

EMERGENT NON-INVASIVE REDUCTION OF PELVIC RING DISRUPTIONS

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INTRODUCTION

Pelvic reduction and stabilization in the early post-injury phase of pelvic ring disruptions is a potentially life saving intervention. It constitutes the most effective means to control pelvic venous bleeding [Burgess, AR et al., 1990]. However, no device for emergent, non-invasive pelvic reduction and stabilization at the accident site is available to date. Several invasive devices for pelvic reduction and stabilization have been introduced, but their application demands an operating room scenario. Most recently, the use of a circumferential sheet for stabilization of pelvic fractures has been reported [Rouff, MLC et al., 1995]. While this technique is non-invasive and applicable at the emergency site, no data are available describing the efficacy and safety of circumferential pelvic compression. This research provides a parametric investigation on the efficacy of a non-invasive ‘pelvic sling’ to induce pelvic reduction by means of circumferential compression. Furthermore, an optimal sling position and the required reduction force have been determined in a cadaveric study.

PROCEDURES

Seven fresh frozen whole-body cadaveric specimens were instrumented with a peritoneal pressure sensors (HP 78534, Hewlett Packard, Englewood, CO), a motion tracking system (pcBird, Ascension Tech. Corp., Burlington, VT) to trace spatial location of the pelvic wings, and a custom symphysis pubis sensor to detect symphysis contact (Fig. 1). A partially stable ‘open book’ pelvic fracture (symphysis gap=50 mm, monolateral disruption of anterior sacroiliac joint) and subsequently an

unstable pelvic fracture (symphysis gap=100 mm, complete monolateral sacroiliac joint disruption) were created by forced external rotation of each hemipelvis after symphysiotomy. A prototype pelvic sling was designed, consisting of a 50 mm wide, flexible, non-elastic reinforced rubber belt. This belt circumvents the pelvis and is guided anteriorly over rollers contained in a belt buckle. Application of tension F_T to the ends of the belt gradually induces circumferential pelvic compression. Two sensors are integrated into the sling to continuously monitor sling tension (ELFS-500N, Entran, Fairfield, NJ) and lateral sling-skin interface pressure (HP 78534). This sling was applied in three distinct transverse plane levels, extending from the symphysis pubis to the iliac crest (Fig. 1), to first reduce the partially stable and then the unstable pelvic ring disruptions.

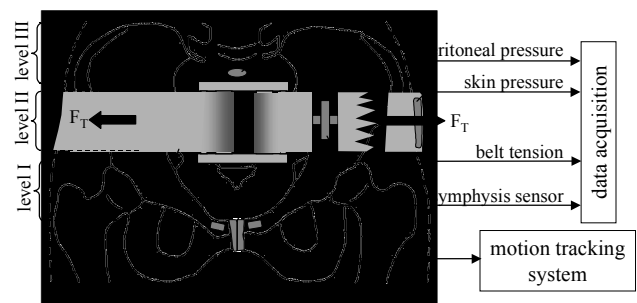


Fig. 1: Transverse view, instrumented pelvis.

Sling tension was applied manually and resulting sling tension, sling-skin pressure and spatial motion of the pelvic wings relative to each other were continuously monitored until symphysis contact was detected.

For each specimen, inlet and outlet radiographs of the pelvis before and after reduction were obtained to document the

fracture pattern and quality of reduction. Finally, computer tomographic scans of one specimen were obtained before and after reduction of an unstable pelvic ring fracture to allow for computation of reduction-induced changes in true and false pelvic volume (V_{true} , V_{false}).

RESULTS AND DISCUSSION

Fracture patterns consistent with clinically relevant partially stable and unstable ‘open book’ pelvic fractures were achieved in all specimens, as documented by the inlet and outlet radiographs. Symphysis contact due to sling application at level I was achieved by $F_T = 177 \pm 44$ N and $F_T = 180 \pm 50$ N for reduction of the partially stable and unstable pelvis, respectively (Fig. 2). Sling application at levels II and III consistently required a significantly higher sling tension to achieve symphysis contact as compared to sling application on level I (two-tailed T-test, $\alpha=0.05$).

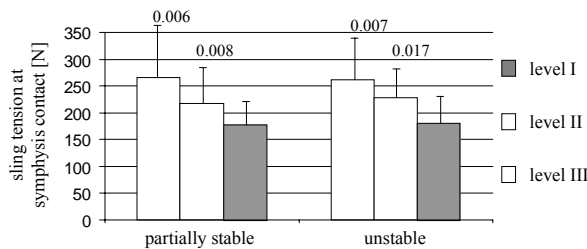


Fig. 2: Sling tension required for reduction.

Reduction of the unstable pelvis (i.e., symphysis contact) due to sling application on level I resulted in a peritoneal pressure increase of 10.1 ± 8.5 mmHg and induced an average sling-skin interface pressure of 24 mmHg, as measured at the lateral aspect of the pelvic soft tissue envelope.

Reduction of the partially stable and unstable pelvis (level I, $F_T=200$ N) yielded in a residual displacement vector at the symphysis of 5.1 ± 2.0 mm and 11.3 ± 5.3 mm magnitude, respectively.

Three-dimensional rendering of the true and false pelvic volume from computer tomographic scans yielded values of $V_{\text{true}} = 1520$ cm³ and $V_{\text{false}} = 1880$ cm³ for the

unstable pelvis and $V_{\text{true}} = 1230$ cm³ and $V_{\text{false}} = 1820$ cm³ for the reduced pelvis.

Application of circumferential compression to the pelvic soft tissue envelope by means of a pelvic sling demonstrated to be an efficient, non-invasive means for controlled reduction of ‘open book’ type pelvic fractures (Fig. 3). This study quantified the sling tension required to achieve pelvic reduction and determined an optimal sling position at which the required sling tension is minimal. These findings are essential to minimize adverse effects such as peritoneal pressure increase and sling-skin interface pressure. Further investigations are necessary to address the effects of sling application to alternative fracture models, such as pelvic lateral compression fractures.

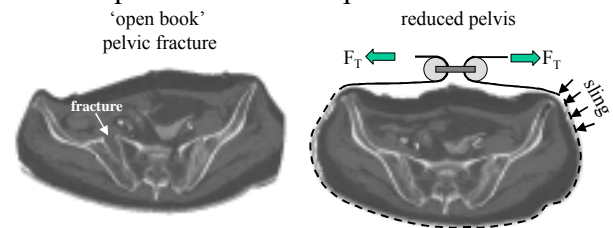


Fig. 3: CT scan, sling-induced reduction.

SUMMARY

The presented research constitutes a quantitative evaluation of the efficacy of circumferential compression to reduce pelvic ring disruptions. It provides results that are directly applicable to advance a potentially life-saving, non-invasive emergent care procedure.

REFERENCES

- Burgess, A.R., et al., (1990), J Trauma, **30**:848-856.
- Rouff, M.L.C., et al., (1995), Clin Orthop Rel Res, **318**, 61-74.

ACKNOWLEDGEMENTS

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