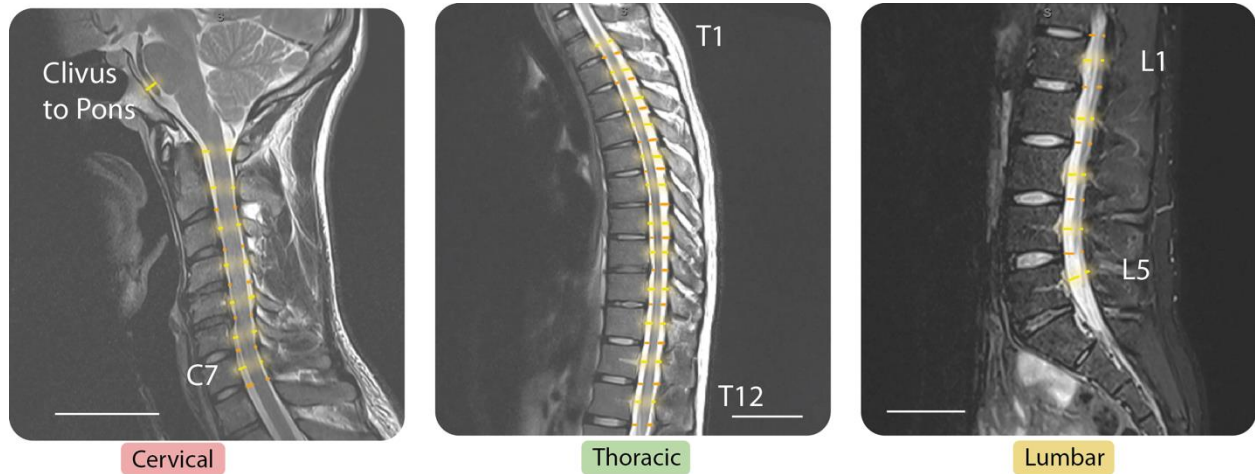


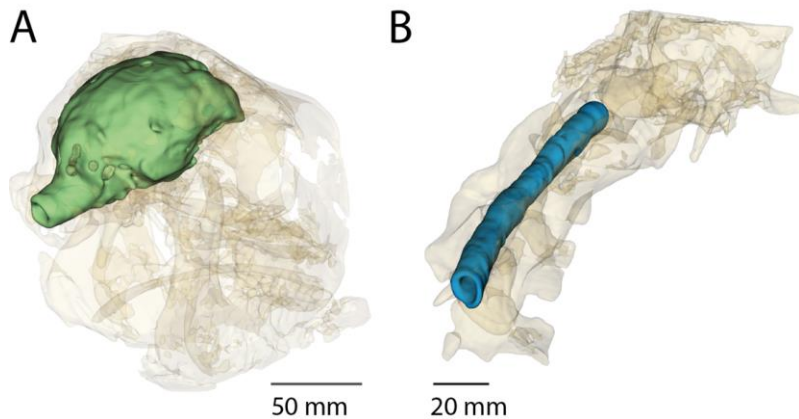
Endocisternal interfaces for minimally invasive neural stimulation and recording of the brain and spinal cord

In the format provided by the
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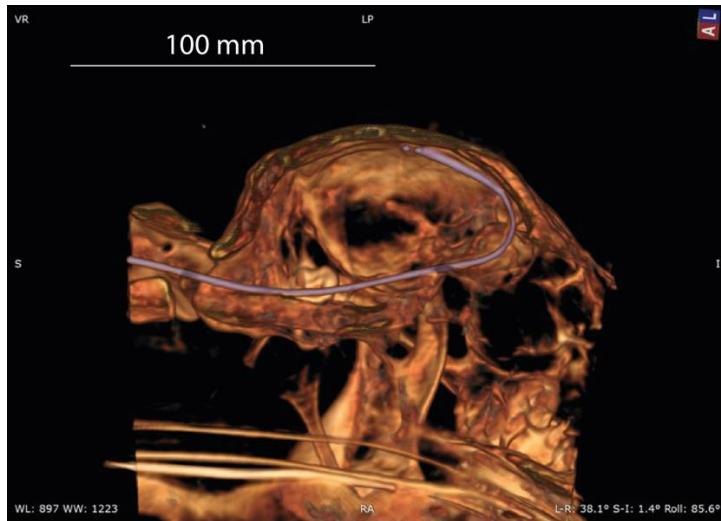
Supplementary Information:



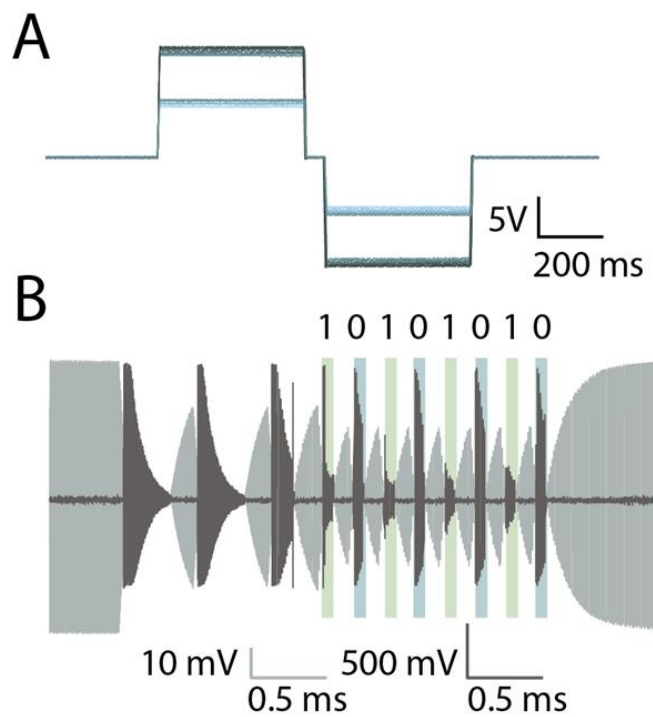
Supplementary Figure 1. Sagittal MRI images of human patients in cervical, thoracic, and lumbar regions to measure dimensions of CSF space (scale bars: cervical – 50 mm, thoracic – 50 mm, lumbar – 50 mm, yellow lines are interdisc measurements and orange lines are disc measurements).



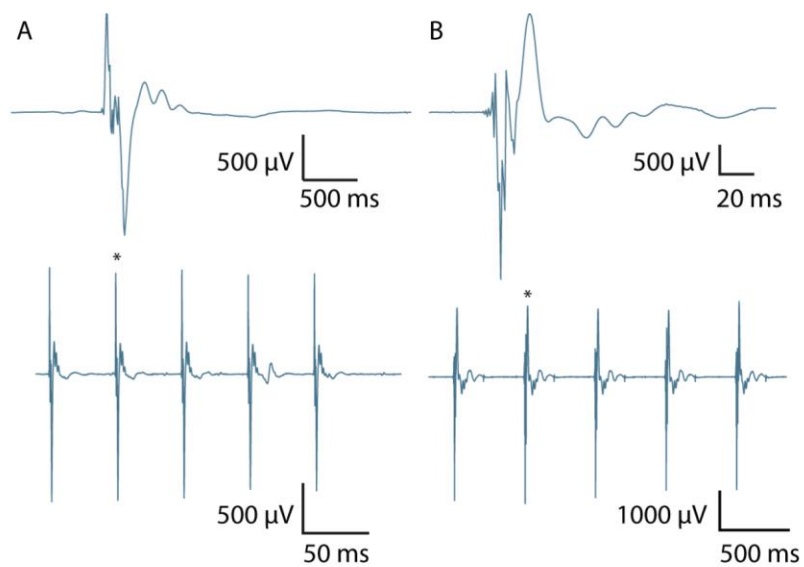
Supplementary Figure 2A. 3D reconstruction of the sheep head highlighting the CSF space (green) visualized by injecting contrast through a navigated catheter (scale bar = 50 mm). B. 3D reconstruction of the spine highlighting the subarachnoid space (blue) surrounding the spinal cord (scale bar = 20 mm).



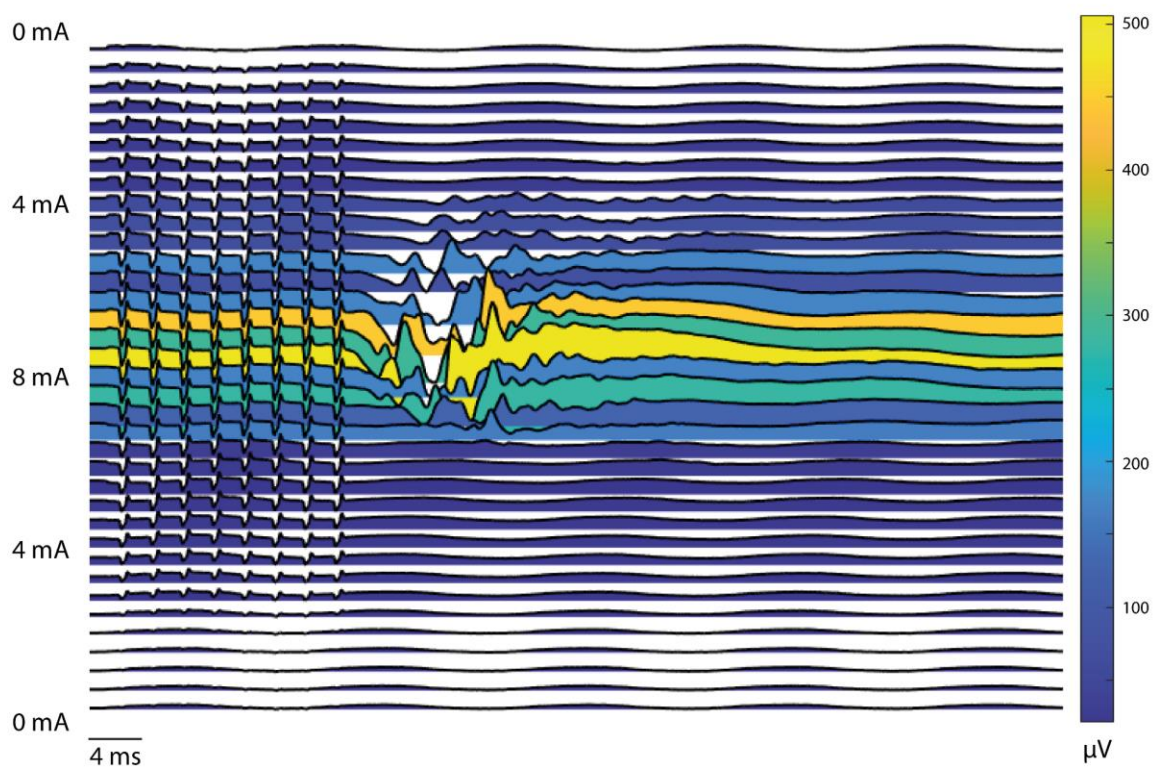
Supplementary Figure 3. 3D reconstruction of the catheter electrode going through craniocervical junction and navigating to frontal cortex of the brain (highlighted in blue, scale bar = 100 mm).



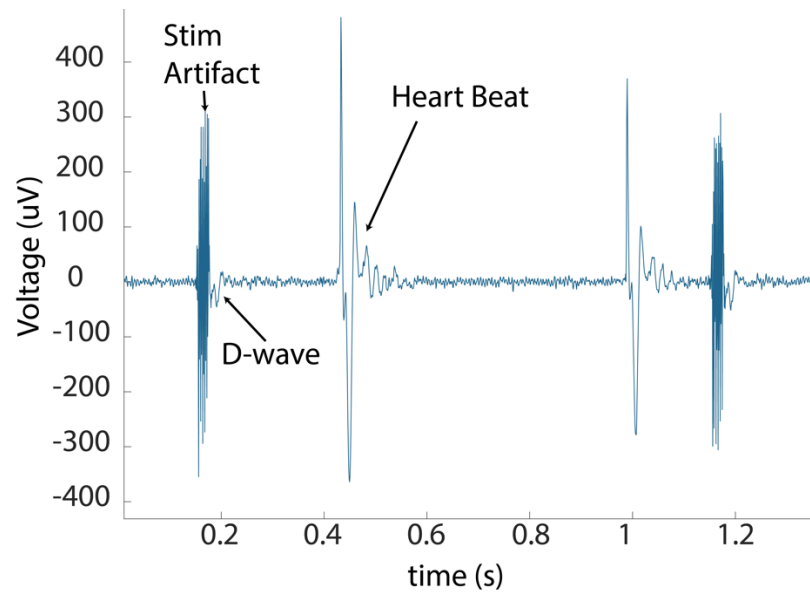
Supplementary Figure 4A. Programmable voltage-controlled stimulation pulses generated by the magnetoelectric wireless implant. B. Sample data uplink where light grey is the transmitter coil current, and dark grey represents the backscattered magnetic field.



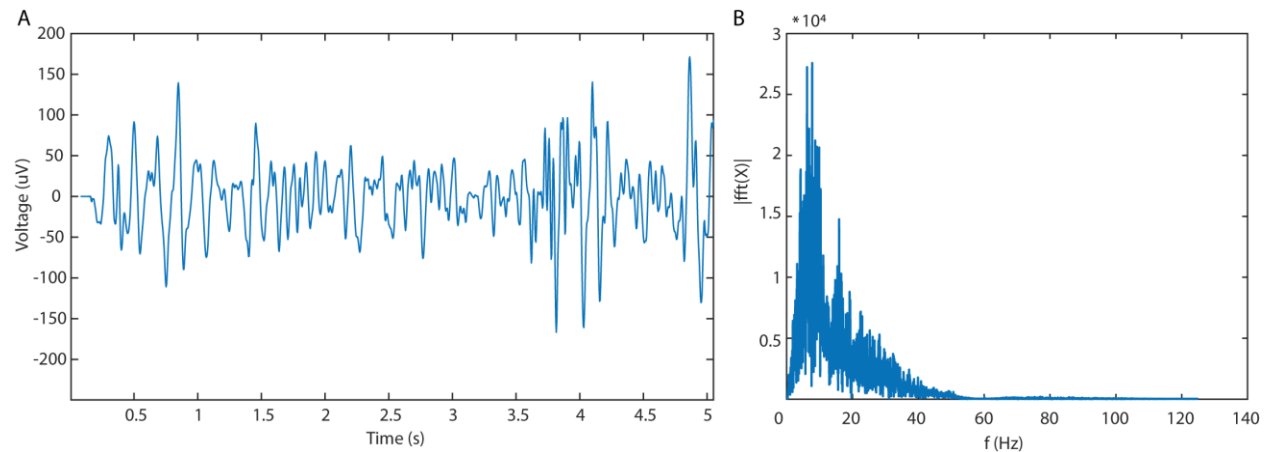
Supplementary Figure 5A. Stimulation with bipolar electrodes in the thoracic region of the spinal cord and recorded CMAPs. **B.** Stimulation with bipolar electrodes in the frontal convexity of the brain and recorded MEPs on the hind legs of the sheep.



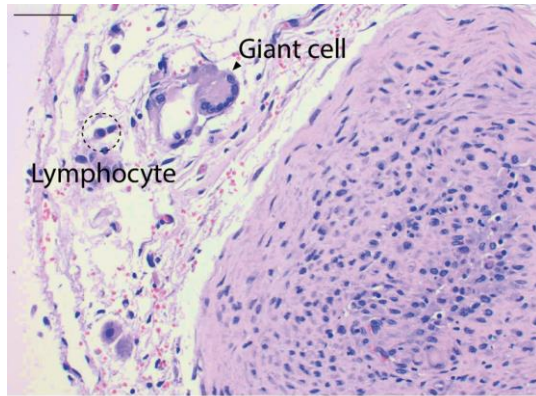
Supplementary Figure 6. Nine pulse waterfall plot showing central activation with shifting latencies with first increasing stimulation amplitude from 0 mA to 8 mA and then decreasing back down to 0 mA. Color represents the max voltage reached on the trace.



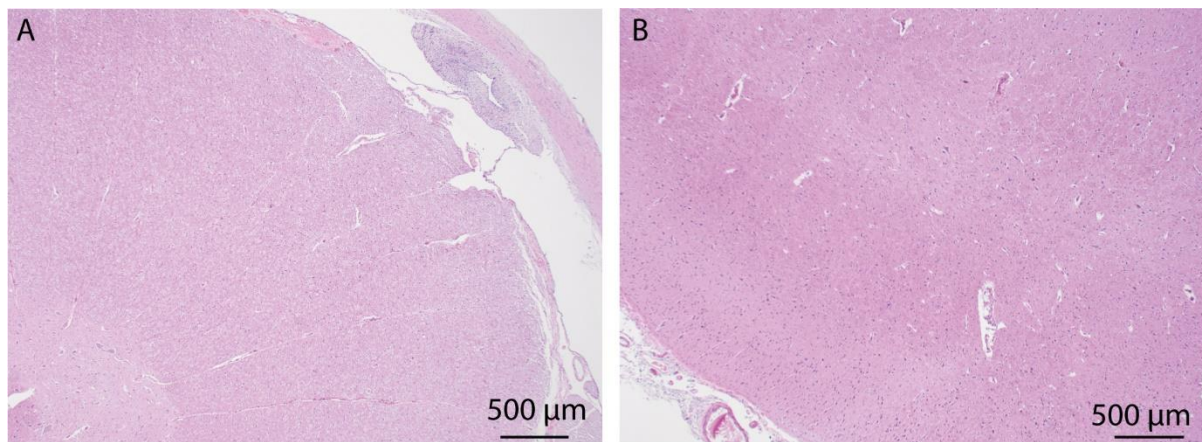
Supplementary Figure 7. Catheter recording from within the subarachnoid space surround the spinal cord where a D-wave is visible following the high frequency stimulation artifact. EKG is also visible.



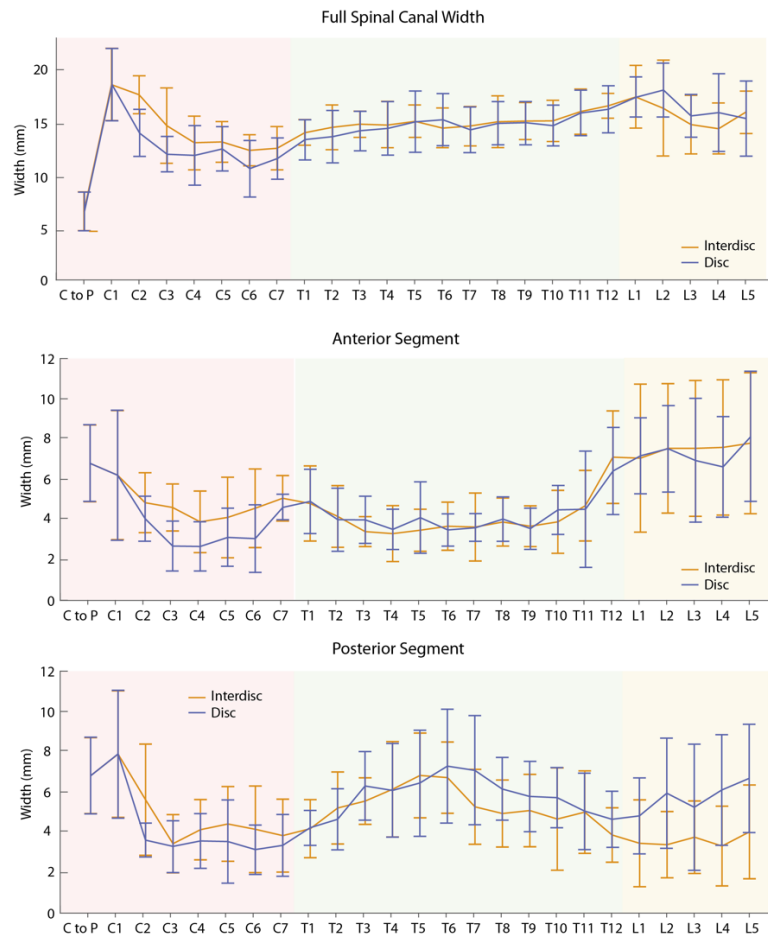
Supplementary Figure 8A. EEG recording through catheter electrode from the frontal convexity of the brain. **B.** Fast fourier transform of the EEG signal to highlight the frequency components of the signal.



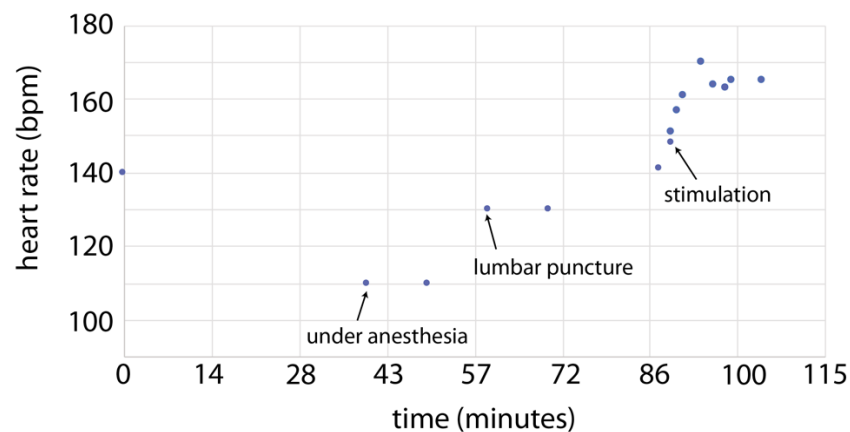
Supplementary Figure 9. High power image of lumbar epidural reactive vasculature with mild lymphocytic and histiocytic inflammation with rare foreign body-type giant cells (scale bar = 50 μ m).



Supplementary Figure 10. A Cervical spinal cord histology in survival sheep 2 showing mild inflammation in subdural space (scale bar = 500 μ m). **B.** Histology of midbrain in survival sheep 2 showing normal parenchyma and only minimal inflammation in leptomeninges (scale bar = 500 μ m).

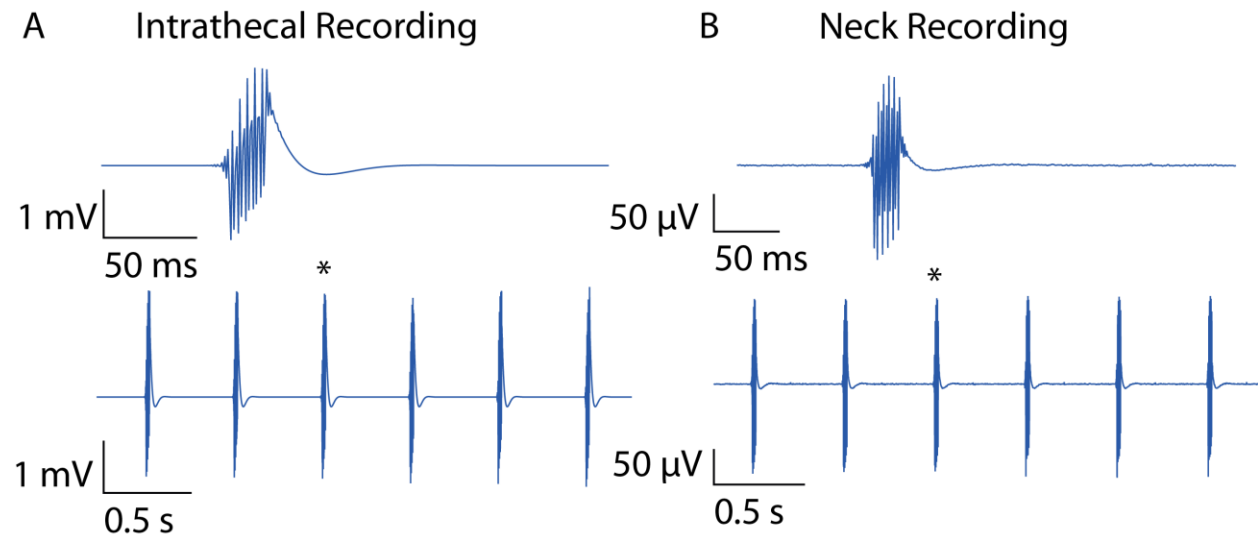


Supplementary Figure 11. Measurements of spinal canal width taken from the MRIs of human patients. Data presented in Figure 1 is the average of the anterior and posterior segments. (Blue line is measured at vertebral disc level while gold line is measured at intervertebral disc level)

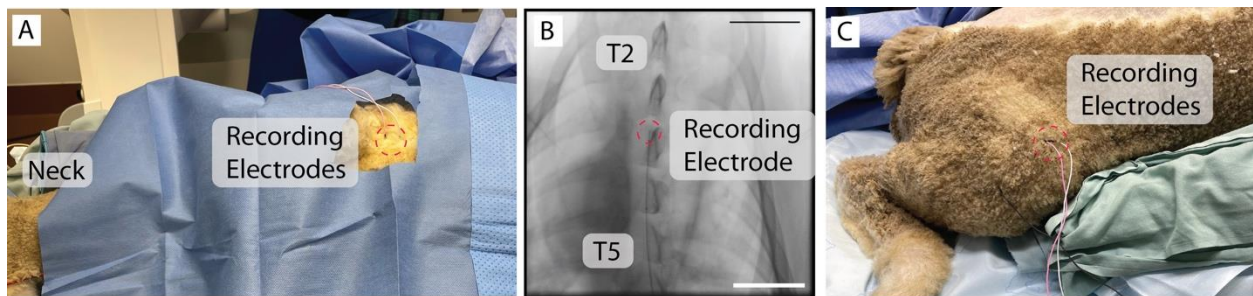


Supplementary Figure 12. Heart rate measurements from one sheep showing heart rate under anesthesia, after lumbar puncture, and during/after electrical stimulation through the subarachnoid space.

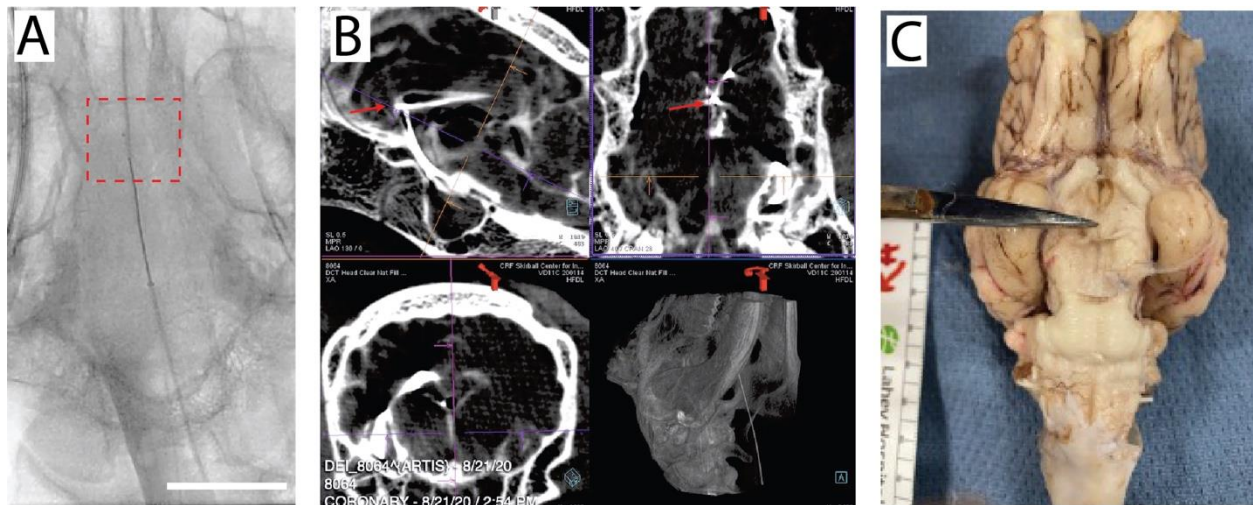
The elevation of heart rate after electrical stimulation is likely a response to pain from stimulation of the dura.



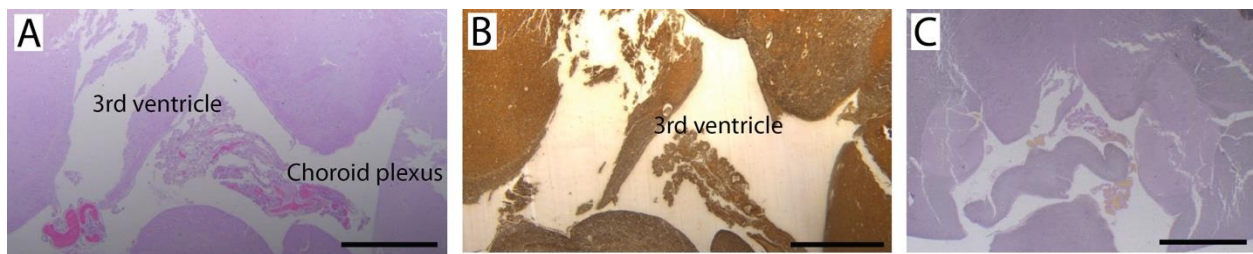
Supplementary Figure 13. **A** Recording from intrathecal space with ME stimulation post-euthanasia of the sheep. Top graph is a zoomed-in waveform marked with a star showing only stimulation artifacts. **B.** Recording from neck electrodes with ME stimulation post-euthanasia of the sheep. Top graph is a zoomed-in waveform marked with a star showing only stimulation artifacts.



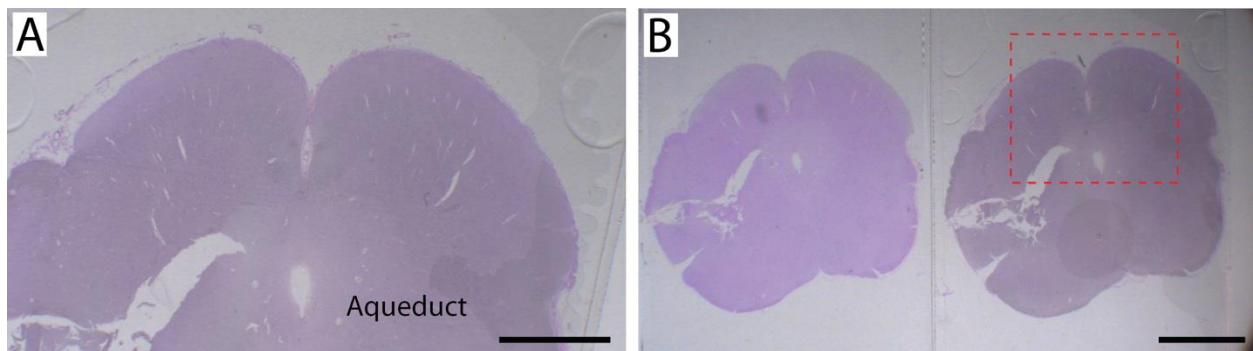
Supplementary Figure 14. Locations of recording electrodes corresponding to Figure 2A-C. **A.** Recording electrodes placed in the back of the sheep **B.** Catheter electrode in the thoracic region of subarachnoid space (scale bar = 50 mm). **C.** Recording electrodes placed in the hind leg of the sheep.



Supplementary Figure 15. **A.** Balloon catheter traversed through the floor of the 3rd ventricle to enter the 3rd ventricle from a lumbar approach. Red box denotes catheter tip. (scale bar = 50 mm) **B.** Contrast injected through the balloon catheter into the 3rd ventricle and the resulting CT 3rd ventriculogram. **C.** Image of the sacrificed sheep brain after reverse 3rd ventriculostomy showing no gross hemorrhage.

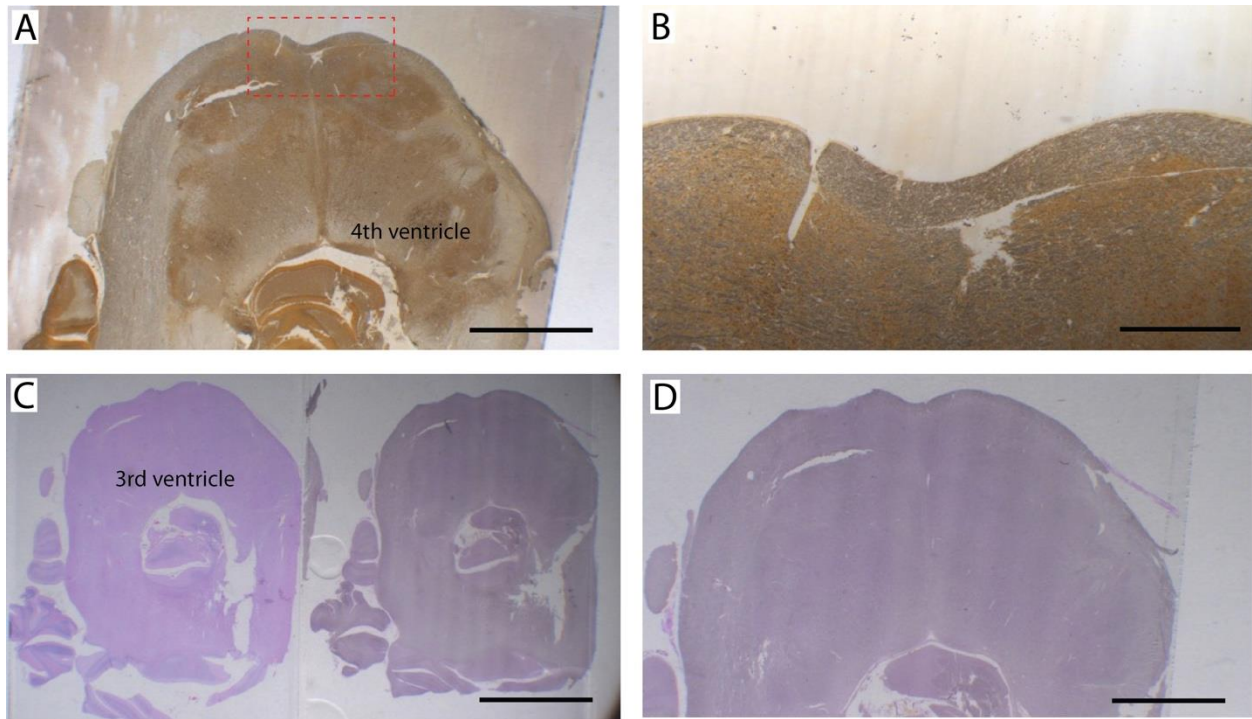


Supplementary Figure 16. **A.** H&E stain of the 3rd ventricle post reverse ventriculostomy (scale bar = 100 μ m) **B.** Silver staining of the 3rd ventricle post reverse ventriculostomy (scale bar = 100 μ m) **C.** Van Gieson stain of the 3rd ventricle post reverse ventriculostomy (scale bar = 250 μ m). 16A-C showed no evidence of hemorrhage in the 3rd ventricle post reverse ventriculostomy.

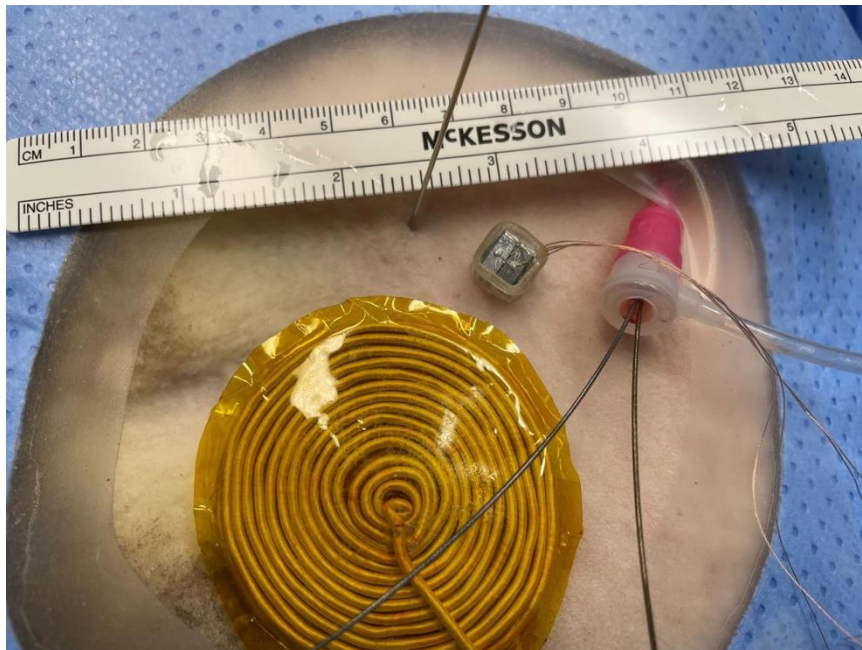


Supplementary Figure 17. **A.** Zoomed in image of a Van Gieson stain of the midbrain post reverse ventriculostomy (scale bar = 250 μ m). **B.** H&E stain (left) and Van Gieson stain (right) of midbrain post reverse ventriculostomy.

reverse ventriculostomy (scale bar = 500 μ m). Red box denotes where Supplementary Figure 18A is zoomed in. 18 A,B showed no evidence of hemorrhage in the midbrain post reverse ventriculostomy.



Supplementary Figure 18. A. Histology and silver staining of the pons post reverse ventriculostomy. Red box denotes where the zoomed image is (scale bar = 500 μ m). B. Zoomed-in image of the pons (scale bar = 25 μ m). C. H&E stain of the pons (scale bar = 250 μ m) D. Van Gieson stain of the pons (scale bar = 500 μ m). A-D showed no evidence of hemorrhage in the pons post reverse ventriculostomy.



Supplementary Figure 19. Image of the magnetoelectric implantable pulse generator and magnetic transmitter on the back of the sheep.

Supplementary Video 1. Stimulation with a catheter electrode over the motor cortex at 2 Hz with the magnetoelectric implant. Observed resulting MEPs in the back of the sheep.