Lower extremity flail is implicated in fatal injury due to anti-personnel mines.

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Introduction

The lower extremity is the most common body region injured in modern warfare which is characterised by proliferation of explosive weapons [1]. Personnel on foot (dismounted) attacked by anti-personnel mines sustain predominantly an open pelvic fracture with disruption at the pubic symphysis (PS) and sacroiliac (SI) joint, with a high incidence of traumatic amputation and vascular injury, which sometimes is fatal [2]. The mechanism of this injury is not known. We postulate that the dismounted injury pattern may be due to predominantly axial load through the lower limb or due to lower extremity flail. The aim of this study was to investigate these two injury mechanisms.

Methods

Experimental: Four fresh-frozen male pelvic specimens were tested under axial impact loading. The sacrum and lumbar spine, and the hemipelvis were held and impact load was applied through the femur (Fig.1 A). The sacrum was mounted on a 6-axis loadcell and strain gauges were secured on either side of the PS and the SI joint. Specimens were CT-scanned post impact to identify injuries.

Numerical: A finite element (FE) model of the pelvis was created from the CT angiogram of a male pelvis. Quasi-static forces were applied at the hemipelvis to simulate the experiment and to assess the outcome of other loading conditions; these were combinations of anteroposterior (flail), lateral (flail), and axial loading directions.

Results

Pure axial load produced femoral neck fracture rather than pelvic disruption. Only with prior disruption at the anterior pelvis did pelvic opening occur, suggesting that axial loading alone cannot produce the injuries seen clinically and that flail, or off-axis loading may be involved. The maximum principal stress in the FE models (Fig.1 B & C) suggested that lateral, in combination with axial loading is more likely than any other combination of loads to cause opening of the PS and SI joint.

Conclusion

Anti-personnel mines cause devastating, sometimes fatal, injuries to service personnel. Axial loading through the lower extremity alone is unlikely to result in pelvic opening and vascular injury. Our results suggest that lower extremity flail, particularly in the lateral direction, is implicated in the dismounted injury pattern. This information along with the numerical tools developed here can now be used to design personnel protective equipment to improve survivability from anti-personnel mines.

References

[1] Chandler, Henry, et al., (2017). Injury, p1439-1443

[2] Oh, John S., et al., (2016). Military medicine, p1069-1074

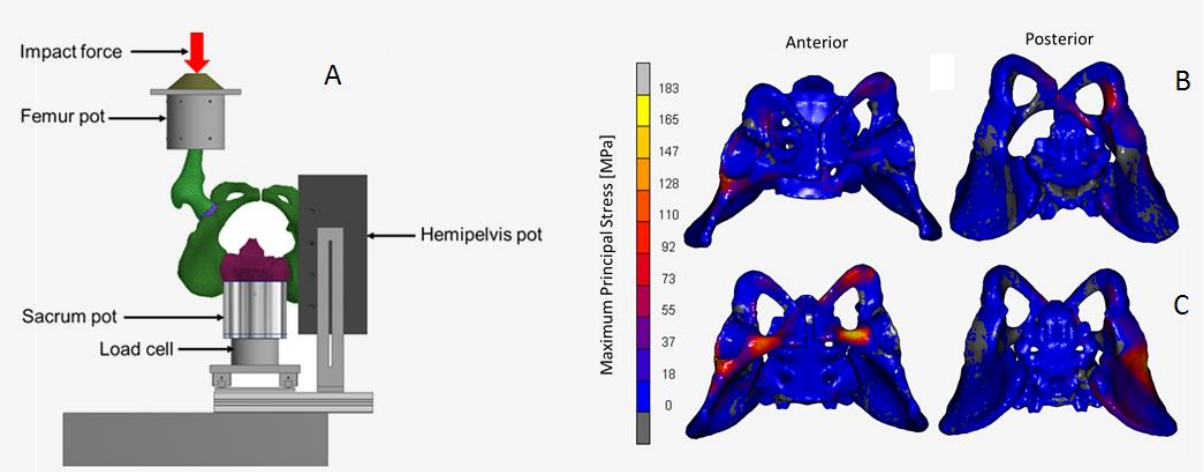

Fig.1: Experimental set-up (A); maximum principal stress within the pelvis under (B) pure axial load & (C) a combination of axial and lateral load.