapping value, DHI slightly decreased (8%) after removing the distraction device but recovered to the preoperative value at 9 months follow-up. Nevertheless, precision of these results could not be indicated in only one dog. Tellegen and colleagues recently published a

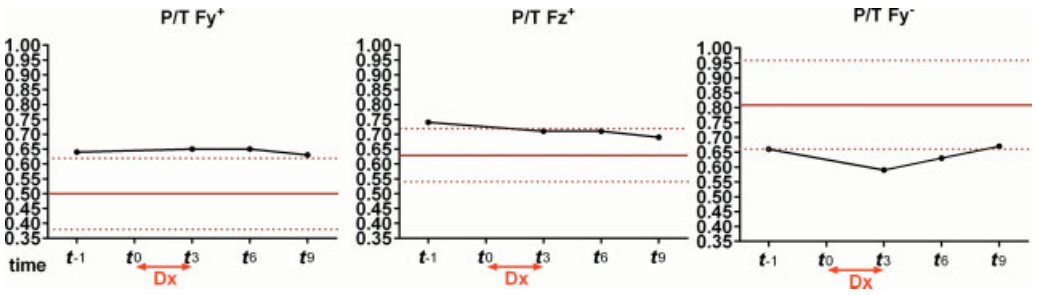

Fig. 2 Line curves of the pelvic/thoracic ratio of the braking force (Fy+), vertical force (Fz+) and propulsive force (Fy-) in a dog with degenerative lumbosacral stenosis, in which pedicle screw-rod fixation in combination with temporary distraction was applied. The dog was evaluated at the following time points: before (t_{-1}), directly after application of the distraction device (t_0), at removal of the device after 3 months of distraction (t_3), and again at 6 (t_6) and 9 months (t_9) follow-up.

translational study in which client-owned dogs with chronic back pain were treated with a local drug delivery system releasing celecoxib, a COX-2 inhibitor.[18] These client-owned dogs were large breed dogs within the same body size and weight range as the dog in the present study. In these dogs, T2 maps were generated with the same protocol as described in this case report. The T2 mapping values in non-injected discs in those dogs showed a maximum variation in measurements of 15%. T2 map values in our case report increased by 21% after distraction, but eventually decreased by 11% compared with the reference value at t_0. Based on these numbers, we cannot rule out that the T2 mapping values in this one individual dog reflect a physiological variation instead of a change related to the treatment.

The fibrotic changes of the facet joints at both levels may be caused by the operative trauma, immobilization of these joints during the distraction period, an increase in biomechanical loading after removal of the static unloading device or some combination of these factors. As shown in people, shortening of the distraction period to 4 or 6 weeks might reduce formation. Furthermore, a shorter period most likely has similar regenerative effects, as biomarker-turnover of cartilage and bone tissue increases within the first 4 weeks of joint distraction, and thereafter stabilizes.[19]

In a rabbit intervertebral disc compression model resulting in a decreased signal intensity of the intervertebral disc on MRI, temporary dynamic distraction showed re-establishment of the physiological signal intensity on MRI. Contrasting findings between the dog and the rabbit model were observed due to several aspects. First, the type of distraction device differed in both animal studies, that is static in the dog, versus dynamic in the rabbit model. Dynamic loading has been shown to maintain the balance between anabolic and catabolic pathways within the extracellular matrix.[20] In a more static loading condition, decreased nutrient supply might have limited extracellular matrix synthesis, resulting in a lower expression of water-binding proteins, and a consequently lower signal intensity on T2W MRI. Furthermore, pins in the rabbits were placed perpendicular to the spinal segments. Pedicle screws in the dog could not be placed strictly perpendicular, due to anatomical limitations and safe pedicle corridors,[11] eventually resulting in distraction of the dorsal, but compression of the ventral part of the intervertebral disc space. Finally, differences in genetic background between rabbit and dog, or the stage of intervertebral disc degeneration or a combination of both may have contributed to the difference.

Dogs with DLSS have decreased propulsive forces of the hindlimbs (P/T Fy^- ratio).[16] The initial decrease in the P/T Fy^- in this dog during pedicle screw–rod fixation and distraction is in line with findings in literature,[2,12] and is most likely associated with a reduction in pelvic limb muscle strength and volume within the rehabilitation period. Shortening of the distraction period might decrease post-treatment stiffness and may reduce this initial decrease in P/T Fy^-, and/or accelerate improvement. In previous in vivo dog studies, the P/T Fy^- ratio initially decreased after fixation of the lumbosacral joint by using pedicle screw–rod fixation at 6 and 12 weeks, but increased at 6 months after surgery.[2,12] Interestingly, the propulsive forces of the dog also improved 9 months after the removal of the pedicle screw–rod fixation + distraction device. A longer follow-up time is needed to give more insight into the long-term outcome.

A commercially available pedicle screw–rod fixation device was used that is designed to fixate a spinal segment permanently. Two limitations of such a device are the unquantified amount of distraction applied during surgery, and a relatively invasive insertion and removal procedure. Distraction of stifle joints in dogs,[4] and intervertebral discs in rabbits,[21] has been performed using external fixators. In this procedure, an external device, including a calibrated spring, serves as a distractor and is attached to bone pins that are placed on either side of the joint under fluoroscopic guidance. By using a spring, a constant controllable dynamic decompression over the entire unloading time can be established, and all implants can be removed via a minimal invasive surgical procedure. Currently, none of the aforementioned devices are commercially available, and need to be customized for the canine spine.

The current study is a pilot study investigating the application of temporary distraction as a treatment for lower back pain related to intervertebral disc degeneration, in a similar way as distraction has been used to treat degenerative osteoarthritis.[4–6] At this moment, clinical efficacy of the distraction

technique for lower back pain has not been proven, the technique remains technically challenging as described in a recent article where the implants were used for permanent fixation and distraction[22] and a second surgery is needed to remove the implants. Also, there is a need for implant development for temporary distraction. Therefore, this pilot study needs to be interpreted with care; it is a starting point, but its clinical efficacy needs to be investigated in future studies with longer follow-up times and more patients.

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Conflict of Interest
None.

Author Contributions
SMvG, FCÖ, MAT and BPM participated in the study conception. All authors were involved in the study design and acquisition, analysis and interpretation of data, and in the drafting and revision of the manuscript. All authors have read and approved the final manuscript.

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