The prevalence of suboptimal sacral outlet imaging with 2D fluoroscopy in Pelvic Surgery and a technical solution

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Introduction: Safe placement of internal fixation in the posterior pelvic ring with 2D fluoroscopy requires technically optimal inlet and outlet views of the sacrum to avoid neurologic injury. Perfect outlet views of S1 and S2 foraminal tunnels may be challenging to obtain, particularly in large patients and patients with a vertically-oriented sacrum. We describe the frequency of technically suboptimal outlet views and describe a technique for obtaining reliable high-quality pelvic outlet imaging.

Methods: Institutional review board (IRB) approval was obtained prior to data collection. A retrospective cohort of patients with closed, AO/OTA 61 pelvic ring fractures was identified from a Level 1 trauma center registry between July 2021-Dec 2021. The C-arm gantry tilt angle necessary to obtain a standard outlet view (pubis overlying S2 body) as well as outlet views parallel to the S1 and S2 foraminal tunnels were measured on CT pelvis midline and paramedian sagittal cuts. A minimum source-detector distance (SDD) z_{min} necessary to obtain each outlet view without striking the patient or the table was calculated (Figure 1A). z_{min} was compared to the SDD of five commercial C-arms commonly used for pelvic fracture surgery to determine if imaging sacral outlet views would be technical feasible. The angle of pelvic retroversion α_{bump} provided by a bump placed beneath the distal sacrum (Figure 1B) necessary to reduce the minimum distance z_{min} such that all outlet views could be obtained in all patients with any common C-arm was calculated. Significance between any technically suboptimal outlet view with age, anterior sacral slope (ant-SS) at S1/S2 vertebral bodies, race and sex were explored with binary logistic regression while statistically controlling for known covariables. Chi-square testing was used to determine any significant relationship between frequency of suboptimal outlet view and all C-ARM models used in this study. All p-values less than 0.05 were considered significant.

Results: The cohort included 72 patients of mean age 46.9±19.1 years (17-91 years), BMI 25.8±5.4 kg/m^2, 31% women. Sixty-eight percent of all patients had at least one measure outlet angle that was determined to be suboptimal. On binary logistic regression analysis, suboptimal outlet imaging was significantly associated with BMI for each measured outlet angle (Standard outlet: OR 0.84, CI 0.79 to 0.89, *P* = <0.001; S1-outlet: OR 0.91, CI 0.87 to 0.97, *P* = 0.002; S2-outlet: OR 0.85, CI 0.80 to 0.91, *P* = <0.001). A significant association was also found between suboptimal outlet imaging and the anterior sacral slope at S1 on an S1-outlet image (OR 1.12, CI 1.07-1.17, *P* = <0.001), and the anterior sacral slope at S2 on standard (OR 1.07, CI 1.02-1.13, P = 0.004) and S2-outlet images (OR 1.16, CI 1.09-1.23, *P* = <0.001). Chi-square testing demonstrated a significant relationship between C-arm model spatial capacity limits and the frequency of suboptimal imaging (x2 (4) =260.266; p<.001). No significant relationship was observed between imagine quality in relation to age, race or biological sex. Pelvic retroversion angle of α_{bump} = 20° permitted an unobstructed optimal outlet in 99% of suboptimal imaging cases with all c-arm models.

Discussion: Patient anatomy frequently limits safe two-dimensional imaging of the sacrum for posterior pelvic fixation. More specifically, BMI and anterior may influence incidences of technically impossible outlet imaging. A bump under the distal sacrum providing up to 20° of pelvic retroversion provides a simple low-tech solution.

Clinical Relevance: Suboptimal intraoperative imaging during posterior pelvic fixation has been reported to be associated with increased early post-operative complications. Implementation of cost-effective methodologies dedicated to enhancing the quality of intraoperative imaging may mitigate post-operative complications in the realm of pelvic surgery.

Figure 1. Schematic of suboptimal outlet and pelvic retroversion calculations