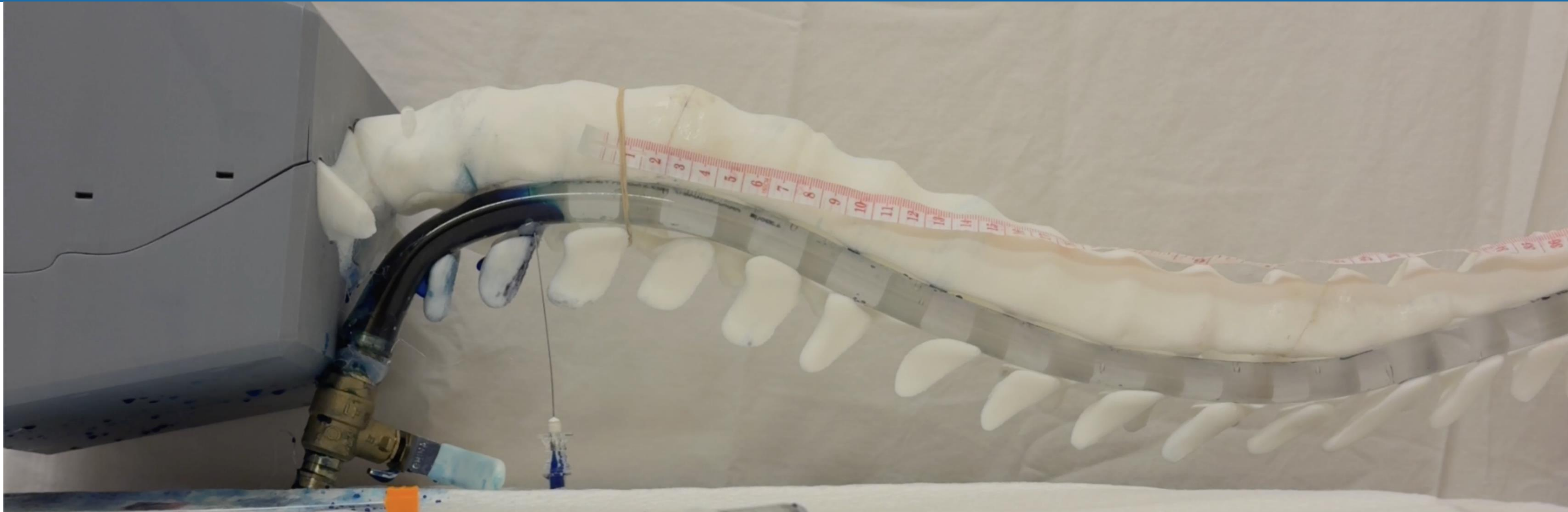


Visualizing Intrathecal Drug Spread With a 3D-Printed Spine Model: Effects of Trendelenburg and Pre-Supine Sitting Duration

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Background

Clinical Context

- Spinal anesthesia for cesarean delivery requires a reliable T4–T6 dermatomal level
- Patient positioning after spinal injection influences cephalad spread of hyperbaric local anesthetic
- Trendelenburg tilt may augment spread; delayed supine positioning may reduce it
- Intrathecal drug spread cannot be directly visualized in clinical practice

Study Rationale

- Enables systematic, reproducible testing of positioning and timing variables
- Hypotheses:
 - *Greater head-down tilt → increased cephalad spread*
 - *Longer upright sitting before supine → reduced cephalad spread intensity*
- Primary outcomes: maximal spread level, dye intensity differences

Positioning after spinal injection is clinically important but mechanistically understudied — this model makes it directly observable

Experiment 1: Trendelenburg Tilt

5° Trendelenburg

T6–T7

31.0 ± 0.0 cm

10° Trendelenburg

T5–T6

33.3 ± 0.6 cm

15° Trendelenburg

T3–T4

40.0 ± 0.0 cm

20° Trendelenburg

C4

50.0 ± 0.0 cm

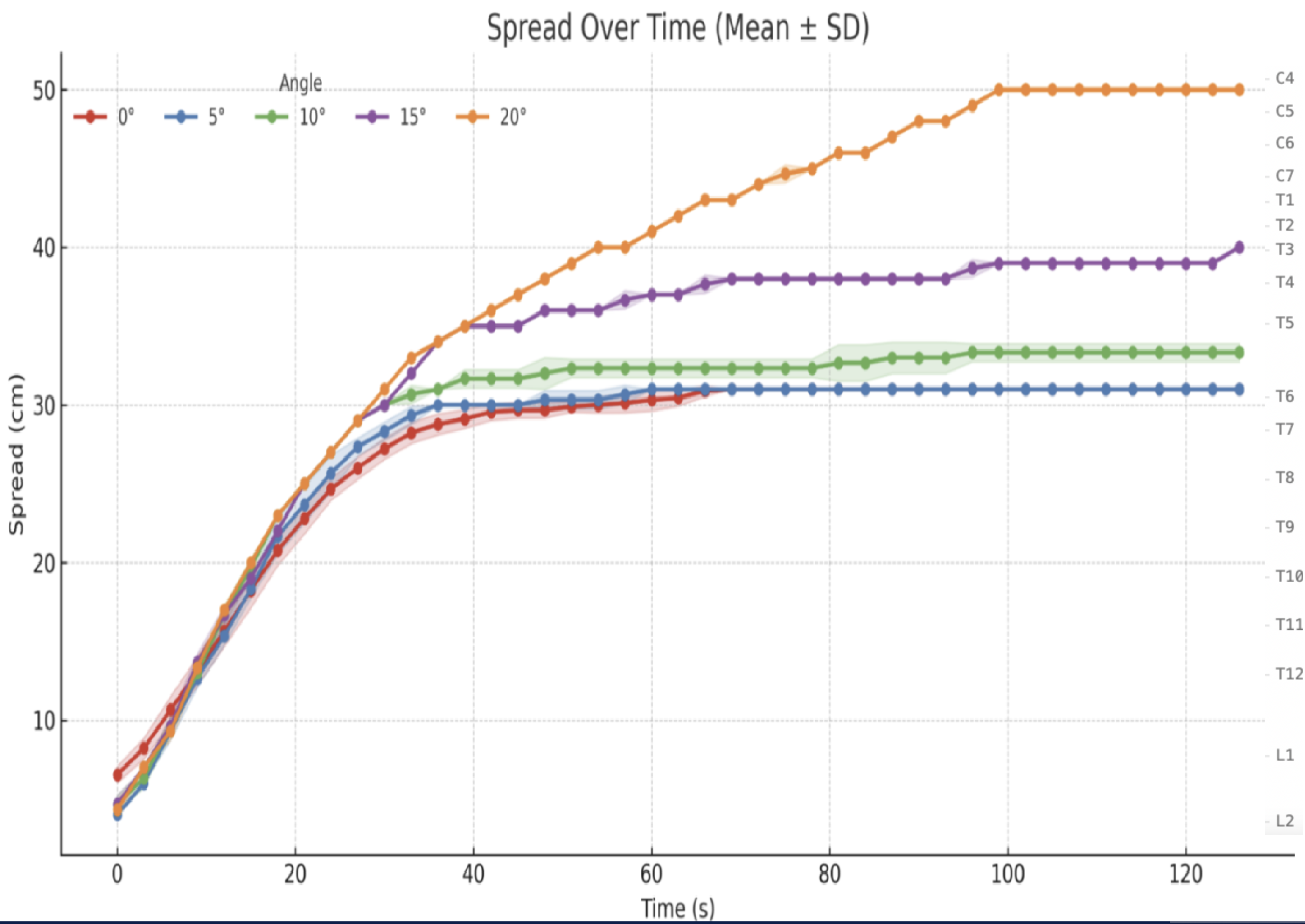
⚠ 15°: spread to T3–T4 — at the upper limit of the desired cesarean block range

⚠ 20°: spread to C4 — traversed entire spinal column, exceeding desired block level

Study Design & Methods

- Model filled with saline–glucose to approximate CSF density
- 2 mL methylene blue in 8.25% dextrose injected at L3–L4 (upright position)
- Model immediately positioned at head-down tilt: 0°, 5°, 10°, 15°, 20°
- Video recorded throughout; dye spread measured every 3 seconds
- Outcome: maximal cephalad spread (cm and vertebral level)

Figure 1: Spine Model 20° Trendelenburg



Experiment 2: Sitting Duration

Study Design & Methods

- Model remained upright for 0, 1, 3, or 5 minutes before placed supine
- Dye intensity at cephalad leading edge compared to initial injection intensity
- Expressed as percentage of maximal signal (normalized for lighting variation)
- Video analyzed with custom Python scripts: GrabCut + color thresholding
- Outcome: relative leading-edge dye intensity at each sitting duration

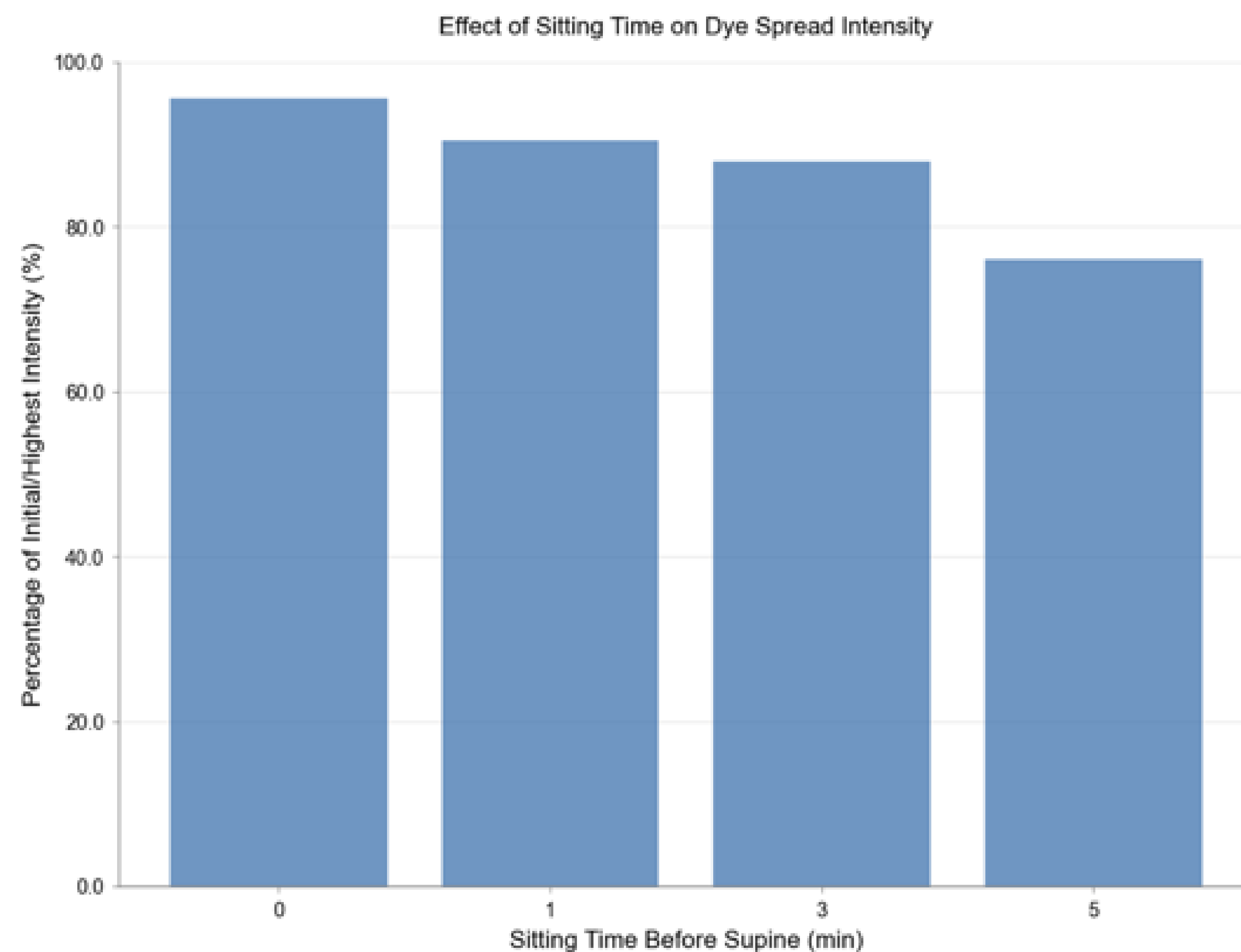
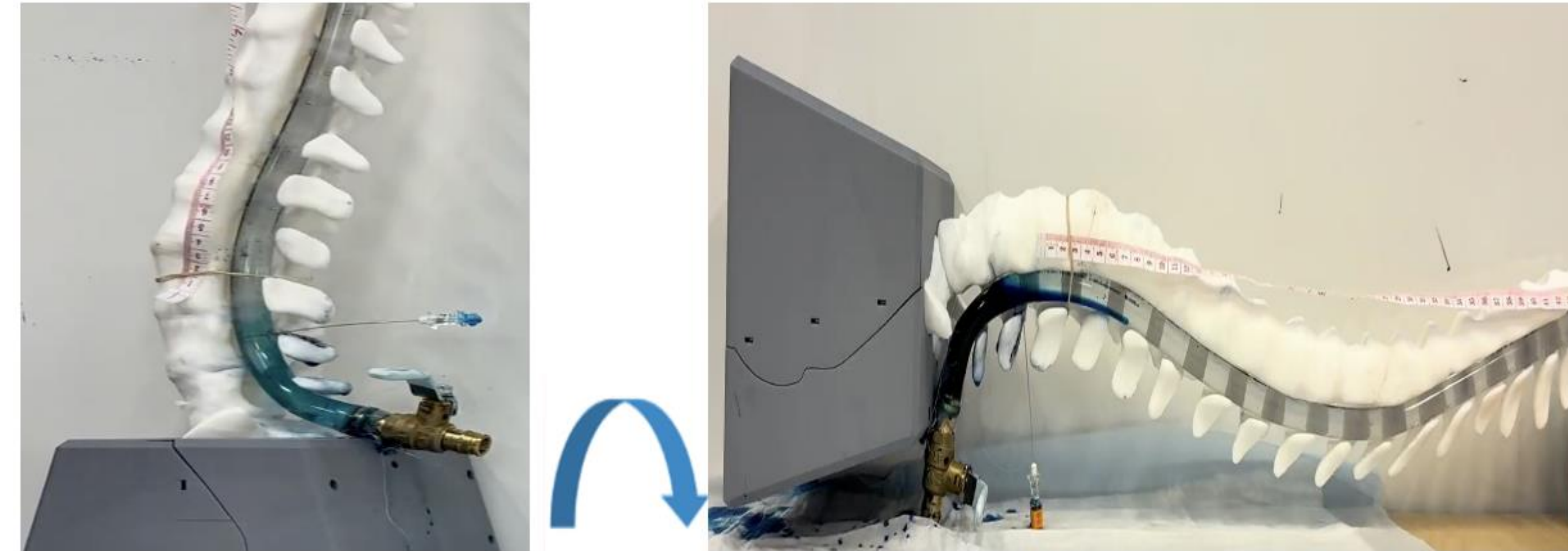


Figure 2. Spine Model Positioning and Experimental Setup



Key Findings

- Longer upright sitting before supine positioning progressively reduced dye intensity at the cephalad leading edge
- Intensity at 0 min: ~95% of initial injection signal
- Intensity at 1 min: ~90%
- Intensity at 3 min: ~88%
- Intensity at 5 min: ~76%
- Terminal cephalad spread distance remained similar across all sitting durations (~31 cm, T6–T7)
 - *Sitting time affects leading-edge dye concentration, not absolute spread distance*

Conclusions

Study Findings

- Trendelenburg $\geq 15^\circ$ markedly increases cephalad spread; 20° reached C4
- Longer upright sitting reduces leading-edge dye intensity but not final spread distance
- Terminal spread plateaued at ~ 31 cm (T6–T7) regardless of sitting duration

Clinical Implications

- Trendelenburg $\geq 15^\circ$ risks unintended high spinal block
- Delayed supine positioning may limit block height
- Model enables reproducible testing of positioning variables

Trendelenburg $\geq 15^\circ$ risks unintended high spinal; delayed supine reduces block intensity
—model can guide positioning protocols

