Extraperitoneal Pelvic Packing: A Salvage Procedure to Control Massive Traumatic Pelvic Hemorrhage

Anna Tøtterman, MD, Jan Erik Madsen, MD, PhD, Nils Oddvar Skaga, MD, and Olav Røise, MD, PhD

Objectives: To describe the method of extraperitoneal pelvic packing (EPP), and to assess the impact of EPP on outcome in severely hemodynamically unstable patients after blunt pelvic trauma.

Methods: Of 661 patients treated for pelvic trauma, 18 underwent EPP as part of our protocol with the intent to control massive pelvic bleeding and constituted the study population. Data retrospectively collected from the medical records and from the Ullevål Trauma Registry included demographics, fracture classification, additional injuries, blood transfusions, surgical interventions, angiographic procedure, physiologic parameters, and survival.

Results: Survival rate within 30 days was 72% (13/18), and correlated inversely to the age of the patient (p = 0.038). Only one of the nonsurvivors died of exsanguination. A significant increase in systolic blood pressure (BP) (p = 0.002) was observed immediately after EPP. Angiography performed after EPP was positive for arterial injury in 80% of patients. All types of pelvic ring fractures were represented.

Conclusions: EPP as part of a multi-interventional resuscitation protocol might be life saving in patients with life-threatening pelvic injury who are exsanguinating. However, the high rate of arterial injuries seen after EPP indicates that the procedure should be supplemented with angiography once the patient is sufficiently stabilized to tolerate transportation to the angiography suite.

Key Words: Pelvis, Hemorrhage, Outcome, Damage control, Transfusion, Trauma.

Mortality after severe pelvic injury is a consequence of continuous hemorrhage within the first 24 hours of hospitalization, whereas coexisting cerebral injuries, thromboembolism, and multiple organ failure (MOF) explain most of the mortality after this period. Vascular injuries in association with pelvic trauma may be difficult to address because of the abundant collateral blood supply of the pelvis, and several different techniques of attaining bleeding control have been described, such as ligation of the iliac artery or vein, application of local hemostatic therapies, and attachment of sterile thumbtacks to the sacrum, cautery, and bone wax. None of these techniques have, however, proven successful because of anatomic reasons. In the past years emergent angiographic embolization has been advocated in the control of life-threatening pelvic hemorrhage. However, the angiographic procedure (AP) may be time-consuming, with reported procedure times of 90 minutes and this might not be tolerated by the severely hemodynamically unstable patient. Furthermore, angiographic services may not be available in all hospital settings. In these patients there is a need for supplementary life-saving procedures.

The technique of pelvic packing as a means of controlling massive pelvic bleeding was described already in 1926 by Logothetopulos. Today, several different techniques of pelvic packing are used, but very little has been published on the effect of pelvic packing on bleeding control. In 1994 the senior author (O.R.) introduced the technique of extraperitoneal pelvic packing (EPP), as first described by Pohlemann et al. in our institution. The procedure has been employed as a salvage procedure as part of the initial treatment protocol in patients with life-threatening traumatic pelvic bleeding who demonstrate continued signs of massive pelvic bleeding after AP, and in patients who are not transportable to the angiography suite because of profound hemorrhagic shock.

In the following we describe the use and outcome of EPP in patients with exsanguinating pelvic bleeding. The aim of the study was to assess survival rate after EPP in hemodynamically unstable patients subjected to blunt pelvic injury, and to study the changes in physiologic parameters and transfusion requirements at the time of the procedure.

MATERIALS AND METHODS

Patient Selection

Eighteen of 661 prospectively registered patients admitted to our regional trauma center between August 1, 2000 and March 31, 2004 because of pelvic, sacral, or acetabular injury underwent EPP with the intent to control massive pelvic bleeding. These patients constituted the study population.

According to the predefined protocol for the initial treatment of patients with pelvic hemorrhage (Fig. 1), angiography was performed in patients with continuous pelvic bleeding who were estimated to tolerate transportation to the

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Volume 62 • Number 4
angiography suite. Indication for EPP was severe hemodynamic instability corresponding to class III to IV hemorrhage according to Advanced Trauma Life Support in patients who were assessed to exsanguinate before or during angiography. EPP was further indicated in patients who continued to show signs of severe ongoing massive bleeding despite the AP. Common to all included patients were the presence of more than one of the following clinical signs before EPP: systolic blood pressure (BP) <90 mm Hg; central venous pressure (CVP) <5 cm H2O, and pulse frequency >100 beats/min. Seven patients arrived in the emergency department (ED) with nonobtainable systolic BP. Of the remaining patients, six were in hemorrhagic shock at admission (BP <90 mm Hg), and five patients were initially described as circulatory stable, but decompensated within the first hours from admission despite ongoing fluid resuscitation. In three of the five initially stable patients, EPP was performed after angiography.

Fig. 1. Flow-sheet for the initial treatment of patients’ pelvic ring fractures and clinical signs of hemorrhage.

angiography suite. Indication for EPP was severe hemodynamic instability corresponding to class III to IV hemorrhage according to Advanced Trauma Life Support in patients who were assessed to exsanguinate before or during angiography. EPP was further indicated in patients who continued to show signs of severe ongoing massive bleeding despite the AP. Common to all included patients were the presence of more than one of the following clinical signs before EPP: systolic blood pressure (BP) <90 mm Hg; central venous pressure (CVP) <5 cm H2O, and pulse frequency >100 beats/min. Seven patients arrived in the emergency department (ED) with nonobtainable systolic BP. Of the remaining patients, six were in hemorrhagic shock at admission (BP <90 mm Hg), and five patients were initially described as circulatory stable, but decompensated within the first hours from admission despite ongoing fluid resuscitation. In three of the five initially stable patients, EPP was performed after angiography.

Management Algorithm for Blunt Pelvic Trauma

The algorithm for the initial treatment of patients with blunt pelvic trauma employed at our regional trauma hospital is summarized in Figure 1.

Initial Resuscitation

Patients suffering from high-energy injuries are managed according to the ATLS (Advanced Trauma Life Support) algorithm. Until the sources of bleeding are identified and controlled, the patients are resuscitated according to the principle of deliberate hypotensive fluid resuscitation. Depending on circulatory state and hemodynamic response to initial fluid resuscitation with up to 2 L of warmed Ringer’s acetate, the patients are assessed to be one of the following:

1. Hemodynamically normal with estimated blood loss by admission of less than 1,500 mL (<30%). These patients receive a continued fluid resuscitation with Ringer’s acetate and/or colloid solutions. Blood transfusions are initiated if signs of ongoing hemorrhage are observed or initial Hb count is <8 g/dL in younger patients, or <9 g/dL in patients older than 65 years, or
2. In hypovolemic shock with estimated blood loss by admission of more than 1,500 mL (>30%), and signs of hemodynamic instability judged by presence of tachycardia, delayed capillary refill >2 seconds, hypotension ≤90 mm Hg, or decreased pulse pressure. In these patients aggressive fluid resuscitation is continued with crystalloids, colloids, and concentrated RBCs (one unit = 300 mL). In cases of gross hemodynamic instability, indicating life-threatening hemorrhage, massive transfusion efforts are commenced before initial Hb count is obtained, and administered until the Hb count is above 9 g/dL, BE tends to improve, and clinical signs of hemodynamic normalization are observed.

Baseline Assessment

Data retrospectively collected from the medical records included time of injury, arrival time at ED, blood transfusions (units of red blood cells [RBCs]), surgical interventions, initial pelvic stabilization, AP (embolization, findings), physiologic parameters plotted immediately around the time of packing (BP, pulse frequency, base excess (BE), hemoglobin (Hb) count). Data from the hospital-based trauma registry (The Ullevål Trauma Registry) included age, gender, additional injuries, patient’s outcome (alive/ dead), and time/cause of death in nonsurvivors. Injuries were coded according to the Abbreviated Injury Scale (AIS) for calculation of Injury Severity Score (ISS), according to convention. Probability of survival was calculated according to Trauma and Injury Severity Score (TRISS) methodology with coefficients revised according to AIS 90 as published by Champion et al. in 1995. Physiologic derangements were classified according to Revised Trauma Score (RTS). Fracture characteristics (type, classification according to AO-OTA) were obtained from an institution-specific prospective registration of pelvic injuries.

EPP was considered primarily effective when the patient survived the first 30 days after injury. The procedure was considered secondarily effective when time-adjusted transfusion requirements decreased after EPP, or when the tested physiologic parameters improved after EPP.
Initial Stabilization of Pelvic Injury

The use of a temporary external fixator as a means to stabilize the pelvis has at our hospital been substituted with the more rapid method of pelvic sheeting. In our modification a folded 20-cm-wide sheet is positioned in a circumferential manner around the trochanteric region after the pelvic fracture is reduced by traction and internal rotation of the hips. The ends of the sheet are crossed, pulled taut, and secured with clamps. Pelvic sheeting is kept until the patient is judged hemodynamically normal and transfusion requirements have ceased, usually 1 to 2 days.

The Technique of EPP

EPP is performed in the emergency room in cases of patients in extremis, who are obviously unable to survive transferal to the angiography suite. With the patient positioned supine, the abdomen is draped from the pubic area to the upper clavicular margins for direct access to emergency thoracotomy and laparotomy, when needed. A lower midline incision from the umbilicus to the symphysis is used. Linea alba is incised and the peritoneum is left intact. The peritoneum is manually pushed free from the inner aspect of the osseous pubic symphysis and the pelvic ring (Fig. 2). The linea terminalis is followed by palpation to the sacroiliac (SI) joint, exposing the inner aspect of the quadrilateral plate. The obturatory nerve with vessels is usually not searched for, but if identified pushed laterally. The internal oblique muscle, which drapes the inner surface of the quadrilateral plate, is left uninterrupted and no attempts to free the peritoneum from the sacrum are attempted. In cases where laparotomy is performed before the pelvic packing, the peritoneum is left intact distally to facilitate packing in the extraperitoneal space. A minimum of three large radio-opaque swabs are placed in the pelvis in the interspace between the bony pelvic ring and the peritoneum, starting posteriorly from the SI joint and advancing anteriorly to the retropubic area (Figs. 3 and 4). The swabs are directed toward branches of the internal iliac artery and the pelvic venous plexus situated in the retroperitoneal space lateral to the sacrum. The procedure is repeated on the contralateral side to achieve sufficient tamponade. In unstable pelvic fractures the levator muscles, as well as the sacrotuberous and ischial ligaments may be torn. This increases the volume of the true pelvis and 3 to 10 more swabs might be needed. When the pelvic fracture is associated with a perineal tear, additional swabs are placed in the open wound cavity. After completing pelvic packing the linea alba is closed with continuous sutures to achieve additional tamponading effect. No wound drains are left. In cases where a coinciding intra-abdominal injury has necessitated damage control surgery intra-abdominally, the upper part of the laparotomy incision may be left open according to the abdominal vacuum principle to reduce the risk of abdominal compartment syndrome.

Extraperitoneal Pelvic Packing

Volume 62 • Number 4

Fig. 2. Lower-midline incision. The peritoneum is visible.

Fig. 3. Pelvic anteroposterior view showing a combined pelvic (bilateral, Type B3.2) and acetabular fracture (left). Bilateral radio-opaque swabs are seen compressing the contrast-filled bladder. Bilateral embolization coils are seen posteriorly.

Fig. 4. Computed tomography scan demonstrating the position of the radio-opaque swabs in the pelvis. The peritoneum is pushed medially (same patient as in Fig. 3).
Additional Hemostatic Procedures

Percutaneous pelvic angiography is performed in patients who have sustained blunt high-energy injuries to the pelvic ring when the predefined transfusion criteria for angiography are met. In our institution these are (1) initial hemorrhage necessitating more than five units of RBCs within the first 24 hours, or (2) protracted hemorrhage after initial stabilization necessitating more than four units RBCs within the following 24 hours. All patients subjected to EPP underwent angiography after successful initial resuscitation. The interventional angiography team provides 24-hour coverage. In the present study, angiography was performed in all patients, and 15 (83%) had signs of arterial injury. Three patients were interpreted as sufficiently hemodynamically stable to tolerate an AP as the primary measure for control of continuing hemorrhage, but EPP later proved necessary because of persistent hemorrhagic shock after angiography. Two of these patients survived.

Emergent left-sided thoracotomy as a salvage procedure is performed parallel to crash laparotomy and/or pelvic packing in patients with no measurable BP at admission who do not respond to aggressive fluid resuscitation. If successful resuscitation is obtained, the procedure is continued and gradually terminated when damage control surgery has been performed and the anesthesiologists have “caught up” with the administration of transfusions. In the present study, aortic clamping was performed before EPP in five patients. In the remaining two patients who arrived to the ED with nonobtainable BPs, a measurable BP was observed after initial fluid resuscitation.

In the present study, a combined emergency laparotomy and EPP was performed in 14 patients, 8 of whom were found to have concomitant gastrointestinal lesions, none of which, however, significantly contributed to the hemorrhage. The remaining four patients underwent a diagnostic peritoneal lavage to exclude abdominal bleeding, all of which were negative. Thirteen patients underwent internal fixation of the pelvic fracture on mean day 3 (range, 1–6); two of whom later died from unrelated causes. Five of the injuries were open fractures (Gustillo III). Conservative treatment was scheduled for the remaining patients.

Pelvic sheeting as a means to achieve initial stabilization was applied to all patients with pelvic fractures excluding the three patients with acetabular fractures and one patient who had an external fixator applied at the referring hospital. The pelvic sheeting was converted to an external fixator in two patients who were not eligible to early definitive surgery because of additional injuries. A C-clamp was not used in any of these patients.

Statistical Analysis

Statistical analysis was performed using SPSS 12.0 software (SPSS Inc., Chicago, IL). To study the association between continuous variables the Spearman’s correlation coefficient was used. A comparison between means was calculated using the paired samples t test, except for variables with a markedly skewed distribution, where a Mann–Whitney U test was used. An independent samples t test was used to compare means between survivors and nonsurvivors. A 5% significance level was used.

The Regional Committee for Research Ethics approved the study.

RESULTS

Results are given as mean values and range if not stated otherwise.

Background Data

All but one patient had been involved in high-energy injuries. Traffic crashes accounted for 15 of the included cases (83%), falls from height for 2 (11%), and fall from standing position for 1 (6%). All patients with high-energy injuries were severely injured as measured by ISS (48; range, 9–66 for all). Associated injuries occurred in 17 patients (94%) (Table 1). The most frequent concomitant injuries were orthopedic (n = 17, 94%), pulmonary (n = 14, 78%), cerebral (n = 9, 50%), and gastrointestinal tract injuries (n = 8, 44%). Injuries to three or more organ systems occurred in 15 cases (83%). Seventeen patients (94%) filled the criteria for “polytrauma”, defined as injury to two or more organ systems and ISS >15. Seventeen patients (94%) underwent surgery for associated injuries.

Median transferal time from injury to the ED was 98 minutes (9–1,520 minutes). Only five patients arrived within an hour after injury. Twelve of the patients (67%) were admitted directly from the site of injury, and the remaining via a referring hospital. Patients arriving directly from the site of the crash arrived within a median of 63 minutes (9–68 minutes). Transferring a patient via a referring hospital increased the transferal time from injury to ED by a median of 417 minutes (100–1,450 minutes). The transferal time was

<table>
<thead>
<tr>
<th>Table 1 Patient Characteristics (n = 18)</th>
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<tbody>
<tr>
<td>Age at accident</td>
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<tr>
<td>Proportion male patients</td>
</tr>
<tr>
<td>Associated injuries</td>
</tr>
<tr>
<td>Injury Severity Score (ISS)</td>
</tr>
<tr>
<td>ISS &gt;15</td>
</tr>
<tr>
<td>Revised Trauma Score (RTS)</td>
</tr>
<tr>
<td>Glasgow Coma Scale (GCS)</td>
</tr>
<tr>
<td>Probability of survival (GCS)</td>
</tr>
</tbody>
</table>

* Mean (Range).
longer for the 13 survivors (252 minutes, 9–1,520 minutes), as compared with the five nonsurvivors (73 minutes, 10–170 minutes), but the difference was not statistically significant (p = 0.149).

EPP was performed within 41 minutes of arrival in the 13 patients presenting with manifest signs of hemorrhagic shock at admission. The corresponding time for all patients was 134 minutes (5–720 minutes), including the three patients who underwent EPP after angiography. Removal of swabs was possible within 48 hours in 14 of the 15 (93%) early survivors. Repacking was necessary in two survivors because of significant bleeding at the time of the second look surgery.

In the 15 patients who had angiography performed after EPP, 12 (80%) had positive findings for arterial injury.

A total of 59 transfusions (RBC) (12–191) were administered to each patient during the whole hospitalization period (27 days; range, 1–102 days). Patients were administered 12 RBC transfusions (0–58) from injury to EPP, and an additional 17 (0–43) within 24 hours of completed EPP. An insignificant increase in total transfusion requirements was seen with higher injury scores, as measured by ISS (p = 0.097). In all patients, the mean transfusion rate decreased from 0.1 (0.00–0.92 units/min before EPP, to 0.012 (0.003–0.30) units/min within 24 hours after completed EPP (p = 0.044). Nonsurvivors were administered more transfusions before EPP (0.38 units/min, 0.00–0.92), compared with survivors (0.07 units/min, 0.00–0.32), but the difference was nonsignificant (p = 0.155).

### Physiologic Parameters

Mean systolic BP at arrival was 60 mm Hg (0–130 mm Hg). All seven patients with nonobtainable BP at arrival (patients “in extremis”) survived, two of who were resuscitated from cardiac arrest that occurred during resuscitation.

At the time of EPP all patients had a measurable BP (80 mm Hg, 60–120 mm Hg) because of initial fluid resuscitation, pelvic sheeting, and aortic clamping (n = 5). There was a statistically significant increase in BP measured immediately after EPP (99 mm Hg, 70–130 mm Hg), as compared with BP measured before EPP (80 mm Hg) (p = 0.002). A summary of the physiologic findings and transfusion requirements plotted around the time of EPP is given in Table 2.

Pulse frequency at admission (119 bpm, 40–165) had not changed markedly by the time of EPP (105 bpm, 70–140) despite aggressive fluid resuscitation. A slight decrease in pulse frequency was seen after completion of EPP (102 bpm, 55–150), but the reduction in pulse frequency plotted around EPP was not significant (p = 0.541).

BE at the time of arrival was −6.6 mmol/L (+2 to −23.6 mmol/L). At the time of pelvic packing acidosis had increased to −7.9 mmol/L, (0 to −16.7 mmol/L), and persisted after completed EPP (BE −9.0 mmol/L; range, −2.5 to −21.9 mmol/L). The impact of EPP on BE before and after the procedure was not significant (p = 0.259). An improvement of BE after completed EPP was, however, seen more often in survivors compared with nonsurvivors, but the difference was not significant (p = 0.088). Admission delay was found to increase the level of acidosis, but the difference was not significant (p = 0.413).

Mean Hb count at admission was 8.8 g/dL (6.5–12.9 g/dL). Immediately before EPP a reduction of Hb to 8.0 g/dL (4.4–11.9 g/dL) was observed despite blood transfusions. After completed damage control surgery Hb had risen to 9.4 g/dL (6.1–13.6 g/dL), probably as a consequence of the anesthesiologists “catching up” with transfusions. The improvement in Hb before and after EPP was significant (p = 0.012), but the improvement did not differ significantly in survivors (0.7 g/dL), and nonsurvivors (2 g/dL) (p = 0.138). Lower Hb at the time of EPP tended to increase the risk of later mortality, but not to a statistically significant extent (p = 0.627).

### Mortality

Overall mortality rate after EPP, defined as death within 30 days of injury, was 28% (n = 5). Characteristics of the five nonsurvivors are summarized in Tables 3 and 4. All five nonsurvivors had sustained multiple associated injuries. The cause of death was verified by autopsy in four of the five patients. Two of the nonsurvivors died within 24 hours of injury; in these cases the primary cause of death was multifocal hemorrhage from pelvic, liver, and pulmonary injuries (n = 1), and cerebral injury (n = 1). MOF accounted for death in the remaining three nonsurvivors on days 2, 9, and 28, respectively. Thus, only one patient died of ongoing hemorrhage. Nevertheless, pelvic injury was interpreted as a

### Table 2 Physiologic Parameters and Transfusion Rate at Time of EPP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prior to EPP</th>
<th>After EPP</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>80</td>
<td>99</td>
<td>p = 0.001*</td>
</tr>
<tr>
<td>Pulse frequency (beats/min)</td>
<td>105</td>
<td>102</td>
<td>p = 0.541</td>
</tr>
<tr>
<td>Base excess (mmol/L)</td>
<td>−7.9</td>
<td>−9.0</td>
<td>p = 0.259</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>8.0</td>
<td>9.4</td>
<td>p = 0.012*</td>
</tr>
<tr>
<td>Time adjusted RBCs† (units/min)</td>
<td>0.1</td>
<td>0.012</td>
<td>p = 0.044</td>
</tr>
</tbody>
</table>

* Significant with a 95% level of confidence.

† RBCs, packed red blood cells. One unit = 300 mL.
major contributor to death in four of five nonsurvivors. Significant comorbidity (systemic lupus erythematosus with ongoing immunosuppressive therapy) contributed to the death in one of the nonsurvivors who died as a result of MOF and septicemia on day 28.

When comparing survivors and nonsurvivors, survivors were younger (37 years), compared with nonsurvivors (59 years) \((p < 0.038)\) (Table 5). There was no significant difference in ISS or the number of administered transfusions in the different ages. Furthermore, no significant difference was found in the assigned trauma scores between survivors and nonsurvivors. An insignificantly shorter delay between admission and the packing procedure was observed in survivors (123 minutes; range, 5–720), compared with the nonsurvivors (162 minutes; range, 5–660), \((p = 0.519)\).

### Complications

Pelvic infection necessitating wound revisions occurred in six patients (33%), five of whom had routine revisions performed because of severe open pelvic fractures (Gustillo III). In one patient, swabs were not removed until day 3 because of logistic problems, this patient later died of MOF on day 9. One patient developed sepsisemia after transfer from Ullevål to the local hospital and was found to have a swab accidentally left in the pelvis. The swab was removed and the patient survived.

### DISCUSSION

The initial management of traumatic pelvic bleeding is dependent on hemodynamic stability of the patient at admission. In the majority of cases, bleedings stop after pelvic stabilization and adequate initial resuscitation. However, a small percentage of patients present with life-threatening

<table>
<thead>
<tr>
<th>Table 3 Fracture Classification* and Mortality Rate</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Pelvic fractures</td>
</tr>
<tr>
<td>Type A</td>
</tr>
<tr>
<td>Type B1</td>
</tr>
<tr>
<td>Type B2</td>
</tr>
<tr>
<td>Type B3</td>
</tr>
<tr>
<td>Type C</td>
</tr>
<tr>
<td>Sacral fracture</td>
</tr>
<tr>
<td>Acetabular fracture</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

* Classification according to AO-OTA.21

Table 4 Characteristics of the Nonsurvivors (n = 5)

<table>
<thead>
<tr>
<th></th>
<th>Patient A</th>
<th>Patient B</th>
<th>Patient C</th>
<th>Patient D</th>
<th>Patient E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>80</td>
<td>39</td>
<td>54</td>
<td>51</td>
<td>72</td>
</tr>
<tr>
<td>Time of death</td>
<td>Day 1 (13 h)</td>
<td>Day 9</td>
<td>Day 28</td>
<td>Day 1 (2 h)</td>
<td>Day 2</td>
</tr>
<tr>
<td>Primary cause of death</td>
<td>Cerebral injury and multiple fractures</td>
<td>MOF</td>
<td>MOF, cerebral abscess, septicemia</td>
<td>Multiple hemorrhage</td>
<td>MOF</td>
</tr>
<tr>
<td>Pelvic injury primary cause of death</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>59</td>
<td>45</td>
<td>38</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>Comorbidity</td>
<td>Unknown</td>
<td>No</td>
<td>SLE, vasculitis</td>
<td>No</td>
<td>Unknown</td>
</tr>
<tr>
<td>Fracture type</td>
<td>B2</td>
<td>B1</td>
<td>C2</td>
<td>C2</td>
<td>A2</td>
</tr>
</tbody>
</table>

Multiple organ failure.

Table 5 Comparison Between Survivors and Nonsurvivors

<table>
<thead>
<tr>
<th></th>
<th>Survivors (n = 13)</th>
<th>Nonsurvivors (n = 5)</th>
<th>Level of Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>38 years (16–80)</td>
<td>59 years (39–80)</td>
<td>(p = 0.0038 (~41.8 \text{ to } -1.4))</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>47 (9–66)</td>
<td>48 (38–59)</td>
<td>(p = 0.84 (16.8 \text{ to } -13.8))</td>
</tr>
<tr>
<td>New Injury Severity Score</td>
<td>50 (18–66)</td>
<td>52 (43–66)</td>
<td>(p = 0.750 (~15.9 \text{ to } -11.7))</td>
</tr>
<tr>
<td>Revised Trauma Score</td>
<td>10 (4–12)</td>
<td>9 (5–12)</td>
<td>(p = 0.340 (~1.5 \text{ to } -1.1))</td>
</tr>
<tr>
<td>Probability of Survival Score (%)</td>
<td>63 (18–97)</td>
<td>43 (6–94)</td>
<td>(p = 0.203 (~11.9 \text{ to } -51.9))</td>
</tr>
<tr>
<td>Time from injury to admission (min)</td>
<td>252</td>
<td>67</td>
<td>(p = 0.352 (~217 \text{ to } 576))</td>
</tr>
<tr>
<td>Time from injury to EPP (min)</td>
<td>360</td>
<td>221</td>
<td>(p = 0.626 (~452 \text{ to } 730))</td>
</tr>
<tr>
<td>Time from admission to EPP (min)</td>
<td>123</td>
<td>162</td>
<td>(p = 0.744 (~286 \text{ to } 209))</td>
</tr>
</tbody>
</table>

* Independent samples test (95% confidence interval), difference in means.

† RBCs, packed red blood cells. One unit = 300 mL.
harmorrhage. Most of these patients may successfully be treated with arterial embolization for definite arterial control. However, a subgroup of patients will not tolerate transportation to the angiography suite because of life-threatening hemorrhage. In these cases “damage control” surgery is indicated.26

The present study describes the method of extraperitoneal packing as a damage control procedure in the treatment of patients with severe hemorrhage after pelvic ring injury, and looks at the effects of the procedure on survival, transfusion requirements, and physiologic parameters. Of the 661 patients admitted with pelvic, acetabular, or sacral fractures during the study period, 18 patients (2.7%) had clinical signs of massive pelvic hemorrhage necessitating pelvic packing to control pelvic bleeding. In the present study, the success rate, defined as 30-day survival, of EPP as part of a multidisciplinary approach, was 72%. This corresponds to a previous report by Ertel et al.,14 who described a 71% survival rate in 10 of 14 patients with hemorrhagic shock after retroperitoneal pelvic packing and application of a C-clamp.

To test the efficacy of a treatment that goes beyond the conventional morbidity parameters, a variety of resuscitative end points have been proposed. Previous studies have demonstrated that high lactate and base deficit levels are important predictors of mortality in pelvic trauma,14,27,28 and that pelvic fracture patients with a base deficit $\geq 5$ mmol/L are significantly more likely to die compared with patients with normal values.29 In the present study we defined the efficacy of EPP secondary as improvement of physiologic parameters plotted around the time of EPP, or a reduced need for transfusions after EPP. We observed metabolic acidosis measured by BE in all patients at admission, but the acidosis did not significantly differ between survivors and nonsurvivors, or improve with the procedure. However, in the majority of patients an immediate increase in systolic BP immediately after EPP was observed, together with a decrease in time-adjusted transfusion requirements. This improvement in physiologic parameters, combined with reduced transfusion requirements may indicate that EPP, as part of a multidisciplinary resuscitative approach, reduces the rate of pelvic bleeding, thereby enabling the anesthesiologist to “catch up” with fluid resuscitation and transfusions before definite control of arterial bleeding by angiographic embolization is achieved.

As simple resuscitative measures suffice in the majority of patients with pelvic ring fractures, it is assumed that the majority of pelvic bleedings are caused by injury to small pelvic vessels.12,30 However, in the hemodynamically unstable patient with pelvic trauma little is known regarding the precise anatomic site of bleeding. Several authors implicate venous injury as the main cause of bleeding in severe pelvic hemorrhage.14,31,32 and foremost injury to the presacral venous plexus.14 Nevertheless, as few studies have formally examined the prevalence of pelvic venous injuries, the rate of significant venous injury in pelvic trauma is largely unknown. Kataoka et al.33 found venous injury on transfemoral venography after angiography in 9 of 11 hypotensive patients. The veins involved were the common iliac vein (n = 5), the internal iliac vein (n = 3), and the external iliac vein (n = 1). The researchers recommended venography to be performed immediately after arteriography in patients who remained in shock, and venous stenting performed when major venous injury was diagnosed.

Information about the rate of arterial injury in pelvic trauma has primarily been derived from angiographic studies, with reported rates ranging from 0.01% to 2.3%12,34,35 for all pelvic trauma, and from 9% to 80% in unstable pelvic injuries.11,12,32,36–38 In the present study, consisting only of patients with severe traumatic pelvic hemorrhage, a high rate (80%) of arterial injury was observed on angiography after EPP. The combination of improvement in systolic BP and the positive findings on angiography after the procedure may indicate that the hemostatic effect of packing is mainly attributed to control of venous bleeding. Our results may therefore indicate that in patients subjected to high-energy pelvic trauma with massive pelvic bleeding, a combined injury to both intrapelvic veins and arteries is common. Therefore, to control arterial bleeding, EPP needs to be complemented with angiography once sufficient hemodynamic stability has been attained. We think that in the three unstable patients who underwent EPP after negative angiography, EPP may either have controlled arterial bleeding or, more probably, that bleeding was mainly caused by significant venous injury.

At our hospital the method for pelvic packing is extraperitoneal, but several different techniques for pelvic packing have been described.14,16,39–41 In the intraperitoneal techniques the pelvis is approached through an abdominal midline incision. The abdominal peritoneal cavity is opened and the intestines are pushed deep into the upper abdomen before placing the swabs in the lower abdomen.41,42 In the EPP or retroperitoneal pelvic packing techniques swabs are placed in the space formed by the pelvic peritoneum and the bony pelvic side walls to access directly the extraperitoneally situated vessels. Ertel described a technique of retroperitoneal pelvic packing through a laparotomy incision.43 In this technique the retroperitoneum is entered after bilateral colonic mobilization and direct manual access down to the sacrum and the SI joints, and swabs are placed in the presacral and prevesical regions bilaterally. To minimize the risk of ACS, the abdominal cavity is left open. In the technique of EPP described by Pohlemann et al.,16 and slightly modified by us, the extraperitoneal pelvic space is entered from a lower midline incision and the swabs are placed in the space formed by the peritoneum and the true pelvis. As the peritoneum is loosely attached to the pelvis in these areas, it is frequently already dissected from the osseous pelvis by the fracture hematoma. Contrary to Pohlemann et al., we do not attempt to identify the bleeding sources when profuse extraperitoneal bleeding is encountered at the time of packing. In our modification the SI joints form the most posterior border of dissection and the presacral retroperitoneal space is not en-
tered. By detaching the tightly attached pelvic fascia from the sacrum we think that the tamponading effect on injured presacral veins would be lost. Furthermore, as the presacral veins are easily lacerated during blunt mobilization, dissection may in itself result in life-threatening bleeding.7,8 We attempt wound closure of the lower midline incision as an intact abdominal wall has been shown to contribute to decreased pelvic volume and increased stability.34 Midline fascial closure may further limit the decompression of hematoma and assist with pelvic tamponade.

The potential advantage of the extraperitoneal packing technique is that it is quick and easy to perform. By placing the swabs extraperitoneally, they remain in the pelvis and do not dislocate intra-abdominally. In the intra-abdominal techniques, the swabs might migrate cranially as there are no natural cranial boundaries in the true pelvis. Because of the large intra-abdominal cavity, sufficient pressure directed to the true pelvis may be difficult to obtain unless larger amounts of swabs are used. These swabs may interfere with intra-abdominal circulation by compression of the vena cava, increasing the risk of ACS with secondary impact on the cardiopulmonary system.45 By placing the swabs extraperitoneally, the risk of swabs interfering with intra-abdominal circulation or pulmonary function may be reduced, keeping the risk of ACS to a minimum.

As hemostatic packing is performed on severely hemodynamically unstable patients, the rate of complications will be high. Sharp and Locicero46 reported a 27% complication rate in 22 survivors after intra-abdominal packing; 5 abdominal abscesses, 2 wound dehiscence, and 2 enterocutaneous fistulae. In patients treated with intra-abdominal packing for liver injury the rate of perihepatic infection has been shown to be independently associated with increasing abdominal trauma indices and transfusion requirements,47 but the incidence of infection has not been shown to significantly increase by the packing as such.30 Mild transient neuropathy involving the obturator and the sciatic nerves has been reported after intraperitoneal pelvic packing secondary to massive intra-operative hemorrhage in gynecological surgery.39

The overall incidence of ACS after damage control laparotomy for severe abdominal or pelvic trauma has been reported to be 5.5%,45 and Ertel et al. reported a 36% ACS rate (5 of 14) in patients treated with retroperitoneal pelvic packing and C-clamp after pelvic trauma.14 In the present study intrapelvic infection necessitating surgical revision occurred in six patients (33%), but five of these patients had severe open pelvic fractures necessitating wound revisions as part of their routine wound management. As abdominal compartment pressures were not registered routinely during the whole study period, the association between abdominal pressure and extraperitoneal packing as performed in our unit needs to be systematically addressed in further studies.

The strength of this study is the use of a strictly defined population of patients from a single trauma center with an established protocol for the initial treatment of pelvic trauma. Continuous data capture of all patients admitted and treated for pelvic trauma provides reliable data.

The limitations obviously constitute the small and heterogeneous study population, and statistical analysis should therefore be interpreted with caution. When assessing the effect of the procedure we used two outcome measures; 30-day survival, and improvement of physiologic parameters. We found that the mortality rate after pelvic packing was similar to those published by Ertel et al.14 However, a comparison of mortality rates between centers, or between different hemostatic procedures, is difficult as most of the mortalities in pelvic trauma cases are related to additional injuries. In addition, the indication for different hemostatic procedures may differ, as is the case in our institution where angiography is the primary choice of bleeding control in patients with significant pelvic bleeding, and EPP is used as a supplementary salvage procedure in patients who would not survive the AP.3,48–51 As a prolonged time to achieve hemostasis has been shown to have an adverse effect on survival,52 the relatively long time interval observed in our study from injury to EPP in the severely unstable patients (41 minutes) indicates that greater efficiency is needed to further reduce late mortality.

To evaluate the isolated impact of EPP on physiologic parameters as a measure of effect will remain problematic for two reasons. First, as the majority of patients with massive pelvic bleeding have multiple bleeding sites, several interventions are performed simultaneously. Second, the reduction in transfusion rate observed in our study may also partly be explained by the natural hemostasis that occurs in most patients. EPP as part of a multidisciplinary approach is performed in the severely hypovolemic pelvic trauma patient who would not otherwise survive transferal to the angiography suite, disregarding type of pelvic ring fracture. Temporary pelvic packing can control hemorrhage and provide crucial time to correct physiologic derangements. The technique is easy, quick to perform, and associated with a high survival rate. In the present study pelvic packing was performed in 18 hemodynamically unstable patients as a life-saving emergency procedure. Initial bleeding control was achieved in all but one patient who died of uncontrollable multiple hemorrhages. In the remaining patients an increase in systolic BP was observed after the initial resuscitation and damage control surgery, which enabled transferal to the intensive care unit or to the angiography suite for further stabilization and arterial bleeding control. The higher age observed in nonsurvivors corresponds to previous studies on mortality after pelvic trauma.53 Life-threatening pelvic hemorrhages were observed in all types of pelvic fractures, and also in isolated acetabular and sacral fractures. This emphasizes the need for alertness in the treatment of all pelvic traumas. The high proportion of arterial injuries observed indicates that arterial injuries play an important role in massive pelvic bleeding. Consequently, we think that EPP should be complemented with angiography in all patients once transferable to the angiography suite.
However, in a minority of cases significant venous injury is the primary cause of bleeding and these patients may be successfully treated with EPP as a means to achieve definite bleeding control. Furthermore, in hospitals without angiographic facilities, pelvic packing may be the only option in patients with massive hemorrhage after pelvic trauma.

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