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ORIGINAL RESEARCH

Mortality with Circumferential Pelvic Compression for Pelvic Ring Disruption in Polytraumatized Patients: A Retrospective Analysis of 1,639 Pelvic Ring Injuries

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ABSTRACT

Introduction: Pelvic ring disruption (PRD) has been identified as an independent risk factor for mortality in trauma patients. The optimal prehospital and emergency management to control the accompanying hemorrhage remains undetermined. We hypothesized that provisional stabilization with a pelvic circumferential compression device (PCCD) is associated with a reduction in mortality.
Methods: This is a four-year retrospective review of all PRD at a Level I trauma center. Trauma patients with documented PRD were included. Patients dead on hospital arrival or transferred from another center were excluded. Medical records were reviewed to determine PCCD use, and mortality evaluated using multiple logistic regression and propensity score matching.
Results: Of the 22,968 trauma admissions, 1,639 (7.3%) with PRD were included. In-hospital mortality was 11%. PCCD was used in 130 (8.3%) patients at median time of 2.07 hours postinjury. PCCD application was found to be not associated with a significant reduction in mortality (OR 0.678; 95%CI: 0.326,1.414; p=0.301).
Discussion: The study did not establish a statistically significant association between PCCD use and a reduced mortality rate. The limited sample size, confounded by the delay in application, may have introduced a type II error, and thus a potential survival benefit cannot be discounted.
Keywords: Pelvic fracture; Shock; Pelvic binder; Trauma-related mortality.

INTRODUCTION

Pelvic ring disruption (PRD) is as an independent mortality risk factor for the polytraumatized patient (1). PRD presents with an increased risk for exsanguination from associated intrapelvic vascular injuries, and rapid control of hemorrhage is imperative for survival. A recent review implicated delayed management of massive pelvic bleeding as the major cause of preventable blunt trauma deaths (2).

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Despite continued advances in identification and trauma resuscitation, mortality rates associated with PRD have remained fairly constant among multiple centers and studies (1,3-5). Optimal emergent management of PRD remains undetermined.

Pelvic circumferential compression devices (PCCDs) are currently recommended by the American college of Surgeons for emergent stabilization of PRD (6). Medical personnel can apply PCCD in under a minute, to provide rapid, noninvasive reduction of pelvic volume and stabilization of the pelvic ring (7). The subsequent reduction in volume is theorized to provide tamponade and control massive pelvic hemorrhage. There has been some concern with the development of pressure sores through prolonged application (8); however, periodic loosening of the PCCD is recommended to prevent this complication once the hemodynamics have stabilized. Despite the potential life-saving nature of these devices, a correlation between the use of PCCDs and a mortality reduction has not yet been established (8).

We hypothesized that the emergent use of PCCDs would be associated with a reduction in PRD mortality. Secondary measures included timing of PCCD placement, need for angioembolization, and surgical procedure including exploratory laparotomy or operative pelvic stabilization.

MATERIALS & METHODS

After approval was obtained from our institutional review board, our trauma database was queried for trauma patients (ages 16 and over) admitted directly to our academic Level I trauma center from January 2008 through December 2012 with a pelvic ring disruption (ICD-9 code 808.8). Protected populations such as minors (age <16 years), prisoners, and pregnant women were excluded from this study in accordance with our IRB. In addition, patients who received more than 5 min of CPR in the prehospital setting or who were pronounced dead on arrival were excluded.

Medical records were reviewed for patient demographics, body mass index (BMI), mechanism of injury, arrival physiological parameters and lab values, Abbreviated Injury Scale (AIS) scores, Injury Severity Scores (ISS), specific injury profiles, hospital procedures performed, time of injury, time of ED arrival and timing of binder application. All variables were defined using a data dictionary specifically designed for the study to promote uniformity of data collection. Hemodynamic instability (shock) was defined as SBP<90 or a base value <-4.

The primary outcomes measure was mortality. Secondary outcomes included time to angiography and embolization, time to death, and incidence of hemodynamic instability.

Statistical Analysis

The primary data analysis evaluated the association between PCCD use and mortality. To address concerns of selection bias in patients receiving PCCDs, a propensity score was developed using several demographic and patient characteristics on arrival that were felt to be influential in the propensity for receiving treatment. To more closely resemble clinical practice, continuous data were dichotomized to low and high ranges by using commonly accepted cutoffs. Variables significantly associated with treatment ($p<0.05$) were then used to estimate the propensity of receiving PCCD and included age >60 years, arrival by helicopter, SBP <90 mmHg, pulse >100 bpm, GCS ≤ 8, abdominal AIS ≥3, extremity AIS ≥3, and year of injury to control for temporal confounders.

Patient groups were compared using two different analytical approaches. The first approach evaluated outcomes in the entire cohort by using multivariate logistic regression adjusted for the propensity to receive treatment. Purposeful regression modeling was used to construct a multivariate logistic regression model predicting death. In an effort to minimize the risk of falsely identifying significant results with multiple comparisons, variables used in the multivariate analysis were prespecified and judged a priori to be clinically sound and all were incorporated into the final model. Those found to be potential predictors of mortality ($p<0.20$) in the study cohort were included in the final logistic regression model. These independent variables were age, sex, arrival by helicopter, SBP, pulse, GCS, AIS scores for anatomical regions (head, chest, abdomen, and extremity), and year of admission.

The second analytical approach used propensity score matching to evaluate the risk-adjusted average treatment effect of PCCDs on mortality. This was done using a one-to-one matching scheme of propensity scores to the nearest neighbor within 0.1 points. This allowed each patient who received a PCCD to be matched to the single most similar corresponding control patient, provided that the difference in both patients propensity for treatment was no more than 10%. Control patients were not reused in cases where treated patients did not have a match. Continuous data are presented as medians with 25th and 75th interquartile range (IQR) with comparisons between groups performed using the Wilcoxon rank sum test (Mann-Whitney U test). Categorical data are reported as proportions with comparisons between groups performed using χ^2 and, where appropriate, Fisher exact tests. All statistical tests were two-tailed with $p<0.05$ set as significant. All analysis was performed using STATA (version 12.2; College Station, TX).

RESULTS

Records from the 22,968 patients in the Trauma Registry database were reviewed; 1,683 patients were identified with pelvic ring injuries. Of those, 44 patients declared dead upon arrival were excluded. A total of 1,639 patients were included in the study. PCCDs were applied to 130 patients (7.9%) (Figure 1). When comparing patients who received a PCCD to those without, PCCD patients presented with significantly higher ISS scores, lower GCS scores, lower ED systolic blood pressure, lower RTS, and a higher incidence of hemodynamic instability (Tables 1 and 2). Patients receiving a PCCD were also more likely to require angiography/embolization, surgical pelvic stabilization, and exploratory laparotomy.

Time of PCCD application was documented for only 56 (44.6%) of the PCCD patients. Of these patients, time of injury was available for 33 (58.9%), while time of hospital arrival was documented for all patients. PCCD application was at a median of 2.07 hours postinjury (1.38-3.65). The average time of application was 0.52 hours post-hospital arrival (0.25-1.18) (Figure 2).

To account for selection bias and discrepancy, the propensity model was utilized to create a matched cohort. The PS matched model consisted of 82 patients. When comparing PCCD and non-PCCD in the matched cohort, there were no differences in ISS, ED, GCS, ED SBP, RTS, and incidence of hemodynamic instability. Among the matched

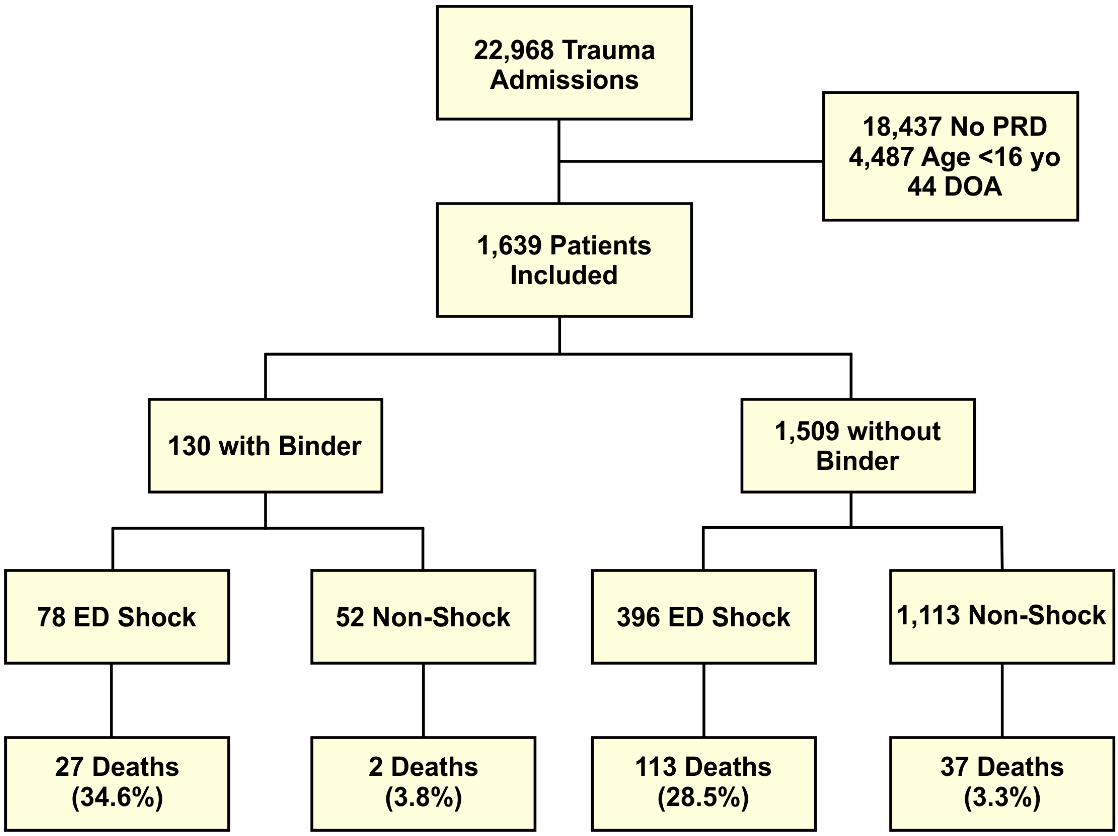

Figure 1. Consort diagram of trauma patients.

Table 1. Characteristics of patients with pelvic ring disruption.

Patient	No Binder (n=1,509) Median (IQR: 25%, 75%)	Binder (n=130) Median (IQR: 25%, 75%)	P Value
Age	42 (25-59)	38 (26-51)	0.044
ED SBP	121 (105-140)	102 (80-124)	<0.001
ED HR	93 (80-109)	109 (92-125)	<0.001
ED GCS	15 (14-15)	14 (3-15)	<0.001
ED RTS	7.841 (7.55-7.841)	7.108 (4.094-7.841)	<0.001
Head AIS	0 (0-2)	0 (0-3)	0.150
Face AIS	0 (0-0)	0 (0-0)	0.080
Chest AIS	2 (0-3)	3 (0-3)	<0.001
Abdomen AIS	2 (0-2)	3 (2-3)	<0.001
Extremity AIS	3 (2-3)	3 (3-4)	<0.001
External AIS	1 (0-1)	1 (0-1)	0.001
ISS	18 (10-29)	29 (21-41)	<0.001

ED, emergency department; SBP, systolic blood pressure; HR, heart rate; GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; AIS, Abbreviated Injury Score; ISS, Injury Severity Score.

Table 2. Dichotomized demographics of pelvic ring trauma patients.

Patient	No Binder (n=1,509) (%)	Binder (n=130) (%)	P Value
Male	56.7	75.4	<0.001
Age >60	23.9	9.2	<0.001
White race	63.4	54.6	0.048
Helicopter transport	45.9	60.0	0.002
SBP ≤90	14.6	38.3	<0.001
HR >100	36.5	64.0	<0.001
GCS ≤8	18.4	38.6	<0.001
Head AIS ≥3	24.1	26.2	0.592
Face AIS ≥3	0.8	0.8	0.974
Chest AIS ≥3	43.5	56.9	0.003
Abdomen AIS ≥3	23.1	50.8	<0.001
Extremity AIS ≥3	60.8	94.6	<0.001
External AIS ≥3	0.3	0.0	0.557

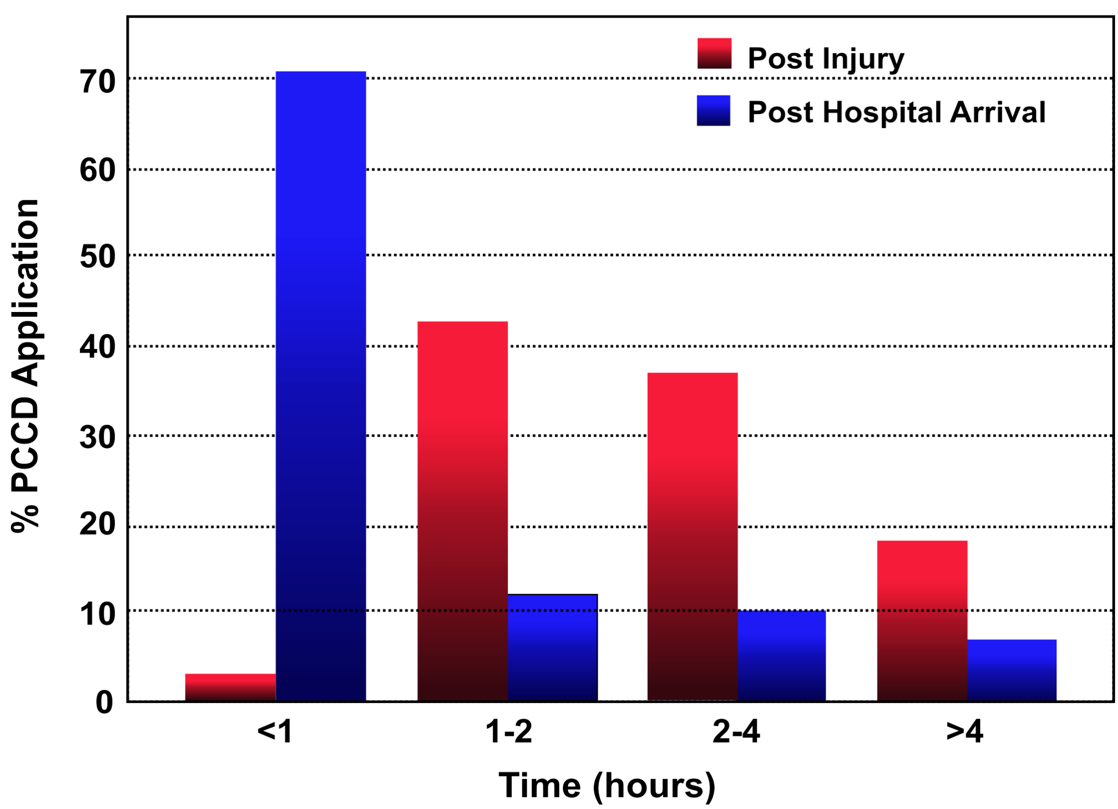

Figure 2. Post-injury time versus post-admission time to pelvic circumferential compression device (PCCD) application.

Table 3. Matched cohort dichotomized demographics of pelvic ring injury patients.

Patient	No Binder (n=41) (%)	Binder (n=41) (%)	P Value
Male sex	68.3	65.9	0.814
Age >60	26.8	24.4	0.800
White Race	48.8	68.3	0.073
Helicopter	65.9	63.4	0.817
SBP ≤90	51.2	53.7	0.825
HR >100	51.2	51.2	1.000
GCS ≤8	48.8	46.3	0.825
Head AIS ≥3	40	20	0.230
Face AIS ≥3	2.4	0.0	0.314
Chest AIS ≥3	61.0	61.0	1.000
Abdomen AIS ≥3	48.8	48.8	1.000
Extremity AIS ≥3	82.9	82.9	1.000
External AIS ≥3	0.0	0.0	N/A
Mortality	29.3	19.5	0.304

cohort, mortality rate was lower (19.5%) in the PCCD population compared to (29.3%) without PCCD; however, this reduction was not statistically significant (p=0.30) (Table 3).

The multivariate logistic regression model accounted for the propensity to treat and established predictors of mortality. The odds ratio for mortality associated with PCCD application was 0.68 (95%CI: 0.33-1.41, p=0.30). The result did not achieve statistical significance (Table 4). Patient chart reviews did not reveal any incidences of soft tissue breakdown as a result of PCCD application.

A post-hoc power analysis was performed. On multivariate analysis, we would have achieved only 80% power if binders were associated with a 70% or greater decrease in mortality (OR 0.30). After adjusting for clear imbalances in injury severity

Table 4. The odds ratio for mortality in the multivariate logistic regression model.

Variable	Odds Ratio	P Value	95%CI
Binder	0.679	0.301	(0.326, 1.414)
Age	1.039	<0.001	(1.026, 1.052)
ED SBP	0.978	<0.001	(0.971, 0.986)
ED GCS	0.839	<0.001	(0.798, 0.883)
Head AIS	1.538	<0.001	(1.346, 1.758)
Abdomen AIS	1.264	0.007	(1.065, 1.500)
Extremity AIS	0.516	0.027	(0.287, 0.928)

and other confounders associated with patients who received binders, we found a 32% reduction in mortality (OR 0.679; p=0.3), indicating we had about 40% power, or in other words, there is a 60% chance our observed results are subject to a type II error. For the matched cohort, to achieve 80% power, we would have needed to demonstrate a 23% or higher risk difference with binder use. Instead, we demonstrated a 9.8% risk reduction in this analysis, indicating 45% power or a 55% chance of a type II error.

DISCUSSION

We did not find a statistically significant decrease in mortality with PCCD (19.5% vs 29.3%) use for pelvic ring disruption using a matched cohort model to control for confounding variables; however, our post-hoc power analysis suggests we are underpowered. This is largely because of the low sample size of patients receiving binders (n=130). Overall in-hospital mortality for PRD was 11%. When a patient presented with PRD and shock, mortality was 29.7%.

We also found that PCCDs were not extensively used in our Level I trauma center. A total of 396 patients with pelvic ring disruption and hemorrhagic shock over a 5-year period did not have PCCDs, despite recommendations from the ACS for use of PCCDs in all patients with suspected PRD and hemodynamic instability (6). It is difficult to determine the exact reasons for the limited application in this period as decisions were made individually by attending emergency department physicians and trauma surgeons, and there was no defined protocol in place for PCCD application. When PCCDs were used, median time from injury to application was more than 2 hours.

The complex treatment of the polytraumatized patient can lead to delayed assessment of the pelvis (2), with life-threatening results. Hemorrhage associated with blunt pelvic trauma was identified as the cause of 86% of preventable deaths due to delayed identification of the pelvis as the bleeding source (2). Sathy et al. (1) found pelvic fracture to be associated with mortality in a review of more than 63,000 trauma patients. These studies and our data support the importance of early diagnosis and treatment of blunt pelvic injury in the polytraumatized patient, especially considering the elevated mortality rate (29.7%) associated with PRD and hemodynamic instability in our cohort. We advocate routine AP pelvis views early in the evaluation of all blunt trauma patients in accordance with ACS recommendations (6) to promote early identification of this life-threatening injury.

Recent literature has suggested pre-hospital use of PCCD (13), and the delay in application warrants further investigation regarding expedited application. In addition to our center's limited use of PCCDs, PCCD application was often delayed. Despite relatively rapid application, when chosen, upon hospital arrival (0.52 hours), PRD patients are at risk of developing irreversible shock when the time of application post-injury (2.07 hours) is considered. Pre-hospital PCCD should be considered for potential incorporation into future protocols.

PCCD patients in our cohort had higher injury severity scores and lower systolic blood pressures on arrival, indicating a different physiology than patients that did not receive PCCD. The PS model was used to account for this discrepancy between the experimental and control populations. Despite controlling for confounding and selection bias, a statistical significance between PCCD use and mortality reduction was not established.

The study may have been underpowered owing to the limited number of PCCDs. Despite a greater than 30% reduction in odds of mortality among the matched cohort, statistical significance was not achieved. One plausible consideration, in addition to the small sample size, is the high incidence of accompanying traumatic brain injury (TBI), the leading cause of death in PRD patients (8). Given this consideration, other outcome variables, including transfusion requirements, may be studied in future investigations.

The retrospective nature of this study was a significant limitation owing to missing data on several important physiological parameters and variability of treatment based upon the attending emergency department provider. Base value information was absent from 61.3% of all patients, complicating the definition of hemodynamic instability. Time of application was not recorded for a large portion of PCCD patients and precluded an opportunity to correlate any potential benefit associated with early application. Consideration will be made to adapt future protocols with emphasis on inclusion of these data sets.

Although no statistically significant mortality reduction was associated with PCCD use, there were also no significant complications associated with PCCD use. Specifically, there were no documented cases of soft tissue breakdown. While an associated survival benefit remains undetermined, the relative ease of application and limited complications establish use of PCCD as a potential emergent treatment of PRD. Opportunities for earlier application await further study.

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