INTRODUCTION:
Multi-level fusion is often performed to stabilize the cervical spine in cases of severe trauma or degeneration. Posterior fusion historically has required lateral mass screw fixation with plating. However, plates are often difficult to position and secure. Thus, rod-screw fixation constructs have become more prevalent. Transverse connectors are often added to rod-screw constructs in an attempt to increase their stability. Insufficient data exists to determine if these connectors increase construct stiffness in multi-segment fusion procedures, and if so, how many connectors are needed. The objective of this study was to determine if the addition of transverse connectors (TC) to a rod-screw fixation construct results in further stabilization of the cervical spine.

METHODS:
Eleven fresh frozen human cervicothoracic spines (C2-T1) were obtained from the Mayo Anatomical Bequest program. Specimens were thawed and kept moist with saline. All non-ligamentous soft tissues were removed. C2 and T1 were potted in fixtures designed to integrate with a custom spine simulator apparatus with T1 oriented in neutral position. Prior to experimentation, bi-cortical lateral mass screws were placed from C3 to C6 and pedicle screws (DePuy Spine, Inc., Raynham, MA) were placed at C7 bilaterally. Placement was verified with coronal and lateral fluoroscopy. The screws did not interfere with any testing procedures when they were not connected to rods.

Potted specimens were attached to a custom spine simulator (Fig. 1A) and tested to ± 2.0 N-m torque in flexion/extension (FE), left/right lateral bending (LB), and left/right axial rotation (AR). Three-dimensional kinematic measurements were obtained using an Optotrak™ Certus optoelectric data acquisition system (Northern Digital Inc., Ontario, Canada) and accompanying software (The Motion Monitor™, Innovative Sports Training, Chicago, IL, USA). Active Optotrak marker triad sensors were rigidly fixed to each vertebral body (C2-T1).

Each spine was tested during each step of a 3 step progressive destabilization procedure with no TC, 1 TC and 2 TCs. The order of TC testing within each destabilization step was randomized. Thus there were seven conditions: (1) Intact spine; (2) C3-C6 wide laminectomy destabilization (WL); (3) C3-C7 fixation with rod-screw construct and addition of no transverse connector (0TC), one TC connecting C5 screws (1TC), and two TCs connecting C4 and C6 screws (2TC) in randomized order; (4) Destabilization with WL and partial facetectomy at the C4-C5 and C5-C6 levels (WL+50F); (5) C3-C7 fixation with rod-screw construct and 0, 1, or 2 TCs; (6) Destabilization with WL and complete facetectomies at C4-C5 and C5-C6 (WL+100F); and (7) C3-C7 fixation with rod-screw construct and 0, 1, or 2 TCs in randomized order. The construct with 2 TCs is shown in Fig. 1B.

DISCUSSION:
We evaluated the role of transverse connectors in cervical spine rod-screw fixation constructs. Flexion and extension were not significantly affected. Regardless of the amount of destabilization of the spine (Fig. 2), TCs provided similar stabilization (Fig. 3). Axial rotation was most affected and was significantly reduced by adding one or two TCs, with two TCs being significantly more restrictive than one. Clinically, the use of TCs for highly destabilized cervical spines may be appropriate. Two TCs resulted in the stiffest construct; however, the use of only one TC still provided increased stiffness compared to no TCs, and thus may provide adequate stabilization.

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