Motor Bur Milling State Identification via Fast Fourier Transform Analyzing Sound Signal in Cervical Spine Posterior Decompression Surgery

Objectives: To investigate the real-time sensitive feedback parameter of the motor bur milling state in cervical spine posterior decompression surgery, to possibly improve the safety of cervical spine posterior decompression and robot-assisted spinal surgeries.

Methods: In this study, the cervical spine of three healthy male and three healthy female pigs were randomly selected. Six porcine cervical spine specimens were fixed to the vibration isolation system. The milling state of the motor bur was defined as the lamina cancellous bone (CA), lamina ventral corticalbone (VCO), and penetrating ventral cortical bone (PVCO). A 5-mm bur milled the CA and VCO, and a 2-mm bur milled the VCO and PVCO. A miniature microphone was used to collect the sound signal (SS) of milling lamina which was then extracted using Fast Fourier Transform (FFT). When using 5-mm and 2-mm bur to mill, the CA, VCO, and PVCO of each specimen were continuously collected at 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 kHz frequencies for SS magnitudes. The study randomly selected the SS magnitudes of the CA and VCO continuously for 2 s at 1, 2, 3, 4, and 5 kHz frequencies for statistical analyses. When milling the VCO to the PVCO, we randomly collected the SS magnitudes of the VCO for consecutive 2 s and the SS magnitudes of continuous 2 s in the penetrating state at 1, 2, 3, 4, and 5 kHz frequencies for statistical analyses. The independent sample t-test was used to compare the SS magnitudes of different milling

states extracted from the FFT to determine the motor bur milling state.

Results: The SS magnitudes of the CA and VCO of all specimens extracted from the FFT at 1, 2, and 3 kHz were statistically different ($P < 0.01$); three specimens were not statistically different at a specific FFT-extracted frequency (first specimen at 5 kHz, SS magnitudes of the CA were $[25.94 \pm 8.74] \times 10^{-3}$, SS magnitudes of the VCO were $[28.67 \pm 12.94] \times 10^{-3}$, $P = 0.440$; second specimen at 4 kHz, SS magnitudes of the CA were $[23.79 \pm 7.94] \times 10^{-3}$, SS magnitudes of the VCO were $[24.78 \pm 4.32] \times 10^{-3}$, $P = 0.629$; and third specimen at 5 kHz, SS magnitudes of the CA were $[16.76 \pm 6.20] \times 10^{-3}$, SS magnitudes of the VCO were $[17.69 \pm 6.44] \times 10^{-3}$, $P = 0.643$).The SS magnitudes of the VCO and PVCO of all the specimens extracted from the FFT at each frequency were statistically different ($P < 0.001$).

Conclusions: Based on the FFT extraction, the SS magnitudes of the motor bur milling state between the CA and VCO, the VCO and PVCO were significantly different, confirming that the SS is a potential sensitive feedback parameter for identifying the motor bur milling state. This study could improve the safety of cervical spine posterior decompression surgery, especially of robot-assisted surgeries.