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# Automatic Classification of Traumatic Pelvic Ring Fractures Based On a Rule-Based Regional Radiologic Classification Method

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## 1 Purpose

Traumatic pelvic fractures may be life threatening, requiring a timely and accurate assessment to determine the preferred course of treatment. The Young-Burgess (YB) pelvic ring classification system [2] is commonly used for the classification of these fractures [1]. In the emergency room, the classification is performed pelvic anteroposterior radiographs (pelvic AP Xray) based on general guidelines. However, it may not be performed by knowledgeable clinicians, or not at all. Also, it may vary between observers, and its rationale may not be amenable to explanation.

We are developing a computerized method for the automatic YB classification of traumatic pelvic ring fractures based on a novel rule-based regional anatomical system, called YB-RRRC (Young-Burgess Rule-Based Regional Radiologic Classification). The aim of this study was to conduct a preliminary evaluation of the method.

## 2 Methods

The YB-RRRC method divides each pelvic AP X-ray (Fig. 1a) into 11 distinct, partially overlapping anatomical regions (Fig. 1b). Each pelvic region is evaluated independently for main radiographic findings – normal or injured (Fig. 1c). The combination of the findings across these regions determines the final classification into one of the eight YB classes: Lateral Compression (LC1, LC2, LC3), Anteroposterior Compression (APC1, APC2, APC3), Vertical Shear (VS), and Combined Mechanical Injury (CM). The YB class is derived from a set of rules based on the pelvic regions classification. For example, when pelvic region PS is injured and all other regions are normal, the YB class is APC1.

The method for automatic YB classification of pelvic AP X-rays consists of four steps (Fig. 2): 1) Image normalization: image intensity, image cropping to the pelvic area, and image rotation for pelvis vertical orientation; 2) Pelvic regions computation: extraction of 11 pelvic regions using a pelvic regions atlas and a first deep-learning network [2]; 3) Pelvic regions evaluation: classification of pelvic regions into normal or injured with a second deep-learning network; 4) Rule-based YB classification based on the classification of the pelvic regions using region-based rules. The output is the pelvic AP X-ray with overlayed color-coded pelvic regions, the YB fracture class, and the classification confidence.

Preliminary evaluation by retrospectively collecting 662 pelvic AP X-rays of patients with/without traumatic pelvic ring injuries; 564 with sufficient quality were selected.

For the pelvic regions computation (Step 2), a junior surgeon supervised by a senior surgeon delineated all 11 pelvic regions in the 564 pelvic AP X-rays. Then, 20 pelvic AP X-rays were randomly selected for the test set; the remaining 544 were used to train a YOLOv8m classifier. Pelvic region detection was evaluated with the F1-score.

For the pelvic regions evaluation (Step 3), a junior surgeon independently classified each region in each scan as normal or injured, resulting in six ground-truth datasets: one for the PS region (564) and five combining the left and right regions, with the left region vertically mirrored to the right region: OBT (1,095), MI (1,103), LI (1,024), SI (888) and SIJ (1,038). Then, 20 pelvic regions (10 normal, 10 injured) were randomly selected from each dataset for the test set; the remaining were used to train a YOLOv8m-cls classifier. The binary pelvic region classification was evaluated with specificity and sensitivity.

For the rule-based YB classification (Step 4), a senior surgeon classified the 564 pelvic AP X-rays according to the YB classification following the conventional approach. The evaluation was performed by 20-fold cross-validation using the rule-based classification (weighted kappa score of conventional vs. rule-based), and three machine learning methods: decision tree, random forest, and Bayes classifier (AUC measure).

# 3 Results

For the pelvic regions computation, the F1-scores were 1.00 for OBT, 0.99 for LI, SI, SIJ, and 0.98 for PS, MI. For the pelvic regions evaluation, the specificity was 1.00 for all regions, while the sensitivity was 1.00 for PS, 0.80 for OBT, 0.50 for MI and LI, and 0.20 for SI and SIJ. For the rule-based YB classification, the mean weighted kappa score was 0.47, and the AUC scores were 0.85 for the decision tree, 0.96 for the random forest, and 0.97 for the Bayes classifier.

# 4 Conclusion

Our study show that performing YB pelvic ring injury classification on pelvic AP X-rays with a rule-based regional radiologic approach holds promise, yielding results that may be comparable to conventional evaluation. It indicates that the pelvic region computation is nearly perfect and that the rule-based YB classification using a normal/injured pelvic regions classification has excellent performance. However, the pelvic region classification requires further investigation, as it yielded perfect specificity but varied sensitivity, most likely due to the limited training dataset size and the severe class imbalance. The advantages of our method compared to deep-learning black box models [3,4] are that divides the process into steps, requires smaller training annotated datasets, and provides a visual and fully explainable result.

# References

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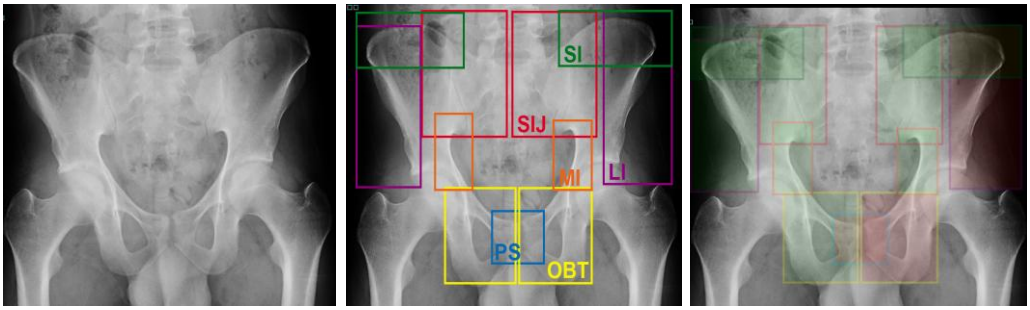


**Fig. 1**. (a) Pelvic AP X-ray of a pelvic rig fracture; (b) Pelvic regions for radiological classification of traumatic pelvic ring fractures: PS, pubic symphysis (blue) and left and right OBT, obturator foramina (yellow), MI, medial ilium (orange), LI lateral ilium (purple), SI, superior ilium (green), and SIJ, sacroiliac joint (red); (b) Gestalt evaluation; (c) Per-region evaluation; (c) pelvic regions classification into normal (green) and fracture (red) regions.

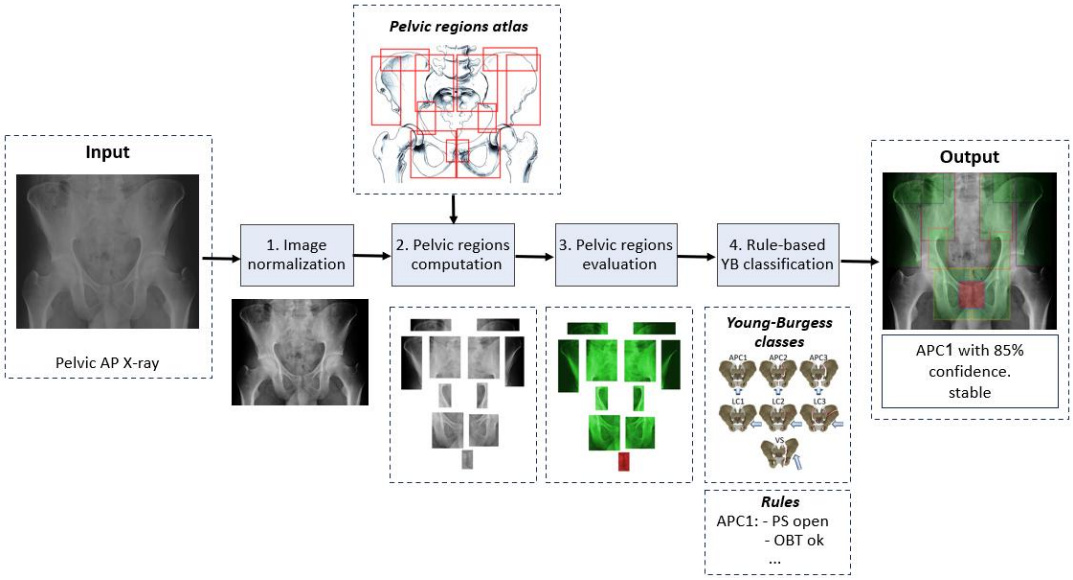


**Fig. 2.** Method for the automatic Young-Burgess classification of traumatic pelvic fractures with YB-RRRC, a rule-based pelvic regions approach on a pelvic AP X-ray; 1) Image normalization; 2) Pelvic regions computation using a pelvic regions atlas; 3) Pelvic regions evaluation: classification of each region as normal (green) or injured (red); 4) Rule-based YB classification based on the YB classes and the region-based rules. Output: pelvic AP X-ray with an overlay of the pelvic regions and their color-coded evaluation, the YB fracture type, the classification confidence, and the fracture stability.