The effect of radiographic rotation and tilt on the pelvic ring teardrop distance: Important parameters for measuring displacement on stress radiographs of lateral compression pelvic ring injuries

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INTRODUCTION: Lateral stress radiographs (LSR) have been proposed as an alternative to the examination under anesthesia (EUA) for the evaluation of lateral compression type 1 (LC1) injuries. This method, based on an anteroposterior (AP) pelvis radiograph taken in the lateral decubitus position, focuses on dynamic displacement of the teardrop distance (TD) with application of stress—a measurement that has demonstrated excellent interobserver and intraobserver reliability. However, some have cited rotation and/or tilt of these stress radiographs as a confounding factor in its evaluation. The purpose of this study was to determine the effect of rotation and tilt on the distance between radiographic teardrops (TD) on anteroposterior (AP) pelvis radiographs.

METHODS: Prospective examination of a pelvis model (Sawbones; Vashon Island, WA) was conducted utilizing increasing degrees of beam rotation and tilt on portable C-arm fluoroscopy. The C-arm was rotated in 2.5° iterations from 0° (standard anteroposterior) to 15° of rotation and tilted in 7.5° iterations from -30° (inlet view) to 30° (outlet view). TD, symphyseal-mid-sacrum distance (SMS, x-plane displacement), and sacroiliac joint-symphysis distance (SIS, y-plane displacement) were recorded at equal iterations by four independent observers and subsequently analyzed for interobserver reliability using intraclass correlations. SMS (distance of orthogonal line connecting the most superior aspect of the pubic symphysis and a vertical line passing through the midline of the sacrum) and SIS (distance of orthogonal line connecting the most superior aspect of the pubic symphysis and a line passing along the inferior aspect of the bilateral sacroiliac joints) measurements are demonstrated in Figures 1b-d. Pixels were converted to millimeters utilizing the measurement of a metal marker with a known diameter.

RESULTS: Interobserver reliability among observers was excellent (0.92). TD was altered by less than 2 mm with up to 7.5° fluoroscopic rotation (SMS distance of 3 cm) and up to 30° of inlet and 15° of outlet (SIS distance of +/- 3.3 cm). SMS distance effectively corresponded to the degree of rotation present (r=1.00, CI: 0.97 to 1.00, p<0.0001) and was strongly correlated to TD (r=-0.95, CI: -0.99 to -0.67, p=0.001). SIS distance effectively corresponded to the degree of tilt present (r=-0.97, CI: -0.99 to -0.88, p<0.0001) and was correlated to TD (r=0.94, CI: 0.75 to 0.99, p=0.0001). Linear regression models determined that, with every degree of rotation and tilt, TD was altered by 0.4 mm and 0.09 mm, respectively (p=0.0004, r^2=0.93 and p<0.0001, r^2=0.94, respectively).

DISCUSSION AND CONCLUSION: Teardrop distance on AP pelvis radiographs has excellent interobserver reliability and is minimally impacted (<2 mm difference) by up to 7.5° of rotation (SMS distance of 3 cm) and within a range of 30° inlet to 15° outlet of tilt (SIS distance of 3.3 cm). The x-oriented geometric plane measurement of SMS and the y-oriented geometric plane measurement of SIS were reliably representative of C-arm rotation and tilt respectively. Surgeons can utilize the cutoffs described from this model to ensure reliability of TD.

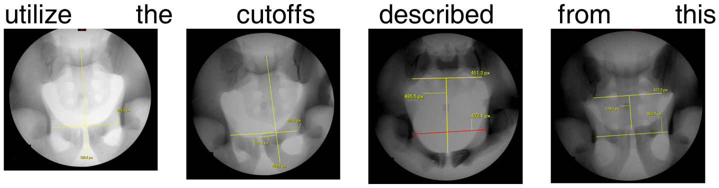

FIGURE LEGEND

Figure 1. Rotated and tilted fluoroscopic images of a pelvis model illustrating study measurements, including teardrop distance (TD), symphyseal-mid-sacrum distance (SMS), and sacroiliac joint-symphysis distance (SIS). TD was the distance between radiographic teardrops. **(A)** Standard anteroposterior (AP) pelvis. Average TD across observers was 123.22 mm. **(B)** Film rotation of 7.5° with demonstration of SMS (x-oriented plane) to determine the degree of rotation based strictly on radiographic landmarks. This was evaluated by measuring an orthogonal line connecting the most superior aspect of the pubic symphysis and a line passing through the midline of the sacrum. Average TD was 121.25 mm (difference = 1.98 mm). **(C)** Film tilt of 30° inlet with demonstration of SIS (y-oriented plane) to determine the degree of tilt. This was evaluated by measuring an orthogonal line connecting the most superior aspect of the pubic symphysis and a line passing along the inferior aspect of the bilateral sacroiliac joints. Average TD was 125.09 mm (difference = 1.86 mm). **(D)** Film tilt of 15° outlet with SIS measurement. Average TD was 121.32 mm (difference = 1.90 mm).

Table 1. Effect of Rotation on Teardrop Distance Measurements

Rotation (°)	SMS Distance (x-plane) (mm)	TD (mm)	TD Standard Deviation (mm)	Gross TD Difference (mm)	Percent TD Difference (%)
0	0.00	123.22	0.40	--	--
2.5	13.21	123.42	0.24	0.20	0.16%
5.0	21.53	122.64	0.63	-0.58	-0.47%
7.5	30.34	121.25	0.63	-1.98	-1.60%
10.0	36.17	120.56	0.45	-2.66	-2.16%
12.5	44.58	118.97	0.44	-4.25	-3.45%
15.0	53.99	117.24	0.98	-5.99	-4.86%

(SMS: symphyseal-mid-sacrum distance, TD: teardrop distance)

Table 2. Effect of Tilt on Teardrop Distance Measurements

Tilt (°)	SIS Distance (y-plane) (mm)	TD (mm)	TD Standard Deviation (mm)	Gross TD Difference (mm)	Percent TD Difference (%)
-30.0 (Inlet)	128.75	125.09	0.34	1.86	1.51%
-22.5	125.99	124.86	0.47	1.64	1.33%
-15.0	117.11	124.76	0.33	1.54	1.25%
-7.5	100.56	124.03	0.56	0.81	0.66%
0	90.18	123.22	0.40	--	--
7.5	76.08	122.25	0.82	-0.97	-0.79%
15.0	56.83	121.32	0.49	-1.90	-1.54%
22.5	38.29	120.22	0.38	-3.00	-2.44%
30.0 (Outlet)	3.02	120.86	1.58	-2.37	-1.92%

(SIS: sacroiliac joint-symphysis distance, TD: teardrop distance)