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Systematic Rule-Based Regional Radiologic Classification of Traumatic Pelvic Ring Fractures: An Observer Variability Study

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1 Purpose

Traumatic pelvic fractures constitute 1.5-3% of all skeletal injuries [1]. As they may be life threatening, they require a timely and accurate assessment to determine the preferred course of treatment. The Young-Burgess (YB) pelvic ring classification system is commonly used for the systematic classification of these fractures [2]. In the emergency room, the classification is performed on the pelvic anteroposterior radiograph (AP Xray) based on general guidelines. However, it may not be performed by knowledgeable clinicians, or not at all. Moreover, the classification may vary between observers, and the rationale for the classification may not be available or amenable to explanation.

We have developed a systematic, rule-based regional anatomical system for YB classification, called YB-RRRC (Young-Burgess Rule-Based Regional Radiologic Classification) that supports systematic and explainable classification and that is amenable to automation. To validate this approach, we aimed to compare human expert performance in conventional whole-image (Gestalt) versus the YB-RRRC (per-region) evaluation

2 Methods

The rule-based pelvic regions method divides each pelvic radiograph (Fig. 1a) into 11 distinct, partially overlapping anatomical pelvic regions (Fig. 1b): the pubic symphysis (PS), and bilateral (L/R) regions – the obturator foramina including the rami of the pubis and ischium (OBT L/R), the medial ilium including the base of the ramus pubis and superior part of the iliopectineal line (MI L/R), the lateral ilium (LI L/R), the superior ilium (SI L/R), and the sacroiliac joints extending medially to include the sacral foramina (SIJ L/R). Each pelvic region is evaluated independently for main radiographic findings – normal or injured – and other region-specific characteristics, e.g., displacement (Fig. 1c). The severity and combination of 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.

To evaluate the YB-RRRC approach, 50 pelvic radiographs of patients with traumatic pelvic ring injuries were retrospectively collected and evaluated by three experienced orthopedic trauma surgeons. Each radiograph was assessed twice in two sessions performed a week apart: once as a full image (Gestalt, Fig. 1b) and once with the 11 pelvic regions only (Per-region, Fig. 1c). For the Per-region evaluation, the regions were presented in random locations to avoid providing spatial cues. Inter-observer agreement was calculated using weighted kappa agreement scores between two observers [3]. Weighting was performed to account for different classifications that are clinically similar. For example, for anteroposterior compression injuries, APC1 and APC2 indicate the same pattern with different severity (weight of 0.5), while APC1 and LC3 indicate different patterns (weight of 1).

3 Results

Inter-observer agreement was comparable between the Gestalt and the Per-region evaluation (Table 1). For the Gestalt evaluation, the unweighted and weighted kappa scores ranged from 0.36 to 0.62 (mean 0.46) and 0.40 to 0.61 (mean 0.47), respectively. For the Per-region approach, the unweighted and weighted kappa scores ranged from 0.36 to 0.50 (mean 0.42) and 0.39 to 0.56 (mean 0.47), respectively. The explanation for each per-region classification was directly provided by the region classification and the corresponding rules of the YB class in YB-RRRC.

4 Conclusion

Our study shows that performing YB pelvic ring injury classification with a region-based approach yields reliability scores comparable to conventional whole-image evaluation. The analysis of weighted agreement and kappa scores shows that while both approaches achieve moderate to substantial agreement, the YB-RRRC method may offer non-inferior performance across pairs of observers.

This finding has important implications for machine learning development, suggesting that an automatic algorithm analyzing individual anatomical regions followed by rule-based integration could achieve similar reliability to human experts while providing more transparent and interpretable results than deep-learning black box models [4].

The variability observed in both approaches also highlights the inherent complexity of pelvic fracture classification and suggests that machine learning methods should be designed to accommodate some degree of classification uncertainty. These results validate our region-based machine learning pipeline design and provide a benchmark for its future performance evaluation.

References

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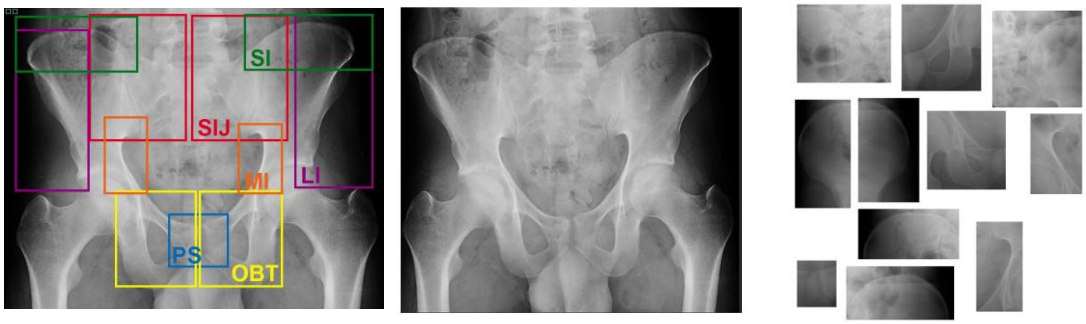

(a) (b) (c)

Fig. 1. The YB-RRRC system: (a) 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.

Inter-Observer Kappa Score				
Observers	**O1 & O2**	**O1 & O3**	**O2 & O3**	**Mean**
Gestalt	0.62	0.40	0.36	0.46
Per-region	0.36	0.40	0.50	0.42
Inter-Observer Weighted Kappa Score				
Observers	**O1 & O2**	**O1 & O3**	**O2 & O3**	**Mean**
Gestalt	0.61	0.41	0.40	**0.47**
Per-region	0.39	0.45	0.56	**0.47**

Table 1: Observer variability results for three pairs of observers (O1, O2, O3): Gestalt and per-region evaluation, Kappa and weighted Kappa scores. Bold numbers indicate the significant results.