Dynamic Radiographs are Unreliable to Assess Arthrodesis following Cervical Fusion: A Modeled Radiostereometric Analysis of Cervical Motion

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INTRODUCTION:

The utility of flexion-extension radiographs in clinical practice remains in question due to poor reliability of the parameters utilized to measure motion. The purpose of the present study was to utilize an idealized cervical spine model to determine whether the parallax effect or changes in the position of the spine relative to the x-ray generator influence intervertebral motion parameters on dynamic cervical spine radiographs.

METHODS:

A cervical spine model was affixed to a heavy piece of plywood in an upright position. A tantalum bead was inserted into the tip of each spinous process to serve as precise anatomic landmarks for the measurement of interspinous process distance (IPD) (Figure 1). To determine the impact of isolated changes in generator angle on the IPD, the model was rotated such that the spinous processes rotated away from and then toward the generator in 5 degree increments to a maximum of -30° and +30° while in neutral, flexion, and extension. To determine the impact of isolated changes in generator distance on the IPD, the model was moved 4cm toward and then 4cm away from the x-ray generator while in neutral, flexion, and extension. The impact of combined changes in generator angle and generator distance were then assessed by performing radiographs of the spine model at every combination of generator angle and generator distance in neutral posture and analyzed with multivariate analysis (Tables 5 and 6). To evaluate the impact of parallax on interspinous process distance measurements, the magnification of the interspinous process distance measurements was calculated at each vertebral level in neutral, flexion, and extension by dividing the 'radiographic' IPD by the 'true' caliper-measured IPD. The difference in magnification in flexion versus extension was then calculated.

RESULTS:

There was no difference identified in the radiographic magnification of the IPD at each intervertebral level with the spine model in neutral, flexion, or extension, suggesting that the parallax effect is not a significant source of variability in the cervical spine. Furthermore, there was no difference in the magnification at each intervertebral level in flexion versus in extension. Isolated changes in the generator distance and generator angle and combined changes in these parameters led to significant changes in the measured IPD at each intervertebral level in neutral, flexion, and extension, which, in many instances, exceeded an absolute change of >1mm or >2mm.

DISCUSSION AND CONCLUSION:

In an idealized cervical spine model, small clinically feasible changes in spine position relative to the x-ray generator produced substantial variability in interspinous process distance measurements, with absolute changes that often exceeded established cutoffs for determining the presence of pathologic motion across a fused segment. This study further reinforces that motion assessment on dynamic radiographs is not a reliable method for determining the presence of an arthrodesis unless these sources of variability can be consistently eliminated.
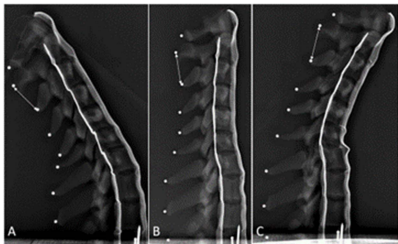

Table 6: Combined Impact of Generator Distance and Angle on Interspinous Process Distance (mm*) at C6-7 in the Neutral Position

	+4cm	0cm	-4cm
+30°	31.5 ± 0.5	30.8 ± 0.6	30.2 ± 0.3
+25°	31.8 ± 0.2	31.3 ± 0.1	30.7 ± 0.5
+20°	32.2 ± 0.2	31.8 ± 0.2	31.0 ± 0.1
+15°	33.1 ± 0.4	31.5 ± 0.2	31.0 ± 0.3
+10°	32.9 ± 0.1	32.2 ± 0.3	31.6 ± 0.2
+5°	33.4 ± 0.3	32.7 ± 0.4	31.8 ± 0.6
0°	34.1 ± 0.4	32.9 ± 0.6	32.2 ± 0.3
-5°	34.4 ± 0.5	32.8 ± 0.5	32.6 ± 0.5
-10°	35.0 ± 0.4	33.6 ± 0.4	32.9 ± 0.3
-15°	35.0 ± 0.5	34.1 ± 0.3	32.9 ± 0.3
-20°	34.9 ± 0.3	34.4 ± 0.3	33.5 ± 0.1
-25°	35.6 ± 0.4	34.5 ± 0.2	33.6 ± 0.3
-30°	36.2 ± 0.4	34.9 ± 0.4	34.4 ± 0.3

Continuous variables are represented as mean ± standard deviation.
*Abbreviations: millimeters (mm)
Boxes shaded in blue represent values that differ by ≥1mm from baseline. Boxes shaded in orange represent values that differ by ≥2mm from baseline. The box shaded in yellow represents the baseline measurement at C6-7.

TABLE 5. Coefficients for Interspinous Process Distance

Variable	Coefficient	95% Confidence Interval	P value
Generator Angle	-0.04	-0.05 - -0.03	<0.001
Generator Distance	0.21	0.14 - 0.29	<0.001
Position of the Spine (Flexion)	2.7	-6.38 - -5.17	<0.001
Position of the Spine (Extension)	-5.8	2.12 - 3.32	<0.001