Analysis of 185 Iliac Vessel Injuries

Risk Factors and Predictors of Outcome

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Hypothesis: Iliac vascular injuries incur high mortality.

Design: Retrospective 100-month study (January 1, 1992, through April 30, 2000).

Patients: One hundred forty-eight patients with 185 iliac vessel injuries.

Outcome Measures: Survival and mortality, analyzed by univariate and logistic regression.

Results: Admission mean±SD systolic blood pressure was 81±42 mm Hg, mean Revised Trauma Score was 6.0±2.8, and mean Injury Severity Score was 20.0±9.5. The mechanism of injury was penetrating in 140 patients (95%) and blunt in 8 (5%). The mean estimated blood loss was 6246±6174 mL. Of the 185 injured vessels, 71 (99%) of 72 iliac arteries were repaired, 101 (89%) of 113 iliac veins were ligated, and 12 (11%) of 113 iliac veins were repaired. Overall survival was 51% (76/148). Mortality was 82% (49/72) in patients with exsanguination. Survival by vessel: iliac artery, 57% (20/35); iliac vein, 55% (42/76); and iliac artery and vein, 38% (14/37). Significant predictors of outcome were thoracotomy in the emergency department, associated aortic injury, inferior vena cava injuries, iliac artery and vein injury, intraoperative arrhythmia, and intraoperative coagulopathy. On logistic regression, independent risk factors for survival were absence of thoracotomy in the emergency department, surgical management, and arrhythmia. Mortality by grade on the Organ Injury Scale of the American Association for the Surgery of Trauma (AAST-OIS) was as follows: grade III, 35% (33/95); grade IV, 71% (24/34); and grade V, 79% (15/19).

Conclusions: Mortality remains high. Associated vessel injuries and intraoperative complications predict mortality. AAST-OIS grade for abdominal vascular injuries correlates well with mortality.

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LIAC VESSEL injuries are some of the most lethal injuries sustained by trauma patients. They are also among the most difficult and challenging injuries managed by trauma surgeons. Frequently, these patients arrive at trauma centers in profound shock secondary to massive blood loss and have already embarked on the vicious cycle of acidosis, hypothermia, and coagulopathy. Exsanguination accounts for their high mortality.

Multiple factors increase the lethality of these injuries, such as refractory hemorrhage and the presence of multiple associated injuries, particularly to the genitourinary and gastrointestinal tracts, which produce significant contamination, require complex surgical techniques for management and reconstruction, and pose difficult management paradigms. Moreover, the anatomic arrangement of these vessels places the patients at risk for multiple vascular and combined arteriovenous injuries. Their difficult exposure and vascular control often taxes the skills of even the most experienced trauma surgeons.

Rapid transport to a trauma center, prompt recognition of the injury, superb knowledge of the local anatomy, and sound surgical judgment remain the cornerstones for survival. The purposes of this study are to report our experience with iliac vessel injuries, identify predictors of outcome, and correlate mortality with the American Association for the Surgery of Trauma Organ Injury Scale (AAST-OIS) for abdominal vascular injury.

METHODS

During a 100-month study (January 1, 1992, through April 30, 2000), 148 patients with iliac vessel injuries were admitted at our institution, a large level I urban trauma center. All patients were resuscitated by means of the treatment protocols outlined in the Advanced Trauma Life Support Manual of the American Medical Association.
Factors having a $P<.2$ that did not have more than 10% of the data missing were preselected for the stepwise logistic regressions performed in 3 stages. The first stage focused on the preoperative factors, while the second stage included intraoperative and postoperative factors. The significant factors selected by these 2 models were then combined in the third and final logistic regression model.

For comparison of each categorical risk factor among iliac artery, iliac vein, and combined iliac artery plus iliac vein injuries, the 2-sided Fisher exact test was used to test the equality of proportions among the 3 types of iliac vessel injuries. We used the stepdown Sidak method to adjust for multiplicity of pairwise comparisons. We used the Wilcoxon rank sum test to compare the mean of continuous and ordinal variables among the 3 types of iliac vessel injuries, and we used the stepdown Bonferroni method to adjust for multiple comparisons.

During the span of this 100-month study, 148 patients were admitted with iliac vessel injuries. This group included 131 men (89%) and 17 women (11%). Their mean age was 27.0±12.7 years. One hundred forty patients (94.6%) were admitted with penetrating injuries, among whom 128 (91.4%) sustained gunshot wounds and 12 (8.6%), stab wounds. Eight patients (5.4%) were admitted secondary to blunt trauma, of whom 5 (63%) were pedestrians struck by vehicles and 3 (37%) sustained motor vehicle crashes.

The mean systolic blood pressure at admission was 81±42 mm Hg. Mean heart rate at admission was 98±39 beats/min. The mean Revised Trauma Score was 6.0±2.8. The mean ISS was 20.0±9.5, indicating a severely injured patient population. In the ED, 22 patients (15%) underwent thoracotomy, aortic cross-clamping, and open cardiopulmonary resuscitation, of whom 4 (18%) survived. Mean volume of resuscitative fluids in the ED was 2985 mL. Mean volume of crystalloids was 2628±1398 mL, and mean volume of packed red blood cells was 357±368 mL.

The ED factors significantly associated with mortality included absence of blood pressure ($P=.03$; relative risk [RR], 1.56; 95% confidence interval [CI], 1.16-2.11), absence of spontaneous ventilation ($P=.006$; RR, 1.67; 95% CI, 1.25-2.33), and ED thoracotomy ($P<.001$; RR, 2.03; 95% CI, 1.60-2.58). Similarly, Revised Trauma Score of 0 ($P=.03$; RR, 1.68; 95% CI, 1.22-2.32) and ISS ($P<.001$; RR, 1.67; 95% CI, 1.24-2.24) were significantly associated with outcome.

All patients were rapidly transported to the OR. Furthermore, an additional 31 (21%) underwent OR thoracotomy, of whom 5 (16%) survived. Operative findings showed a total of 134 retroperitoneal hematomas, 38 (25%) zone I, 27 (17%) zone II, and 89 (58%) zone III. There were a total of 185 vessels injured in 148 patients, for an average of 1.25 vessels injured per patient. Of the 185 vessels injured, there were 72 iliac artery injuries (39%), of which 33 were isolated. There were 113 iliac vein injuries (61%), of which 76 were isolated. Thirty-seven patients experienced combined iliac artery and vein injuries.

All patients’ injuries were graded according to the AAST-OIS for abdominal vascular injuries. Mortality stratified by AAST-OIS injury grade was as follows: grade III, 35% (33/95); grade IV, 71% (24/34); and grade V, 79% (15/19). Injury grade predicted mortality. Ninety-five pa-
iliac vein injury were strong predictors of mortality.

The significant number of associated vascular injuries, as well as specific associated vessel injuries to the aorta or inferior vena cava (IVC), and the presence of an iliac artery injury either alone or in combination with an iliac vein injury were strong predictors of mortality (Table 3). Seventy-one patients (48.0%) experienced coagulopathy, 52 (35.1%) experienced arrhythmias, 49 (33.1%) developed hypothermia, and 51 (34.5%) developed acidosis. Intraoperative complications were also significant predictors of outcome (Table 4).

Of the 148 patients admitted, 76 survived, for an overall survival rate of 51%. If nonsurviving patients who underwent ED thoracotomy (n=18) are excluded, the overall survival rate is 58%. Fifty-nine patients (82% of the 72 who died) died in the OR secondary to exsanguination. The remaining 13 (18%) died in the surgical intensive care unit of postoperative complications. Risk factors associated with outcome between nonsurvivors and survivors were classified into preoperative, intraoperative, and postoperative (Table 5). Isolated arterial or venous injuries resulted in survival rates of 57% and 55%, respectively, consistently higher than the 38% survival from combined iliac artery plus vein injury (Table 6).

A comparison between isolated iliac artery or iliac vein injuries vs combined iliac artery plus vein injuries showed significant differences. Combined injuries were more likely to require ED thoracotomy (P = .01) and result in intraoperative shock (P = .04) and arrhythmias (P = .04); incurred a greater number of intraoperative complications (P = .02); and were more likely to require reintervention (P = .02). Postoperative complications included infections in 13 patients (17% of the 76 survivors), sepsis and multiple-system organ failure in 8 (11%), deep venous thrombosis in 5 (7%), and arteriovenous fistula in 2 (3%). One patient (1%) who sustained a blunt iliac artery injury required a below-the-knee amputation.

Using the significant factors identified in the univariate analysis, the stepwise logistic regression analysis identified 2 significant factors associated with survival, no need for ED thoracotomy and surgical management (representing the ability to repair the injured vessel and restore flow, which are associated with decreased mortality), whereas the presence of intraoperative arrhythmias was associated with a significant decrease in survival (Table 7).

Table 3. Associated Injuries and Mortality by Associated Injuries

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Subjects in Group (%)</th>
<th>Nonsurvivors, No. (%)</th>
<th>Relative Risk (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of vessels injured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>53/148 (35.8)</td>
<td>29/53 (54.7)</td>
<td>1.4 (0.96-2.08)</td>
<td>.10</td>
</tr>
<tr>
<td>2</td>
<td>23/148 (15.5)</td>
<td>18/23 (78.3)</td>
<td>2.02 (1.39-2.92)</td>
<td>.002</td>
</tr>
<tr>
<td>3</td>
<td>3/148 (2.0)</td>
<td>3/3 (100.0)</td>
<td>2.58 (1.91-3.48)</td>
<td>.07</td>
</tr>
<tr>
<td>Aorta injury</td>
<td>19/148 (12.8)</td>
<td>15/19 (78.9)</td>
<td>1.64 (1.22-2.21)</td>
<td>.01</td>
</tr>
<tr>
<td>IVC injury</td>
<td>29/148 (19.6)</td>
<td>24/29 (82.8)</td>
<td>1.86 (1.43-2.42)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Iliac artery injury</td>
<td>72/148 (48.6)</td>
<td>43/72 (59.7)</td>
<td>1.34 (0.98-1.84)</td>
<td>.07</td>
</tr>
<tr>
<td>Combined iliac artery and venous injury</td>
<td>36/148 (24.3)</td>
<td>24/36 (66.7)</td>
<td>1.49 (1.06-2.11)</td>
<td>.04</td>
</tr>
</tbody>
</table>

Table 4. Incidence of Intraoperative Complications and Mortality by Complications

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Subjects in Group (%)</th>
<th>Nonsurvivors, No. (%)</th>
<th>Relative Risk (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative shock</td>
<td>86/148 (58.1)</td>
<td>61/86 (70.9)</td>
<td>2.94 (1.83-4.73)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>OR complications</td>
<td>61/148 (45.7)</td>
<td>59/81 (72.8)</td>
<td>2.79 (1.81-4.28)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coagulopathy</td>
<td>71/148 (48.0)</td>
<td>54/71 (76.1)</td>
<td>2.59 (1.78-3.77)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>52/148 (35.1)</td>
<td>47/52 (90.4)</td>
<td>2.93 (2.14-4.02)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>49/148 (33.1)</td>
<td>43/49 (87.8)</td>
<td>2.58 (1.92-3.47)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Acidosis</td>
<td>51/148 (34.5)</td>
<td>41/51 (80.4)</td>
<td>2.18 (1.62-2.93)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; IVC, inferior vena cava.
ordary to blood loss and large numbers of associated injuries. The incidence of iliac vessel injury varies depending on the setting. During World War I, Makins reported 5 iliac artery injuries in 1202 patients, for an incidence of 0.4%. During World War II, DeBakey and Simeone reported 43 iliac artery injuries in 2471 patients, for an incidence of 1.7%. Hughes during the Korean conflict and Rich et al during the Vietnam conflict reported incidences of 2.3% and 2.6%, respectively.

Iliac vessel injuries are reported with greater frequency from the civilian arena. In a recent survey at an urban level I trauma center, Bongard et al reported that iliac artery injuries represented only 10% of abdominal vascular injuries and less than 2% of all vascular trauma. Mattox and colleagues, in a series of 5760 cardiovascular injuries and less than 2% of all vascular trauma. The presentation of patients sustaining iliac vessel injuries is characteristically in patients with contained retroperitoneal hematomas, to those presenting in shock, with abdominal distention, and in cardiopulmonary arrest. In Millikan and coworkers’ series, 52 patients presented in severe shock with systolic blood pressures less than 60 mm Hg. Ryan et al reported that 94 (82%) of their 114 patients were admitted with blood pressures less than 90 mm Hg. Burch et al reported that 140 of their patients were admitted with blood pressures less than 80 mm Hg, while Cushman et al and Carrillo et al reported incidences of hypotension in 70% and 86% of their patients, respectively.

In our series, the mean admission blood pressure was 81 mm Hg. Our patients’ low Revised Trauma Score and high mean ISS of 20 indicate both a physiologically comprised and severely injured patient population. To date, no series in the literature, to our knowledge, has reported this measure for iliac vessel injury.

Penetrating trauma remains the predominant cause of the majority of iliac vessel injuries. Series by Mattox, Milikan, Ryan, Burch, DeGiannis, and Carrillo et al reported no blunt iliac vessel injuries. Of series reporting blunt iliac vessel injuries, Cushman et al reported an incidence of 5% in 53 patients admitted with iliac vessel injury. In our series, 8 patients (5%) sustained blunt injury.

### Table 5. Preoperative, Intraoperative, and Postoperative Risk Factors in Nonsurvivors and Survivors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Nonsurvivors</th>
<th>Survivors</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure in ED</td>
<td>72 ± 45</td>
<td>92 ± 38</td>
<td>.008</td>
</tr>
<tr>
<td>Respiratory rate/min in ED</td>
<td>16 ± 12</td>
<td>21 ± 8</td>
<td>.03</td>
</tr>
<tr>
<td>Glasgow Coma Scale score</td>
<td>10 ± 5</td>
<td>13 ± 4</td>
<td>.001</td>
</tr>
<tr>
<td>Revised Trauma Score</td>
<td>4.86 ± 3.13</td>
<td>6.76 ± 1.85</td>
<td>.001</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>25 ± 13</td>
<td>15 ± 8</td>
<td>.001</td>
</tr>
<tr>
<td>Hematocrit, %</td>
<td>26 ± 10</td>
<td>30 ± 9</td>
<td>.04</td>
</tr>
<tr>
<td>Crystalloids in ED, mL</td>
<td>2875 ± 2361</td>
<td>2622 ± 1548</td>
<td>.89</td>
</tr>
<tr>
<td>Blood in ED, mL</td>
<td>456 ± 376</td>
<td>252 ± 334</td>
<td>.001</td>
</tr>
<tr>
<td>Intraoperative</td>
<td>8185 ± 6930</td>
<td>4699 ± 4678</td>
<td>.001</td>
</tr>
<tr>
<td>Crystalloids in OR, mL</td>
<td>7376 ± 6931</td>
<td>5349 ± 4292</td>
<td>.04</td>
</tr>
<tr>
<td>Blood in OR, mL</td>
<td>5522 ± 5405</td>
<td>3451 ± 3523</td>
<td>.001</td>
</tr>
<tr>
<td>Total fluids, mL</td>
<td>17 137 ± 12 422</td>
<td>10 663 ± 7867</td>
<td>.001</td>
</tr>
<tr>
<td>Postoperative</td>
<td>1.2 ± 4.1</td>
<td>7.0 ± 13.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Surgical intensive care unit, d</td>
<td>2.6 ± 4.2</td>
<td>17.1 ± 20.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospital, d</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 6. Survival by Vessel Injury

<table>
<thead>
<tr>
<th>Vessel Injured</th>
<th>No. of Patients</th>
<th>No. (%) of Survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliac artery</td>
<td>35</td>
<td>20 (57.1)</td>
</tr>
<tr>
<td>Iliac vein</td>
<td>76</td>
<td>42 (55.3)</td>
</tr>
<tr>
<td>Combined iliac artery and vein</td>
<td>37</td>
<td>14 (37.8)</td>
</tr>
<tr>
<td>Total</td>
<td>148</td>
<td>76 (51.4)</td>
</tr>
</tbody>
</table>

Abbreviations: ED, emergency department; OR, operating room.
The use of resuscitative thoracotomy has been reported as an adjunct for the management of these injuries. Millikan et al\textsuperscript{16} reported its use in 5 of 27 patients, with 1 survivor. In Burch and coworkers’ series\textsuperscript{14} of 233 patients, 29 (13\%) required ED thoracotomy, with no survivors. Of 12 patients treated with resuscitative OR thoracotomy, only 1 survived. In DeGiannis and coworkers’ series\textsuperscript{27} of 5 patients requiring ED thoracotomy, 2 survived. Carrillo et al\textsuperscript{15} performed ED thoracotomy in 2 of 64 patients, with no survivors. In our series of 148 patients, 22 patients (15\%) required ED thoracotomy and 4 survived, for an 18\% survival rate. An OR thoracotomy was required in 31 patients (21\%), with a 16\% survival. In our experience, both resuscitative ED thoracotomy and OR thoracotomy allowed for salvage of 9 patients.

The high mortality of iliac vessel injuries has frequently been attributed to absence of retroperitoneal tamponade, which often leads to rapid and massive hemorrhage culminating in irreversible shock.\textsuperscript{1,14-18,26} The high incidence of combined iliac artery and vein injuries is also an important risk factor for mortality.\textsuperscript{1,14-18,26} As with all vascular injuries, time to proximal and distal control is one of the most important factors predictive of outcome. Several series report significant delays in admission to the OR. In the series by Burch et al,\textsuperscript{14} 89 patients whose condition did not improve with resuscitation experienced a mean delay of 34 minutes, although 29 of those patients also required ED thoracotomy. Of the 138 patients whose condition was stable or responsive to fluid resuscitation, the mean delay from admission to OR was 176 minutes. Similar times were reported by DeGiannis et al.\textsuperscript{27} In this series, 34 patients who did not respond to resuscitative measures experienced a mean time of 50 minutes from admission to OR, while the 28 patients who were normotensive on admission or responsive to fluid resuscitation had a mean hospital preoperative time of 155 minutes. Carrillo et al\textsuperscript{15} reported a mean time from hospital admission to operation of 55 minutes. Time remains of the essence. The policy of our trauma center mandates admission to the OR within 15 minutes for any patient requiring surgical intervention.

Mortality from iliac vessel injury is largely due to a large number of associated injuries. These injuries can be divided into 2 categories, vascular and nonvascular. Burch et al\textsuperscript{14} reported 345 associated abdominal injuries in a series of 233 patients, for a mean of 1.5 associated nonvascular injuries per patient. An additional 44 patients had injuries to intra-abdominal vessels, for a mean of 0.2 associated vascular injury per patient. Sixteen patients with associated IVC injury had a mortality rate of 42\%, 7 with injuries to the abdominal aorta had a 58\% mortality rate, and all 3 patients with injuries to the superior mesenteric vessels died.

Carrillo et al\textsuperscript{15} reported the presence of associated nonvascular injuries in 62 of their 64 patients, for an incidence of 97\%, with an average of 2.8 injuries per patient. Associated abdominal vascular injuries were present in 22\%, for an incidence of 0.2 associated vascular injury per patient. Cushman et al\textsuperscript{16} reported 1.7 associated nonvascular injuries per patient, and 9 injuries to the aorta and IVC, for a mean of 0.17 associated vascular injury per patient. In our series, our patients experienced a mean of 1.83 associated nonvascular injuries per patient and a mean of 0.52 associated vascular injury per patient, representing the highest number of associated injuries reported in the literature to date.

Burch et al\textsuperscript{14} reported mortalities ranging from 42\% to 58\% when the aorta or IVC was injured in association with either an iliac artery or vein injury, although their numbers were small. In the series by Wilson et al\textsuperscript{28} that consisted of 49 iliac vein injuries, there was a 100\% mortality when iliac vein injuries were found in association with either an aortic or IVC injury or when there were 2 or more iliac veins injured. Also reported was a 57\% mortality rate for combined arterial and venous injuries. Ryan et al\textsuperscript{15} reported mortality rates of 100\% for combined iliac arteries injured in association with the aorta, 75\% when associated with IVC injuries, and 47\% for combined iliac artery and vein injuries.

Our study focused on predictors of outcome. Associated injuries to the aorta, IVC, and combined iliac artery and vein injuries are strong predictors of mortality. Moreover, iliac artery injuries experienced higher mortality than iliac vein injuries. Of all these predictors of outcome, iliac vein injuries are clearly the most amenable to rapid management; therefore, most iliac vein injuries, unless simple and easily repaired by single lateral venorrhaphy, can be managed by ligation, a technically less challenging procedure. This would certainly decrease intraoperative time for these critically injured patients.

Other important predictors of outcome described in the literature include EBL and persistent shock. Burch et al\textsuperscript{16} correlated the number of associated vessel injuries and found that when 2 to 4 vessels were injured, EBL ranged from 6000 to 8400 mL. For patients experiencing EBL of greater than 3900 mL, the mortality rate was 51\%. In our series, surviving patients experienced a mean EBL of 4600 mL compared with 8200 mL for nonsurvivors.

Both Carrillo et al\textsuperscript{15} and Cushman et al\textsuperscript{16} focused attention on the need for abbreviated laparotomy and/or damage control. In the series by Carrillo et al, patients’ EBL was stratified for those subjected to definitive lap-

### Table 7. Predictors of Mortality for Iliac Vessel Injuries by Stepwise Logistic Regression

<table>
<thead>
<tr>
<th>Step</th>
<th>Risk Factor</th>
<th>Parameter Estimate</th>
<th>Adjusted Odds Ratio (95% CI)</th>
<th>Cumulative Maximum Rescaled $R^2$</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(Intercept)</td>
<td>1.5794</td>
<td></td>
<td></td>
<td>.14</td>
</tr>
<tr>
<td>1</td>
<td>Arrhythmia</td>
<td>2.8808</td>
<td>18.6 (6.8-60.8)</td>
<td>0.416</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2</td>
<td>Arterial surgical manage-</td>
<td>-2.7954</td>
<td>&lt;0.001 (&lt;0.001-0.2)</td>
<td>0.508</td>
<td>.004</td>
</tr>
<tr>
<td>3</td>
<td>ED thoracotomy</td>
<td>2.2820</td>
<td>10.1 (2.2-72.3)</td>
<td>0.561</td>
<td>.006</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ED, emergency department.
Arteriovenous malformations vs those undergoing abbreviated laparotomy. In the groups who had definitive laparotomy, survivors had EBL of 6200 mL compared with 12800 mL in nonsurvivors. For patients subjected to abbreviated laparotomy, survivors had an EBL of 4800 mL compared with 8400 mL in nonsurvivors. The latter figures are very consistent with the findings in our series.

Rapid surgical intervention with immediate exposure to obtain proximal and distal control and stop the rapid blood loss experienced by these patients is key to their survival. The iliac vessels in zone III can be exposed by transecting the avascular line of Toldt of both right and left colon and reflecting them medially by means of a combination of blunt and sharp dissection. Proximal and distal control of these vessels can be very challenging given their anatomic location and large associated retroperitoneal hematomas; in our series, 58% of patients had zone III retroperitoneal hematomas.

Ideally, all iliac vessel injuries should be graded according to the AAST-OIS for abdominal vascular injuries. In this series, injury grade correlated well with mortality. This is the first study, to our knowledge, in which the AAST-OIS was applied to grade iliac vessel injuries. Previous work from our institution has validated its use for abdominal vascular injuries.1,11,19

All iliac arteries should be definitively repaired by primary arteriotomy if possible. When there has been significant destruction of the vessel wall, reconstruction can be accomplished with end-to-end anastomosis or bypass with either autogenous saphenous vein or polytetrafluoroethylene grafts (PTFE). Burch et al14 reported a 7% incidence of end-to-end anastomosis and use of PTFE, while Cushman et al16 reported a 13% incidence of end-to-end anastomosis and 6% incidence of the use of PTFE. In our series, no end-to-end anastomoses or autogenous grafts were used; given the injury severity and degree of destruction, 20% of our patients required PTFE.

Other important predictors of outcome in our series included intraoperative complications, such as acidosis, hypothermia, and coagulopathy along with intraoperative shock. We agree with Burch,14 Carrillo,15 and Cushman et al16 that, in the presence of these complications, damage control or bailout should be performed.30,31 We recently validated a model of reliable variables that indicate damage control and predict outcome, and we are strong proponents of damage control.9

In our series, only 1 patient required an amputation. This compares favorably with results in the literature. Similar experiences were reported by Millikan et al18 and Ryan et al,17 who reported a single amputation in their 86 surviving patients. In the series by Carrillo et al,15 1 patient required an amputation after an extra-anatomic bypass procedure. All 3 amputations required in the series by Burch et al14 also occurred after ligation and extra-anatomic bypass.

Our survival rates compare favorably with those in the literature. Survival rates of 57% and 55% for arterial and venous injuries, respectively, continue to support the current policies of our trauma center, given the injury severity of our patients, the large EBL, and the fact that this is the largest series of associated vascular and non-vascular injuries reported to date. However, much remains to be done. Despite many recent advances in shock management, resuscitation, and damage control, iliac vessel injuries remain very lethal.

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REFERENCES

**DISCUSSION**

Louis M. Messina, MD, San Francisco, Calif: This well-presented and well-written paper highlights an 8-year retrospective review of what is the second-largest published experience in the management of iliac artery injuries at an urban level trauma center. It is the first such study to show a correlation between patient survival and the major dependent variable in this study, and the AAST Organ Injury Scale.

This young cohort of patients, mean age 27 years, presented with significant associated injuries, 1.8 injuries per patient. Gunshot wounds accounted for 90% of the injuries. Associated injuries to the aorta and the IVC were highly significant predictors of death. Similarly, thoracotomy in the ED, 22 patients, and in the OR, 31 patients, accounted for 36% of the patients studied. Of the 31 patients who underwent thoracotomy, only 9 survived. My first question is, what would the effect on the outcome analysis be if this large subgroup were eliminated?

Vascular repair by primary lateral arterioorrhaphy was undertaken in more than 80% of these patients, a somewhat surprising proportion since these injuries were largely caused by gunshot wounds. Conversely, iliac vein injuries were treated almost exclusively by ligation.

Could the authors explain this disparity in the repair of these vessels as well as the frequent use of lateral arterioorrhaphy of arteries injured by gunshot wounds, particularly from the point of view of long-term arterial patency?

At San Francisco General Hospital, significant iliac vein injuries, particularly to the common iliac veins, are treated by expedient transection of the often injured overlying iliac artery, control of venous bleeding by the serial application of Allis clamps, then subsequently a Satinsky clamp, and then primary venorrhaphy. This technique avoids further vein injury due to dissection. Could this approach reduce the near-universal ligation of the injured iliac veins as reported in this series?

The authors report 5 patients who experienced postoperative deep vein thrombosis (DVT). Was routine venous duplex scanning undertaken in this subgroup, and, if so, what was the total incidence? How many patients developed significant leg edema?

Similarly, do the authors have information on the immediate outcome of their arterial repairs, for example, the status of the peripheral pulses or ankle-brachial indices? These would be valuable predictors of the long-term durability of the arterial repairs.

Finally, operative complications, including shock, acidosis, hypothermia, and coagulopathy, occurred in 81 of the 148 patients and 59% of these patients died. Are all of these complications considered together or separately as outcome predictors in your analysis? What strategies do the authors recommend to prevent or minimize these grim complications?

Robert C. Mackersie, MD, San Francisco: My comments pertain to the potential for this study to support or validate the practice of damage control, and I am wondering if you are not missing an opportunity here to undertake a more critical analysis of intraoperative decision making, including the adequacy of intraoperative resuscitation. These factors are probably important determinants of outcome relative to a damage control strategy. You have reported improved outcome in high-ISS patients as a result, in part, of in-house trauma attending coverage that was instituted during the span of the reporting period for this study. I am guessing, therefore, that the maturity and sophistication of intraoperative decision making probably changed during the course of this study. Do you have any comparative data available and have you or will you be able to look at these factors as potential determinants of outcome in this group of patients?

My other comment is in regard to the AAST Organ Injury Score. The purpose of the score is to discriminate between outcomes based on scaled injury severity. Whereas it appeared as though there were significant differences between mortality in grade III, vs grade IV or V, there did not appear to be differences between grade IV and grade V and no data were available for grades I and II due to the stratified nature of the study. Therefore, you therefore were able to demonstrate only a 2-point discriminatory ability of the AAST-OIS. While [these are] important data, it probably doesn’t quite allow legitimate criteria validation of the entire OIS scale.

Clayton H. Shatney, MD, San Jose, Calif: What are your indications for ED thoracotomy? I noticed in your multivariate analysis that both the absence of a blood pressure and the performance of ED thoracotomy were predictors of bad outcome. If you combined those 2, it would be even worse. Have you changed your policy on ED thoracotomy in patients with penetrating abdominal trauma based on some of the results in this series? Also, what was the neurologic outcome of the 9 survivors you had after ED thoracotomy? Lastly, you mentioned you had the largest series of blunt iliac vessel injuries. Was there a difference in outcome between those patients with blunt iliac vascular trauma and penetrating injury?

David Wisner, MD, Sacramento, Calif: I have 2 quick questions for you. One has to do with anticoagulation of your iliac vein survivors when you ligated them. Have you come to any unified approach to both short-term and long-term anticoagulation?

The second question has to do with placement of Gore-Tex in patients with an associated bowel injury, a longstanding question about whether or not you can get away with putting in synthetic grafts. Yours is the biggest series I can report. Did you claim that you could put synthetic grafts in the face of overt contamination and get away with it without too much trouble. It was Bill Blaisdell, who is in this audience, who commented that you could probably get away with that in Texas because Texans were full of stool to begin with [laughter]. Could you tell us if it’s the same in Los Angeles?

Lawrence J. Goldstein, MD, Oakland, Calif: Traumatic injuries to large pelvic veins carry a high risk of DVT and pulmonary embolism and perhaps 1% to 2% fatality from pulmonary embolism. Did you see any of these in your study, and, with this in mind, how do you recommend that we do surveillance for DVT and how do you prophylactically treat these patients who may have coagulopathies and have recently bled?

James J. Peck, MD, Portland, Ore: Who does the repair? Is it the trauma surgeon? Is it the vascular surgeon? There seems to be a reluctance I see in dividing the iliac vein in order to get to the iliac vein. How often was that done? How long do you give postoperative antibiotics in the patient who has an enteric injury and has Gore-Tex in place? And how often did you use a packing or abbreviated laparotomy and then some sort of extra-anatomical bypass, i.e., a fem-fem [ileofemoral] bypass? There were a lot of patients who had iliac vein ligation. How many patients needed fasciectomy in order to save their extremity, and how many patients lost their extremity?
Dr Asensio: I will try to do my very best to answer all of my distinguished colleagues’ questions. Dr Messina, you asked about the effect of outcome analysis if ED and OR thoracotomy patients were eliminated. I can tell you that when we adjusted our survival rates by excluding the ED thoracotomy patients, our survival rate rose to 38%. Unfortunately, I did not calculate what our survival rate would have been if we had eliminated the OR thoracotomy patients.

With regard to primary arteriotomy, you will notice that a lot of our injuries were grade III. By definition of the AAST Organ Injury Scale, all iliac vessel injuries are grade III injuries. These are tangential and are amenable to primary repair. You advance to a grade IV if there are multiple lacerations and to grade V if there is greater than 50% involvement of the wall of the vessel. This is why we were able to repair a number of these injuries.

With regard to ligation of the iliac veins, our group pretty much believes that the ligation is the way to go. Many of these patients are critical, and when you have a choice between trying to repair an artery and ligate a vein, then obviously you restore arterial flow and ligate the veins. We did not seem to have a lot of problems with this approach.

With regard to the long-term patency, well, our patient population is rather nomadic, so we cannot tell you, unfortunately, what our long-term patency rate is because many of our patients do not come back.

With regard to the technique of transecting the right iliac artery, this is very well described in the literature but hardly used. Dr Peck also asked about this. We prefer not to and do not recommend it. If you are able to dissect quickly and retract the artery, you can get to the right iliac vein and this is what our experience has been. Transecting a right iliac artery in a critical patient is not advisable.

With regard to reducing the rates of ligation, I like to repair veins, but a lot of times these veins are significantly destroyed, so it leaves us very little option. With regard to routine DVT prophylaxis, we utilize either regular heparin, 5000 units every 12 hours, or low-molecular-weight heparin.

With regard to the significance of edema, no patient had a postphlebitic syndrome. Some had some edema, but we wrapped the extremities, we elevated them, and because they were young, they were able to develop good collateral venous channels and the edema resolved.

With regard to the outcome of our arterial repairs, these patients all had palpable and viable extremities upon discharge. We did not do ankle-brachial indexes postoperatively.

With regard to complications—Dr Peck also asked about this—we only lost one extremity on a patient who had a blunt iliac artery injury. He underwent a below-knee amputation after developing a soft tissue infection in the area of his lower extremity. Some had some edema, but we did not perform any. With regard to extremity losses, we did not perform any. With regard to extremity losses, we do not come back.

With regard to the outcome of our arterial repairs, these patients all had palpable and viable extremities upon discharge. We did not do ankle-brachial indexes postoperatively.

With regard to complications—Dr Peck also asked about this—we only lost one extremity on a patient who had a blunt iliac artery injury. He underwent a below-knee amputation after developing a soft tissue infection in the area of his lower leg fasciotomies. The amputation rate for iliac vessel injuries in the literature is quite low, and the highest is reported in the series by Burch, with 3 amputations in 233 patients, and all of those had the extra-anatomical bypasses.

The strategies to decrease mortality: again, we take these patients quickly to the OR. Our operating rooms are on the 15th floor. We are strong advocates of damage control.

Dr MacKersie, with regard to intraoperative decision making, we do have, as you know from having been our visiting professor, in-house attendings. We live at LA County Hospital and the attending surgeons do make the decisions. We try to get out early and institute damage control utilizing our previously validated model. We try to pack early and get out before we get a pH of 7.2 and before we reach a temperature of 34°C.

With regard to the AAST Organ Injury Scale to predict outcome, iliac artery injuries are not graded as grade I or II. By definition they are all grade III, and then, of course, grade IV and V. This is why our statistical analysis used grade III as a frame of reference, and there is a slight difference between grades IV and V. Mortality was 71% vs 79%. But your point is absolutely well taken, because we as trauma surgeons must try to continue to validate these scales. Our previous work on abdominal vascular injuries and superior mesenteric artery injuries has gone a long way in validating this scale.

Dr Shatney asked about our emergency department thoracotomy indications. We are liberal and use it for patients admitted with cardiopulmonary arrest from penetrating injuries. For blunt injuries we employ it when patients lose their vital signs upon arrival. We have to do a significant number of these in order to be able to get our patients from the first floor all the way to the 15th floor, which is where our ORs are located.

With regard to whether combining predictors of outcome such as need for ED thoracotomies and the absence of blood pressure, would that change our policy in emergency department thoracotomy? It would seem that if we did, we would exclude more patients from this procedure; however, we strongly believe in giving all patients a chance and continue to be liberal in our policy.

Our surviving ED and OR thoracotomy patients experienced no neurological deficits.

You had an interesting question about the differences in mortality between blunt and penetrating iliac vessel injuries. I should have looked at that. Dr Shatney, I didn’t. This is a very good question. Unfortunately, I did not.

Dr Wisner, with regard to anticoagulation, we have not reached a unified approach. Some of us use low-molecular-weight heparin; others use the regular heparin. In my case, I place all of my patients after vascular reconstruction on low-molecular-weight dextran. I use 500 ml in 24 hours for 3 days.

With regard to PTFE, I agree that there is a significant concern when prosthetic materials are placed in a very hostile environment, especially in the presence of gastrointestinal and genitourinary secretions and feces. At times there is nothing else to do, and rather than doing an extra-anatomic bypass, which we did not use in our series, we put in PTFE. The people in Houston believe they can do this safely. We do it out of necessity, but to answer your question, we have not had any problems.

Dr Goldstein, with regard to your question about iliac veins, DVT, and pulmonary embolism, once you ligate iliac veins we should all be concerned, but the pulmonary embolism incidence is low. We did not have any. But we did have 5 patients with deep vein thrombosis. We obviously look at these patients with color flow Doppler. We do not have any routine prophylaxis other than postoperative heparin. Sometimes, some of my colleagues will give them low-dose aspirin upon discharge on an individual basis.

Dr Peck, in regard to the division of the right iliac artery to get to the vein, we believe we can get to the vein without transecting the artery. We do so routinely. We do not consider this to be a very good approach and do not employ it or recommend it. With regard to the use of postoperative antibiotics for the OR who have had PTFE, we adhere very strictly. Dr Peck, to just giving them antibiotics for 24 hours, although we remain concerned about prosthetic grafts in very hostile environments, particularly with people who have had to be packed. Our routine remains 24 hours of antibiotics.

With regard to extra-anatomic bypass, these are either axillofemoral or axillofemoral or the “lazy S” that my dear colleague, Fred Bongard, likes to always talk about. In this series we did not perform any. With regard to extremity losses, we lost one extremity. The patient needed a below-knee amputation, but we are very fortunate.

Indications for fasciotomy are the usual well-known indications.