Pressure Characteristics of Pelvic Circumferential Compression Devices: A Cadaveric Study

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Introduction: Unstable pelvic ring injuries are often the result of high-energy trauma and are associated with significant morbidity and mortality. Hemodynamic instability from such injuries may be secondary to bleeding from the presacral venous plexus, broad cancellous fracture surfaces, or arterial injury. Early osseous stabilization is paramount, with options including both invasive and noninvasive means (1). Noninvasive methods such as pelvic binders and circumferential sheeting have gained favor in recent years for their widespread availability, ease of application, and clinical success. A major concern with use of such devices is prolonged pressure at the skin-binder interface leading to skin necrosis. These fears have been substantiated with several case reports in the orthopaedic trauma literature (2). While data exists regarding the skin-binder interface using several commercially available devices, there is no such data with use of the circumferential pelvic antishock sheeting (CPAS), or folded bedsheet, as a pelvic circumferential compression device (PCCD). The goal of our study was to quantify skin pressure over the greater trochanters (GT), anterior superior iliac spines (ASIS) and back comparing a simple bedsheets to one such commercial device, the T-POD. The null hypothesis was that pressures generated with the bedsheets would not be significantly different from that of the T-POD.

Methods: Ten undissected embalmed cadavers (5 female, 5 male, average age 82.8, range 69 to 90 years) were each placed on a mattress (AccuMax Quantum™ Convertible Pressure Relief System, Hill-Rom, Batesville, IN). During all tests, no air pressure was applied to the mattress. After placing the PCCD (TPOD or sheet) between the cadaver and mattress, a pressure sensor (Iscan® System, Model 5250, Tekscan, Inc., South Boston, MA) was placed under the back in the sacral region between the PCCD and the cadaver, and one sensor each was placed over the left and right hip covering the GT and ASIS. (Figure 1A) The PCCD was centered over the greater trochanters and tensioned using digital force gauges (50lb Digital Scale, Berkley, Spirit Lake, IA), then clamped in place, and corresponding pressure data was collected. (Figure 1B and 1C) The average of three repetitions was calculated to represent the peak contact pressure in the regions of interest. This was conducted at two tensioning loads. The TPOD was tensioned to 40N (low) and 60N (high) representing published force values needed to reduce partially stable and unstable anterior-posterior compression pelvic fractures. (3) The five to one mechanical advantage of the TPOD pulley system suggests that direct loads of 200N and 300N would be equivalent to the 40N and 60N loads. Thus, comparable direct loads of 200N (low) and 300N (high) were applied to the bedsheets (folded in fourths to 39.4cm wide) via grommets which were added to facilitate loading by the force gauges. To test the effect of PCCD and of load, data from each region of interest was analyzed via mixed model ANOVA followed by Tukey-Kramer post-hoc pairwise comparisons with statistical significance set at p ≤ 0.05.
**Results:** The TPOD generated statistically higher peak contact pressures overall on the underlying skin than did the bedsheet for the left and right GT (p < 0.0001), left ASIS (p = 0.008), and the back (p < 0.0001) but not the right ASIS (p = 0.78). (Figure 2) High loads resulted in significantly higher pressures than low loads for the left GT with the TPOD (p = 0.0150) but not the bedsheet (p = 0.99). There was an overall trend for higher pressure with increasing load for the left ASIS (p = 0.0835) and back (p = 0.0830) though not statistically significant. Also, a significant difference between pressures at high and low loads could not be detected overall for the right GT (p = 0.27) and ASIS (p = 0.51).

**Discussion:** Establishing hemodynamic stability following pelvic trauma can be challenging. Hemorrhage may be multifocal, via multiple sources associated with pelvic instability as well as extrapelvic etiology including long bone fracture and visceral injury. Multiple treatment algorithms have been devised to combat hypovolemia associated with pelvic ring disruption. Urgent pelvic reduction is a key tenet of current Advanced Trauma and Life Support (ATLS) recommendations, with a trend toward use of non-invasive interventions such as PCCD’s (4).

Routt et al initially published the technique CPAS, or use of a folded bedsheet, to obtain reduction of unstable pelvic ring disruptions (5). Numerous retrospective clinical studies and case reports have demonstrated the efficacy of CPAS and PCCD’s in general to establish hemodynamic stability (6). Further cadaveric biomechanical studies utilizing various commercially available binders have investigated the amount of circumferential tension required to reduce unstable pelvis (Tile B/C, APCII/III). A recent such study using the TPOD suggested that 40-60 N of force to be appropriate (3). To date, no similar study has been performed using a bedsheet as in CPAS. Thus, although the bedsheet has proven to be an effective modality, the exact tension required to obtain such a reduction is currently unknown. Likewise, although a value of 9.3kPa at the skin-binder interface has been proposed to lead to the soft tissue complications borne out in multiple case reports, quantitative data at the skin-binder interface of applied PCCD’s is limited (7).

Our data quantify the pressure at the skin-binder interface with the bedsheet and TPOD using an equivalent circumferential tension. The bedsheet demonstrated significantly (p<0.05) superior performance at bilateral GT, left ASIS and back, and a trend toward lower pressures at the right ASIS. Thus, with an equivalent pelvic reduction force, the data suggest that the bedsheet may be a more soft tissue friendly construct. We hypothesize this is secondary to improved force distribution through the wider sheet. As an internal control, between trials we alternated which PCCD was used first, as well as the direction of pulling force. In most cases, the pressures achieved with both the sheet and TPOD approached or exceeded the 9.3kPa threshold, substantiating fears of imminent soft tissue complications if the PCCD was to be left in place for a long duration of time. Limitations of the study include use of a cadaver model with inherently less pliable soft tissue as compared to a live patient. Further biomechanical study is needed to investigate pelvic reduction with use of CPAS.

**Significance:** Both the bedsheet and T-POD have shown good clinical effect toward temporary stabilization of unstable pelvic ring disruptions. Our data suggest that the bedsheet may provide a more soft tissue friendly method, cost effective method of stabilization while imparting an equivalent circumferential force. Additionally, unlike commercially available binders, a bedsheet may easily be cut and modified to provide access for placement of femoral catheters, percutaneous iliosacral screws or other interventions while maintaining pelvic reduction.
Figure 1: A) sensor placement over both hips and under the back (not visible but depicted by dashed diamond shape); B) loading of the bedsheet; C) loading of the TPOD.

Figure 2: Peak Contact Pressures measured for the left GT and ASIS, the BACK, and the right GT and ASIS.