Complications Following Renal Trauma

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Objectives: To evaluate and compare the incidence and type of kidney-related complications among different modes of management for kidney injuries.

Design: Trauma registry and medical record review study.

Setting: Level I trauma center in Los Angeles, California.

Patients: All patients with renal trauma injuries treated from January 1, 1993, through December 31, 2006.

Main Outcome Measures: Severity of kidney injury, method of renal treatment, and kidney-related complications.

Results: During the study period, 889 patients had kidney injuries, 227 of whom (25.5%) had severe kidney injuries. In 568 patients (63.9%), the kidney was not explored; 173 patients (19.5%) underwent total nephrectomy, 53 (6.0%) underwent partial nephrectomy, and 95 (10.7%) underwent kidney repair. Of the 227 patients with severe kidney injuries, 89 (39.2%) received no exploration, 105 (46.3%) underwent total nephrectomy, 25 (11.0%) underwent partial nephrectomy, and 8 (3.5%) underwent nephorrhaphy. The overall incidence of kidney-related complications excluding renal failure was 5.2%. The kidney repair group was significantly more likely to develop local kidney-related complications than the total nephrectomy, partial nephrectomy, and no kidney exploration groups, even though the nephorrhaphy group had less severe kidney injuries. Patients with minor or moderate kidney injuries who underwent kidney exploration had more than twice the local complication rate than patients with no kidney exploration (7.1% vs 3.3%, P = .05).

Conclusions: Selective nonoperative management is safe for blunt and penetrating kidney injuries. Patients managed with nephorrhaphy are at higher risk for local kidney-related complications than other therapeutic modalities. Patients with minor or moderate kidney injuries treated with exploration of the kidney are more likely to develop local complications than those treated without exploration.


The evaluation and management of renal trauma have undergone significant changes during the past decade. The liberal use of computed tomographic evaluation in blunt and penetrating trauma has improved the diagnosis and grading of the severity of kidney injuries. More than 90% of blunt trauma renal injuries can safely be managed nonoperatively.1-3 The safety of nonoperative management, even in severe grade IV injuries, is well documented in the literature.4 The introduction of nonoperative management in penetrating solid organ injuries has added a new method to our armamentarium in the treatment of kidney injuries.5-7 To our knowledge, the effect of the different methods of management of kidney injuries on renal-related complications has not been studied in the literature. The present study evaluates the various therapeutic approaches practiced in a large level I trauma center and compares the type and incidence of kidney-related complications among the different methods of kidney management.

METHODS

This trauma registry and archived medical record review study includes all patients with renal trauma injuries admitted to the Los Angeles County and University of Southern California trauma center from January 1, 1993, through December 31, 2006. The trauma registry is maintained by 7 full-time nurses, and the quality of data entry is monitored by the
Emergency Medical Services of the County of Los Angeles. A data file was created using Microsoft Excel 2007 (Microsoft Corporation, Redmond, Washington) for this study; it included the following variables: age, sex, mode of injury, Abbreviated Injury Scale—1990 Revision score, Injury Severity Score,8 American Society for the Surgery of Trauma kidney injury scale score based on International Classification of Diseases, Ninth Revision (ICD-9),9 codes, method of renal management (ie, nephrectomy, partial nephrectomy, nephrohorrhaphy, or no exploration), survival, intensive care unit length of stay, intra-abdominal complications, and specific kidney-related complications (ie, renal failure, urine leak or fistula, urinoma, abscess, false aneurysm, arteriovenous fistula, vascular thrombosis, or persistent bleeding). Grade I or II injuries on the American Association for the Surgery of Trauma kidney injury scale were classified as minor, grade III as moderate, and grades IV and V as severe.10 The patients were grouped into 5 therapeutic categories for analysis: total nephrectomy, partial nephrectomy, nephrohorrhaphy, laparotomy without kidney exploration, and no laparotomy.

The 2-sided Fisher exact test was used to assess the significant difference of complications among therapeutic modalities. For multiple comparisons, the Bonferroni method was used to adjust the P values.11 P < .05 was considered statistically significant. The SAS software, release 8.2 (SAS Institute Inc, Cary, North Carolina), was used for all statistical analysis.

### RESULTS

**MANAGEMENT OF KIDNEY INJURY**

During the 14-year study period, 889 patients had a diagnosis of kidney injury, 582 of which were owing to penetrating trauma and 307 (34.5%) owing to blunt trauma. Gunshot wounds accounted for 452 of all kidney injuries (50.8%), followed by 135 injuries from motor vehicle crashes (15.2%) and 127 stab wounds (14.3%). Overall, 227 patients (25.5%) had severe kidney injury (grade IV or V) and the remaining 662 (74.5%) had minor or moderate injuries (grades I-III). Epidemiologic characteristics of the study patients are given in Table 2.

Overall, 361 of 889 patients (40.6%) were treated nonoperatively. By mechanism of injury, 142 of 582 patients with penetrating trauma (24.4%) and 219 of 307 patients with blunt trauma (71.3%) were treated nonoperatively (P < .001). Among patients with severe renal trauma (grade IV or V), 50 of 227 (22.0%) were treated nonoperatively, including 27 of 172 (15.7%) with penetrating trauma and 23 of 55 (41.8%) with blunt trauma (P < .001).

Of the 889 patients, 207 (23.3%) underwent a laparotomy, but the kidney was not explored (Table 3). Thus, 568 patients (63.9%) either had no laparotomy (n = 361) or had laparotomy but no kidney exploration (n = 207).
including 292 of 582 patients with penetrating injuries (50.2%) and 276 of 307 patients with blunt injuries (89.9%) (P < .001). In severe kidney injuries, 89 of 227 patients (39.2%) did not undergo kidney exploration or laparotomy, including 54 of 172 (31.4%) with penetrating trauma and 35 of 55 (63.6%) with blunt trauma (P < .001). For minor or moderate kidney injuries, 238 patients with penetrating trauma (58.0%) and 241 patients with blunt trauma (96.0%) did not undergo kidney exploration.

Of the 889 patients, a nephrectomy was performed in 173 patients (19.5%), including 146 of 582 patients with penetrating trauma (25.1%) and 27 of 307 patients with blunt trauma (8.8%; P < .001). Kidney repair was performed in 95 of 889 (10.7%) patients, including 93 of 582 patients with penetrating trauma (16.0%) and 2 of 307 patients with blunt trauma (0.7%; P < .001). Partial nephrectomy was performed in only 53 of 889 patients with kidney injuries (6.0%), including 51 of 582 patients with penetrating trauma (8.8%) and 2 of 307 patients with blunt trauma (0.7%; P < .001) (Table 3).

### KIDNEY-RELATED COMPLICATIONS

Overall, 46 patients (5.2%) developed 1 or more kidney-related local complications: 36 of 582 patients with penetrating injuries (6.2%) and 10 of 307 with blunt trauma (3.3%; P = .08). The types of kidney-related complications by management modality are given in Table 4. Nephrectomy was associated with a significantly higher incidence of renal failure than the other therapeutic modalities (4.6% vs 0.6%, P < .001). The overall incidence of kidney-related complications other than renal failure was significantly higher in patients undergoing

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### Table 3. Frequency of Specific Therapeutic Interventions According to Mechanism of Injury and Kidney Injury Severity

<table>
<thead>
<tr>
<th>Mechanism and Severity of Injury</th>
<th>Laparotomy With Nephrectomy (N=173)</th>
<th>Laparotomy With Partial Nephrectomy (N=53)</th>
<th>Laparotomy With Kidney Repair (N=95)</th>
<th>Laparotomy With No Exploration (N=207)</th>
<th>No Laparotomy (N=361)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All mechanisms</td>
<td>173/889 (19.5)</td>
<td>53/889 (6.0)</td>
<td>95/889 (10.7)</td>
<td>207/889 (23.3)</td>
<td>361/889 (40.6)</td>
</tr>
<tr>
<td>Severe injury</td>
<td>105/277 (46.3)</td>
<td>25/277 (11.0)</td>
<td>8/277 (3.5)</td>
<td>39/277 (17.2)</td>
<td>50/277 (22.0)</td>
</tr>
<tr>
<td>Minor or moderate injury</td>
<td>68/662 (10.3)</td>
<td>28/662 (4.2)</td>
<td>87/662 (13.1)</td>
<td>168/662 (25.4)</td>
<td>311/662 (47.0)</td>
</tr>
<tr>
<td>Penetrating trauma</td>
<td>146/582 (25.1)</td>
<td>51/582 (8.8)</td>
<td>93/582 (16.0)</td>
<td>150/582 (25.8)</td>
<td>142/582 (24.4)</td>
</tr>
<tr>
<td>Severe injury</td>
<td>88/172 (51.2)</td>
<td>23/172 (13.4)</td>
<td>7/172 (4.1)</td>
<td>27/172 (15.7)</td>
<td>27/172 (15.7)</td>
</tr>
<tr>
<td>Minor or moderate injury</td>
<td>58/140 (41.4)</td>
<td>28/140 (20.0)</td>
<td>86/140 (60.0)</td>
<td>123/140 (85.7)</td>
<td>115/140 (81.4)</td>
</tr>
<tr>
<td>Blunt trauma</td>
<td>27/307 (8.8)</td>
<td>2/307 (0.7)</td>
<td>1/307 (0.3)</td>
<td>1/307 (0.3)</td>
<td>1/307 (0.3)</td>
</tr>
<tr>
<td>Severe injury</td>
<td>17/55 (30.9)</td>
<td>2/55 (3.6)</td>
<td>1/55 (1.8)</td>
<td>12/55 (21.8)</td>
<td>23/55 (41.8)</td>
</tr>
<tr>
<td>Minor or moderate injury</td>
<td>10/251 (4.0)</td>
<td>0</td>
<td>1/251 (0.4)</td>
<td>4/251 (0.4)</td>
<td>1/251 (0.4)</td>
</tr>
</tbody>
</table>

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### Table 4. Comparison of Kidney-Related Complications Among Management Methods for Patients With Renal Trauma

<table>
<thead>
<tr>
<th>Kidney-Related Complication</th>
<th>All Patients (N=889)</th>
<th>Laparotomy With Nephrectomy (n=173)</th>
<th>Laparotomy With Partial Nephrectomy (n=53)</th>
<th>Laparotomy With Kidney Repair (n=95)</th>
<th>Laparotomy With No Exploration (n=207)</th>
<th>No Laparotomy (n=361)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal failure</td>
<td>12 (1.3)</td>
<td>8 (4.6)</td>
<td>1 (1.1)</td>
<td>2 (1.0)</td>
<td>1 (0.3)</td>
<td>.004</td>
</tr>
<tr>
<td>Renal failure excluding extra-abdominal</td>
<td>9 (1.0)</td>
<td>6 (3.5)</td>
<td>0</td>
<td>1 (1.1)</td>
<td>1 (0.5)</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>AIS-90 score &gt; 3</td>
<td>46 (5.2)</td>
<td>11 (6.4)</td>
<td>2 (3.8)</td>
<td>10 (10.5)</td>
<td>14 (6.8)</td>
<td>9 (2.5)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>20 (2.3)</td>
<td>7 (4.1)</td>
<td>2 (3.8)</td>
<td>4 (4.2)</td>
<td>4 (1.9)</td>
<td>3 (0.8)</td>
</tr>
<tr>
<td>Urine leak or fistula</td>
<td>11 (1.2)</td>
<td>3 (1.7)</td>
<td>1 (1.9)</td>
<td>2 (2.1)</td>
<td>3 (1.5)</td>
<td>2 (0.6)</td>
</tr>
<tr>
<td>Uronima</td>
<td>4 (0.5)</td>
<td>0</td>
<td>1 (1.9)</td>
<td>2 (2.1)</td>
<td>1 (0.5)</td>
<td>0</td>
</tr>
<tr>
<td>Abscess</td>
<td>3 (0.3)</td>
<td>1 (0.6)</td>
<td>0</td>
<td>0</td>
<td>2 (0.6)</td>
<td>.77</td>
</tr>
<tr>
<td>False aneurysm</td>
<td>3 (0.3)</td>
<td>1 (0.6)</td>
<td>0</td>
<td>0</td>
<td>1 (0.5)</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Arteriovenous fistula</td>
<td>1 (0.1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (0.5)</td>
<td>0</td>
</tr>
<tr>
<td>Vascular thrombosis</td>
<td>4 (0.5)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (1.0)</td>
<td>2 (0.6)</td>
</tr>
<tr>
<td>Persistent bleeding</td>
<td>11 (1.2)</td>
<td>1 (0.6)</td>
<td>0</td>
<td>2 (2.1)</td>
<td>5 (2.4)</td>
<td>2 (0.6)</td>
</tr>
<tr>
<td>Incomplete repair</td>
<td>3 (0.3)</td>
<td>1 (0.6)</td>
<td>0</td>
<td>1 (1.1)</td>
<td>1 (0.5)</td>
<td>0</td>
</tr>
<tr>
<td>Infarct or parenchymal loss</td>
<td>2 (0.2)</td>
<td>0</td>
<td>1 (1.9)</td>
<td>1 (1.1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>2 (0.2)</td>
<td>0</td>
<td>0</td>
<td>1 (0.5)</td>
<td>1 (0.3)</td>
<td>.01</td>
</tr>
</tbody>
</table>

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Abbreviations: AIS-90, Abbreviated Injury Scale –1990 Revision; UTI, urinary tract infection.

*Kidney-related complications included renal failure, urine leak or fistula, urinoma, abscess, false aneurysm, arteriovenous fistula, vascular thrombosis, persistent bleeding, incomplete repair, and renal insufficiency.

*P* values were derived from the 2-sided Fisher exact test.
nephrectomy than in patients undergoing nephrectomy, partial nephrectomy, or no exploration of the kidney (Table 4), even though the nephrectomy group was less likely to have severe kidney injuries than the other groups. Further analysis of kidney-related complications showed the incidence of complications after severe renal trauma was similar in patients who did and those who did not undergo kidney exploration (7.3% [10 of 138] vs 7.9% [7 of 89]; P > .99, 2-sided Fisher exact test). However, in patients with minor or moderate trauma, patients who underwent exploration of the kidney had more than twice the complication rate compared with patients who did not undergo exploration (7.1% [13 of 183] vs 3.3% [16 of 479], P = .05).

The kidney is the third most commonly injured solid organ after blunt trauma and the second most common after penetrating trauma. The International Society of Urology estimates that approximately 245,000 renal injuries occur each year worldwide, approximately 80% of which are owing to blunt trauma.\(^{2,3}\) Although less common in most institutions, penetrating trauma is more likely to cause severe renal injury requiring nephrectomy.\(^{13,14}\) In this study, 582 patients (65.5%) experienced renal trauma from penetrating mechanisms. Also, in the present study, 172 patients with penetrating trauma (29.6%) and 35 with blunt trauma (17.9%) had severe kidney injuries (grades IV and V).

The management of blunt renal trauma has not undergone significant change in the past decade. Nonoperative management has remained the standard of care in most cases, with some pediatric series up to 95%.\(^{1}\) In the present study, 276 patients with blunt trauma (89.9%) were treated with no surgical exploration of the kidney injury. However, the management of penetrating injuries has undergone major changes.\(^{5-7}\) Traditionally, penetrating renal injuries were managed with exploration and nephrectomy (61%), partial nephrectomy (48%), or no exploration of the kidney or nephrectomy. Small series of successful nonoperative management of renal stab wounds were reported as long ago as 1985.\(^{2}\) More recently, Wessells et al\(^{15}\) suggested that many grade II penetrating renal injuries can be managed nonoperatively. The approach to gunshot wounds to the kidney remained much more cautious, and operation is widely considered the procedure of choice. This surgical dogma was challenged by a recent study,\(^{4}\) which showed that in approximately 40% of renal gunshot wounds, there was no need for exploration of the kidney. In a more recent prospective study, 30% of isolated penetrating kidney injuries were successfully managed nonoperatively. One case of urinoma was managed without operation.\(^{7}\) The present study showed that 142 penetrating kidney injuries (24.4%) were successfully managed nonoperatively. Overall, 292 patients with penetrating kidney injuries (50.2%) did not undergo kidney exploration. More than 30% of patients with penetrating kidney injuries do not have any other serious associated intra-abdominal injuries.\(^{7}\) These patients are good candidates for nonoperative treatment. More than 26% of grade I or II penetrating kidney injuries can safely be managed nonoperatively. The combination of careful initial and serial clinical examinations and computed tomographic evaluation is highly reliable in identifying patients with associated hollow viscus injuries.\(^{7,16}\)

The management of kidney injuries during laparotomy may include no exploration of the kidney, an approach followed in 207 patients (23.3%) in this series. No exploration of kidney hematomas owing to penetrating trauma should be considered in stable hematomas away from the hilum.\(^{6,7}\) However, expanding hematomas or those involving the hilum should always be explored because of the possibility of underlying significant vascular injuries.\(^{17}\) Routine exploration of kidney injuries, especially after blunt trauma, increases the risk of kidney loss.\(^{18}\) The safety of nonoperative management, even in grade IV renal injuries or injuries with urinary extravasation, is well documented in the literature.\(^{5,19}\) In the present study, patients with minor or moderate injuries undergoing kidney exploration were significantly more likely to develop local complications than those without exploration. No difference was found in the complication rates between exploration or no exploration in patients with severe injuries.

Nephrectomy is the most commonly used surgical intervention for kidney injury, especially after penetrating trauma, and it was performed in 27 patients with blunt trauma (8.8%) and 146 patients with penetrating trauma (25.1%). In a National Trauma Data Bank study, Wright et al\(^{10}\) reported nephrectomy rates of 4% and 21% for patients with blunt trauma and penetrating trauma, respectively. Removal of one of the kidneys in a patient with major associated injuries or other risk factors is more likely to result in renal failure, as clearly shown in the present study. The next most common surgical intervention was nephorrhaphy. This repair should be performed meticulously, with attention to precise suturing of any calyceal injury and good hemostasis. This procedure was used frequently in penetrating trauma but rarely in blunt trauma. It is the procedure with the highest incidence of kidney-related complications, even though its group had less severe kidney injuries. The high incidence of local complications with this method might result from inadequate debridement of devitalized tissues, failure to repair any calyceal injuries, or poor hemostasis. Of patients treated with kidney repair, 10 (10.5%) developed 1 or more local complications. However, almost all these complications can safely be managed with percutaneous drainage, stenting of the ureter, or angioembolization. In patients with hemodynamic stability, it might be appropriate to involve an experienced urologist for meticulous repair of the calyceal system. The least-used surgical intervention was partial nephrectomy. It was performed in 51 patients with penetrating trauma (8.8%) undergoing a laparotomy but in only 2 patients with blunt trauma (0.7%). The procedure is associated with significantly lower local kidney-related complications compared with kidney repair.

In conclusion, selective nonoperative management of penetrating kidney injuries can safely be used in a significant number of patients, including those with severe trauma. Nephrectomy is associated with a higher inci-
dence of renal failure than other therapeutic modalities. Nephorrhaphy is associated with a higher incidence of kidney-related local complications than the rest of the interventions. Exploration of minor- or moderate-severity kidney injuries increases the risk for kidney-related local complications.

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Author Contributions: Drs Starnes, Demetriades, and Inaba had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Starnes and Demetriades. Acquisition of data: Starnes and Hadjizacharia. Analysis and interpretation of data: Starnes, Demetriades, Hadjizacharia, Inaba, Best, and Chan. Drafting of the manuscript: Starnes, Demetriades, and Hadjizacharia. Critical revision of the manuscript for important intellectual content: Demetriades, Inaba, Best, and Chan. Statistical analysis: Hadjizacharia and Chan. Administrative, technical, and material support: Starnes, Demetriades, Inaba, and Best. Study supervision: Demetriades and Best.

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REFERENCES


Renal Trauma
Open With Care

Starnes et al report a 14-year, single-center experience of various treatment options for renal trauma. They identified 889 patients with traumatic kidney injuries, of which 227 (25.5%) were high-grade (ie, American Association for the Surgery of Trauma grades IV and V) injuries. Overall, roughly 63.9% of all renal injuries were managed nonoperatively with most owing to blunt mechanisms. This nonoperative group includes many patients with known renal injuries who underwent a laparotomy for other reasons but had no exploration of the renal injury. For the most part, nonoperative management of renal injuries was successful; however, owing to the retrospective nature of the data, it is not known how many patients who were initially managed nonoperatively required a subsequent operation or the complication rate of those patients whose conditions failed to improve with nonoperative management.

If these data were available, the clinical usefulness of this data set would be greatly enhanced. Nevertheless, this article provides invaluable data about the likely success of nonoperative management of renal trauma and the natural history of attempted renal salvage surgery.

In patients who underwent renal exploration, several important findings were noted. Patients who required a nephrectomy had an 8-fold increase in postoperative renal failure compared with those who did not undergo nephrectomy (4.6% vs 0.6%). Postoperative renal failure was the most common complication following nephrectomy. Once again, the surgical dictum that renal exploration is associated with a higher nephrectomy rate is confirmed by the authors. Partial nephrectomy was an infrequent procedure and was undertaken much less often than, but seemed better tolerated than, nephorrhaphy. Patients undergoing nephorrhaphy had