Operative and nonoperative management for renal trauma: comparison of outcomes. A systematic review and meta-analysis

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Introduction: Preservation of kidney and renal function is the goal of nonoperative management (NOM) of renal trauma (RT). The advantages of NOM for minor blunt RT have already been clearly described, but its value for major blunt and penetrating RT is still under debate. We present a systematic review and meta-analysis on NOM for RT, which was compared with the operative management (OM) with respect to mortality, morbidity, and length of hospital stay (LOS).

Methods: The Preferred Reporting Items for Systematic Reviews and Meta-analyses statement was followed for this study. A systematic search was performed on Embase, Medline, Cochrane, and PubMed for studies published up to December 2015, without language restrictions, which compared NOM versus OM for renal injuries.

Results: Twenty nonrandomized retrospective cohort studies comprising 13,824 patients with blunt (2,998) or penetrating (10,826) RT were identified. When all RT were considered (American Association for the Surgery of Trauma grades 1–5), NOM was associated with lower mortality and morbidity rates compared to OM (8.3% vs 17.1%, odds ratio [OR] 0.471; 95% confidence interval [CI] 0.404–0.548; \( P<0.001 \) and 2% vs 53.3%, OR 0.0484; 95% CI 0.0279–0.0839, \( P<0.001 \)). Likewise, NOM represented the gold standard treatment resulting in a lower mortality rate compared to OM even when only high-grade RT was considered (9.1% vs 17.9%, OR 0.332; 95% CI 0.155–0.708; \( P=0.004 \)), be they blunt (4.1% vs 8.1%, OR 0.275; 95% CI 0.0957–0.788; \( P=0.016 \)) or penetrating (9.1% vs 18.1%, OR 0.468; 95% CI 0.398–0.552; \( P<0.001 \)).

Conclusion: Our meta-analysis demonstrated that NOM for RT is the treatment of choice not only for AAST grades 1 and 2, but also for higher grade blunt and penetrating RT.

Keywords: renal trauma, blunt trauma, penetrating trauma, operative management, nonoperative management, systematic review, meta-analysis

Introduction

The kidney is the third most frequently injured organ in abdominal trauma after the spleen and liver.1 In the last 30 years, the treatment strategy of renal trauma has changed from operative management (OM) to nonoperative management (NOM).1 Several studies showed improving outcomes when NOM was applied in blunt trauma and, therefore, conservative management gained an increasing popularity among trauma surgeons.2–4

However, specific guidelines regarding renal trauma are still lacking and the few papers providing recommendations are not supported by relevant grades of evidence.
Immediate surgical management of injuries with life-threatening hemorrhage is widely accepted; however, when this clear-cut indication is lacking, several differences in management strategies emerge from the literature.\textsuperscript{5–8} A successful conservative management for blunt low-grade renal injury (renal contusions and minor lacerations) is well documented with a low complication rate,\textsuperscript{9,10} but what about the optimal management of penetrating and high-grade blunt injuries?

We first investigated through a systematic review and meta-analysis the efficacy of OM and NOM on any grade, blunt or penetrating, renal trauma and evaluated mortality, morbidity, and length of hospital stay (LOS) for the different types of injuries and management.

**Methods**

**Study selection**

The criteria of the “Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement”\textsuperscript{11} were followed in the present study.\textsuperscript{5,12–30} Embase, Medline, Cochrane, and PubMed databases were used to identify studies, published up to December 2015, comparing blunt and penetrating renal trauma in adults. The following MESH search headings were used: “operative and non-operative management renal trauma”, “operative and non-operative treatment for blunt and penetrating adult renal injury”, “operative and non-operative treatment for genitourinary trauma”, and “operative and non-operative management kidney injury”. The “related articles” function in PubMed database was used to increase and widen the search to all similar abstracts and studies.

**Inclusion criteria**

Studies comparing the selected clinical outcomes – that is, mortality, morbidity and length of stay – of adult patients submitted to NOM and OM for renal trauma were selected for the analysis.

**Exclusion criteria**

We did not consider for meta-analysis: 1) studies in which mortality, morbidity, and LOS were not reported separately for NOM and OM, 2) studies analyzing pediatric patients, or 3) papers reporting series already selected for this meta-analysis.

**Data extraction**

Data concerning study author, year of publication, patient characteristics, study design, number of patients submitted to NOM or OM, mortality rates, morbidity rates, and length of stay (LOS) were extracted and inserted into a database.

**Outcomes of interest and definition**

Patients’ demographics (age and sex), trauma characteristics (open or blunt), trauma severity (Injury Severity Score – ISS), American Association for the Surgery of Trauma (AAST) grade, hemodynamic stability, type of management (operative and nonoperative), and clinical outcomes (morbidity, mortality, LOS) were retrieved.

Morbidity and mortality were defined as in-hospital complication and mortality rates.

Intervention types were defined as: NOM (clinical observation, medical treatment, and proximal or distal renal angio-embolization) and OM (total or partial nephrectomy, nephorrhaphy, or application of hemostatic agents).

**Study endpoints**

The primary endpoint was the overall mortality and morbidity defined as any death or complication that occurred after the start of NOM or OM and during the hospital stay for all renal trauma (blunt and penetrating).

The secondary endpoint was the overall mortality and morbidity that occurred after the start of NOM or OM and during the hospital stay for blunt and penetrating renal trauma considered separately.

The tertiary endpoint was the overall mortality and morbidity that occurred after the start of NOM or OM and during the hospital stay for all high-grade renal trauma (AAST 3–5).

The quaternary endpoint was the length of stay after the start of NOM or OM.

**Study selection**

A total of 465 papers were identified at the end of the literature search. After a first evaluation performed by abstract analysis, 369 studies were excluded because they were irrelevant to the purpose of our study, and 37 studies because of overlapping data. The full-text analysis of the 49 remaining studies resulted in exclusion of 29 because they did not match the inclusion criteria, while 20 were selected for further analysis.\textsuperscript{5,12–30}

**Search strategy results**

Twenty nonrandomized retrospective cohort studies (Table 1) accounting for a total of 13,824 patients affected with renal injury form the basis of our analysis; 11,426 patients underwent NOM and 2,398 OM.

**Quality of included studies**

The quality of included studies was assessed by two authors (MLT and AM) using the Newcastle–Ottawa Scale (NOS).\textsuperscript{31}
Table I  Study selection

| Reference | Type of study | Patients (N) |
|-----------|---------------|--------------|
| McGuire et al\textsuperscript{10} | Retrospective | 117          |
| Sughara et al\textsuperscript{13} | Retrospective | 1,505        |
| Yang et al\textsuperscript{13} | Retrospective | 73           |
| Sahin et al\textsuperscript{14} | Retrospective | 135          |
| Hammer and Santucci\textsuperscript{15} | Retrospective | 51           |
| Buckley and McNinch\textsuperscript{16} | Retrospective | 43           |
| Kansas et al\textsuperscript{17} | Retrospective | 206          |
| Moolman et al\textsuperscript{18} | Retrospective | 92           |
| McClung et al\textsuperscript{19} | Retrospective | 9,584        |
| Aragona et al\textsuperscript{20} | Retrospective | 45           |
| van der Vlies et al\textsuperscript{21} | Retrospective | 186          |
| Gourgiotis et al\textsuperscript{22} | Retrospective | 28           |
| Starnes et al\textsuperscript{23} | Retrospective | 889          |
| Bjurlin et al\textsuperscript{24} | Retrospective | 97           |
| Shariat et al\textsuperscript{25} | Retrospective | 77           |
| Menaker et al\textsuperscript{26} | Retrospective | 434          |
| Raheem et al\textsuperscript{27} | Retrospective | 25           |
| Sangthong et al\textsuperscript{28} | Retrospective | 517          |
| Shoobridge et al\textsuperscript{29} | Retrospective | 338          |
| Bozeman et al\textsuperscript{30} | Retrospective | 26           |

All included studies had good methodological quality (>5 points; mean 6.9 points, range 6–9).

Risk of bias

Distribution of age, sex, and ISS were homogenous between the NOM and OM groups. Conversely, the AAST grade was not homogenous between the two groups: in the NOM group, there were 3,252 (28.5%) high-grade (AAST 3–5) renal trauma whereas in the OM group they were 1,387 (57.8%; \(P<0.0001\)).

Statistical analysis

Statistical analysis was conducted using MedCalc for Windows, version 10.2.0.0 (MedCalc Software, MariaKerke, Belgium).

Odds ratio (OR), for dichotomous outcomes, was calculated by the Mantel–Haenszel method, while standardized mean difference (SMD), for continuous outcomes, was calculated by Hedges \(g\) statistic. Results from the meta-analysis for OR were considered statistically significant (\(P<0.05\)) if the value 1 was not within the 95% CI, whereas for SMD, it was if the value 0 was not within the 95% CI.

Heterogeneity was also studied by calculating the Chi\(^2\) and the inconsistency (\(I^2\)). As \(I^2\) detected the absence of homogeneity (>50%), the fixed effect model could not be used; therefore, the random effect model was used for analysis.

If the test of heterogeneity was statistically significant (\(P<0.05\)), then more emphasis should be placed on the random effects model.

Results

Twenty retrospective cohort studies comprising 13,824 patients were selected (Table 1). Eight studies analyzed 2,998 patients with blunt renal trauma (BRT),\(^{5,12,23,26–30}\) whereas 12 studies analyzed the remaining 10,826 patients with penetrating renal trauma (PRT).\(^{14–24,28}\) Patient characteristics are summarized in Table 2.

NOM was the most frequent and prevalent strategy adopted for renal trauma, with 11,426 (82.4%) patients treated conservatively versus 2,398 (17.3%) patients treated operatively (Table 3).

NOM was significantly more frequently adopted in BRT, compared to PRT (Table 3; \(P<0.0001\)). Table 4 shows the distribution of NOM and OM according to the severity of renal trauma (AAST scale), both for penetrating or blunt trauma. A significantly higher number of patients was treated conservatively for low-grade trauma and a significantly higher number of patients was treated operatively for high-grade trauma (\(P<0.0001\)).

Further analysis pursued the following criteria: 1) An analysis concerning all renal trauma (AAST low and high grades) and 2) an analysis concerning only high-grade renal trauma.

NOM versus OM for all renal trauma

Eleven studies compared morbidity,\(^{5,12,15,18,22–25,28,29,30}\) twelve compared mortality,\(^{12,13,15,17–19,22,26–30}\) and four compared LOS,\(^{19,26,28,30}\) according to OM and NOM.

A higher mortality rate for OM (17.1%, 274/1,598) compared to NOM (8.3% 887/10,642; OR 0.471; 95%
CI 0.404–0.548; $P<$0.001) was observed when all renal trauma were considered (Figure 1).

No statistical differences were encountered in terms of morbidity and LOS (OR 0.490; 95% CI 0.0775–3.101; $P$=0.449 and SMD =0.0407; 95% CI –0.017 to 0.099; $P$=0.171; Figures 2 and 3).

### NOM versus OM for all-grade BRT

Five studies compared morbidity,15,18,22–25 seven compared mortality,15,22–25,29,30 and three compared LOS.26,28,30

We observed significantly higher morbidity and mortality rates with OM versus NOM when only blunt trauma were studied (the analysis included all grades of renal trauma according to the AAST scale; Figures 4 and 5).

After NOM, we observed a lower morbidity rate (38/1,869, 2%) when compared to OM (56/105, 53.3%) (OR 0.0484; 95% CI 0.0279–0.0839; $P$<0.001) as well as a lower mortality rate (130/2,676, 4.8%, vs 33/205, 16.1%; OR 0.445; 95% CI 0.0528–0.942; $P$=0.041).

LOS was similar between OM and NOM (SMD –0.326; 95% CI –0.802 to 0.150; $P$=0.180; Figure 6).

### NOM versus OM for all-grade PRT

Six studies compared morbidity,15,18,22–25 and five compared mortality.15,17,19,22 No studies specifically analyzed LOS.

A significantly lower mortality rate of NOM (757/7,914 vs 18.1%, 757/7,914 vs 18.1%, 224/1,239; OR 0.468; 95% CI 0.195–0.788; $P$=0.016) was recorded (Figure 7).

Morbidity was similar for OM and NOM (OR 1.565; 95% CI 0.422–5.802; $P$=0.503; Figure 8).

### Discussion

The kidney is the third most commonly injured solid organ after blunt trauma, and the second most commonly affected after penetrating trauma.1 Every year, 245,000 renal trauma cases occur worldwide, with blunt trauma representing approximately 80% of cases.1

The treatment strategy of BRT has not changed in the last 30 years. The standard of care is, in most cases, nonoperative and up to 95% of the pediatric patients do not undergo surgery.14,15 Conversely, the management of penetrating injuries has significantly changed.29,30 Traditionally, penetrating renal injuries were managed with exploration, nephorrhaphy, partial nephrectomy, or nephrectomy.17,18
The approach to renal gunshot wounds was still more prudent and careful, with surgical exploration and repair considered mandatory treatment. In 1997, Wessells et al suggested that many grade 2 penetrating renal injuries can be managed nonoperatively.\(^\text{32}\) In 1998, Velmahos et al reported that a kidney exploration was not necessary in approximately 40% of renal gunshot trauma.\(^\text{33}\) In 2006, the same authors showed that a nonoperative management was successful in 50% of isolated penetrating kidney injuries.\(^\text{34}\)

In our meta-analysis, we demonstrated that NOM was the most frequent and prevalent strategy of cure used for renal trauma in adults, with 11,426 (82.4%) patients conservatively treated (17.3%) versus 2,398 patients who underwent surgery. However, when we analyzed the distribution of NOM and OM on the basis of the severity of renal trauma (AAST scale), we observed a significantly higher number of patients with low-grade trauma treated conservatively and a significantly higher number of patients with high-grade trauma treated operatively \((P<0.0001)\). Furthermore, NOM was more frequently used in BRT, compared to PRT \((P<0.0001)\).

Major debate concerns the indications for surgical exploration – both for BRT and PRT in high-grade trauma. The experience translated from NOM in pediatric hepatic and splenic trauma, the availability of multi-slice computerized tomography, and the acquisition of angiographic embolization techniques demonstrated that, NOM in selected hepatic and splenic high-grade trauma, also in adults, has better outcomes in terms of morbidity, mortality, and LOS when compared to surgical exploration.\(^\text{34–37}\) In the present study, we clearly demonstrated that NOM can be safely performed even for high-grade RT, allowing a significant reduction...
of the mortality rate (9.1% vs 17.9%; OR 0.332; 95% CI 0.155–0.708; P=0.004; Figure 9).

When blunt and penetrating high-grade RT data were analyzed separately, we found similar outcomes: mortality in blunt trauma decreased from 8.1% after OM to 4.1% after NOM (OR 0.275; 95% CI 0.0957–0.788; P=0.016), and in penetrating trauma from 18.1% after OM to 9.1% after NOM (OR 0.468; 95% CI 0.398–0.552; P<0.001).

Our data demonstrated that hemodynamically stable patients do not always need surgical exploration, because major renal trauma may heal either spontaneously or after minimally invasive procedures. Matthews et al reported spontaneous healing in 87% of 31 patients affected with a renal injury and urinary extravasation. Haas et al described a high renal salvage rate using ureteral stents in patients with renal trauma and urinary extravasation. In a series of 20 patients with either grade 4 or 5 renal trauma who were conservatively treated, Moudouni et al reported six open delayed procedures, whereas the remaining patients healed spontaneously or after ureteral stent positioning. Altman et al compared two groups of patients affected with grade 5 injuries. Six were managed conservatively and seven were operated on. The authors affirmed that patients treated conservatively had a lower morbidity rate, with functioning renal parenchyma at follow-up CT scan.

Moreover, our analysis showed a lower LOS of NOM versus OM and similar morbidity rates of both NOM and OM in patients with BRT or penetrating high-grade renal trauma, suggesting that NOM can be safely undertaken, avoiding laparotomies, kidney resections, and nephrectomies, and allowing hospital cost reduction.

**Conclusion**

The results of this meta-analysis showed that not only is NOM the treatment of choice for low-grade RT, but also that it should be considered as the first-line treatment.
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| Reference       | NOM | OM | OR  | 95% CI       | P-value |
|-----------------|-----|----|-----|--------------|---------|
| Yang et al<sup>13</sup> | 3/66 | 1/7 | 0.286 | 0.0256–3.191 |         |
| Sugihara et al<sup>12</sup> | 11/1,440 | 6/46 | 0.0513 | 0.0181–0.146 |         |
| Menaker et al<sup>20</sup> | 30/416 | 4/18 | 0.272 | 0.0843–0.878 |         |
| Raheem et al<sup>27</sup> | 0/23 | 0/2 | – | – |         |
| Sangthong et al<sup>26</sup> | 86/422 | 22/95 | 0.849 | 0.499–1.446 |         |
| Shoobridge et al<sup>29</sup> | 0/295 | 0/25 | – | – |         |
| Bozeman et al<sup>13</sup> | 0/14 | 0/12 | – | – |         |
| Total (fixed effects) | 130/2,676 | 33/205 | 0.558 | 0.362–0.860 | 0.008 |
| Total (random effects) | 130/2,676 | 33/205 | 0.445 | 0.0528–0.942 | 0.041 |

Test for heterogeneity: Q=24.2264, P=0.0001

Figure 5 Mortality for blunt renal trauma.

Note: The OR was not calculated when the results at the univariate analysis were not statistically significant: this is represented with “–” and consequently there is no 95% CI.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference       | NOM | OM | Total | SMD  | 95% CI       | P-value |
|-----------------|-----|----|-------|------|--------------|---------|
| Menaker et al<sup>20</sup> | 416 | 18 | 434 | | −0.276 | −0.749–0.196 |
| Sangthong et al<sup>26</sup> | 422 | 95 | 517 | | −0.657 | −0.883–−0.430 |
| Bozeman et al<sup>13</sup> | 14 | 12 | 26 | | 0.264 | −0.526–1.054 |
| Total (fixed effects) | 852 | 125 | 977 | | −0.527 | −0.724–−0.331 | <0.001 |
| Total (random effects) | 852 | 125 | 977 | | −0.326 | −0.802–−0.150 | 0.180 |

Test for heterogeneity: Q=6.6299, P=0.0363

Figure 6 Length of hospital stay for blunt renal trauma.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; SMD, standardized mean difference.

| Reference       | NOM | OM | OR  | 95% CI       | P-value |
|-----------------|-----|----|-----|--------------|---------|
| Moolman et al<sup>13</sup> | 0/47 | 0/25 | – | | | |
| McClung et al<sup>19</sup> | 757/7,815 | 219/1,187 | 0.474 | 0.402–0.559 | | |
| Gourgiotis et al<sup>22</sup> | 0/5 | 3/23 | 0.532 | 0.0238–11.92 | | |
| Kansas et al<sup>17</sup> | 0/52 | 17/154 | 0.0748 | 0.0044–1.267 | | |
| Hammer and Santucci<sup>13</sup> | 0/47 | 2/4 | 0.0105 | 0.0003–0.283 | | |
| Total (fixed effects) | 757/7,966 | 241/1,393 | 0.459 | 0.390–0.540 | <0.001 |
| Total (random effects) | 757/7,966 | 241/1,393 | 0.180 | 0.0342–0.946 | 0.043 |

Test for heterogeneity: Q=6.7917, P=0.0788

Figure 7 Mortality for penetrating renal trauma.

Note: The OR was not calculated when the results at the univariate analysis were not statistically significant: this is represented with “–” and consequently there is no 95% CI.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.
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| Reference          | NOM   | OM   | OR    | 95% CI      | P-value |
|--------------------|-------|------|-------|-------------|---------|
| Moolman et al[2]   | 4/47  | 1/25 | 2.233 | 0.236--21.130 |         |
| Gourgiosis et al[2] | 5/5   | 10/23| 14.143| 0.700--285.58 |         |
| Sterne et al[2]    | 11/361| 47/528| 0.322 | 0.164--0.62 |         |
| Bjurlin et al[2]   | 2/39  | 1/58 | 3.081 | 0.270--35.205 |         |
| Shariat et al[2]   | 13/45 | 4/32 | 2.844 | 0.831--9.730 |         |
| Hammer and Santucci[2] | 2/47 | 0/4  | 0.495 | 0.020--11.977 |         |
| Total (fixed effects) | 37/544 | 63/670 | 0.730 | 0.461--1.157 | 0.180 |
| Total (random effects) | 37/544 | 63/670 | 1.565 | 0.422--5.802 | 0.503 |

Test for heterogeneity: Q=16.5166, P=0.0055

**Figure 8** Morbidity for penetrating renal trauma.
**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference          | NOM   | OM   | OR    | 95% CI      | P-value |
|--------------------|-------|------|-------|-------------|---------|
| McClung et al[2]   | 757/7,815 | 219/1,187 | 0.474 | 0.402--0.559 |         |
| Gourgiosis et al[2] | 0/5   | 3/23 | 0.532 | 0.0238--11.928 |         |
| Hammer and Santucci[2] | 0/47 | 2/4  | 0.0105| 0.00039--0.283 |         |
| Yang et al[2]      | 3/66  | 1/7  | 0.286 | 0.0256--3.191 |         |
| Menaker et al[2]   | 30/416| 4/18 | 0.272 | 0.0843--0.878 |         |
| Shoobridge et al[2] | 0/295| 0/25 |     |             |         |
| Bozeman et al[2]   | 2/14  | 0/12 |     |             |         |
| Total (fixed effects) | 790/8,658 | 229/1,276 | 0.464 | 0.394--0.545 | <0.001 |
| Total (random effects) | 790/8,658 | 229/1,276 | 0.332 | 0.155--0.708 | 0.004 |

Test for heterogeneity: Q=6.1070, P=0.1913

**Figure 9** Overall mortality, high-grade renal trauma.
**Note:** The OR was not calculated when the results at the univariate analysis were not statistically significant: this is represented with “-” and consequently there is no 95% CI.
**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference          | NOM   | OM   | Total | SMD   | 95% CI      | P-value |
|--------------------|-------|------|-------|-------|-------------|---------|
| McClung et al[2]   | 7,815 | 1,187| 9,002 | 0.0955| 0.034--0.157 |         |
| Menaker et al[2]   | 416   | 18   | 434   | -0.276| -0.749--0.196 |         |
| Bozeman et al[2]   | 14    | 12   | 26    | -0.264| -0.526--1.054 |         |
| Total (fixed effects) | 8,245 | 1,217| 9,462 | 0.0905| 0.030--0.151 | 0.003 |
| Total (random effects) | 8,245 | 1,217| 9,462 | 0.0523| -0.145--0.249 | 0.603 |

Test for heterogeneity: Q=2.5597, P=0.2781

**Figure 10** Overall length of stay, high-grade renal trauma.
**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; SMD, standardized mean difference.
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| Reference                          | NOM | OM  | OR   | 95% CI          | P-value |
|------------------------------------|-----|-----|------|-----------------|---------|
| Gourgios et al\textsuperscript{22} | 5/5 | 10/23 | 14.143 | 0.700–285.58 |         |
| Starnes et al\textsuperscript{23}  | 11/361 | 47/528 | 0.322 | 0.164–0.629 |         |
| Bjurlin et al\textsuperscript{24}  | 2/39 | 1/58 | 3.081 | 0.270–35.205 |         |
| Shariat et al\textsuperscript{25}  | 13/45 | 4/32 | 2.844 | 0.831–9.730 |         |
| Hammer and Santucci\textsuperscript{13} | 2/47 | 0/4 | 0.495 | 0.0204–11.977 |         |
| Shoobridge et al\textsuperscript{19} | 2/295 | 12/25 | 0.0073 | 0.0015–0.0365 |         |
| Bozeman et al\textsuperscript{30}  | 1/14 | 0/12 | 2.778 | 0.103–74.700 |         |
| Total (fixed effects)               | 36/806 | 74/682 | 0.472 | 0.309–0.722 | 0.001   |
| Total (random effects)              | 36/806 | 74/682 | 0.733 | 0.125–4.285 | 0.730   |

Test for heterogeneity: $Q=43.7842$, $P<0.0001$

**Figure 11** Overall morbidity, high-grade renal trauma.

**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference                          | NOM | OM  | OR   | 95% CI          | P-value |
|------------------------------------|-----|-----|------|-----------------|---------|
| Yang et al\textsuperscript{13}     | 3/66 | 1/7 | 0.286 | 0.0256–3.191 |         |
| Menaker et al\textsuperscript{24}  | 30/416 | 4/18 | 0.272 | 0.0843–0.878 |         |
| Shoobridge et al\textsuperscript{19} | 0/295 | 0/25 | –     |                  |         |
| Bozeman et al\textsuperscript{30}  | 0/14 | 0/12 | –     |                  |         |
| Total (fixed effects)               | 33/791 | 5/62 | 0.275 | 0.0957–0.788 | 0.016   |
| Total (random effects)              | 33/791 | 5/62 | 0.275 | 0.0957–0.788 | 0.016   |

Test for heterogeneity: $Q=0.001288$, $P=0.9714$

**Figure 12** Mortality in high-grade blunt trauma.

**Note:** The OR was not calculated when the results at the univariate analysis were not statistically significant; this is represented with “–” and consequently there is no 95% CI.

**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference                          | NOM | OM  | OR   | 95% CI          | P-value |
|------------------------------------|-----|-----|------|-----------------|---------|
| Shoobridge et al\textsuperscript{19} | 2/295 | 12/25 | 0.0073 | 0.0015–0.0365 |         |
| Bozeman et al\textsuperscript{30}  | 1/14 | 0/12 | 2.778 | 0.103–74.700 |         |
| Total (fixed effects)               | 3/309 | 12/37 | 0.0669 | 0.0192–0.233 | <0.001 |
| Total (random effects)              | 3/309 | 12/37 | 0.123 | 0.0002–73.434 | 0.521   |

Test for heterogeneity: $Q=12.2296$, $P=0.0005$

**Figure 13** Morbidity in high-grade blunt trauma.

**Abbreviations:** CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.
Mingoli et al

| Reference | NOM | OM | Total | SMD | 95% CI | P-value |
|-----------|-----|----|-------|-----|--------|---------|
| Menaker et al\textsuperscript{23} | 416 | 18 | 434   | −0.276 | −0.749−0.196 |
| Bozeman et al\textsuperscript{23} | 14  | 12 | 26    | 0.264  | −0.526−1.054 |
| Total (fixed effects) | 430 | 30 | 460   | −0.123  | −0.524−0.277 | 0.545 |
| Total (random effects) | 430 | 30 | 460   | −0.0880 | −0.594−0.418 | 0.733 |

Test for heterogeneity: $Q=1.4309$, $P=0.2316$

Figure 14 Length of stay in high-grade blunt trauma.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; SMD, standardized mean difference.

| Reference | NOM | OM | OR   | 95% CI | P-value |
|-----------|-----|----|------|--------|---------|
| Moolman et al\textsuperscript{18} | 0/47 | 0/25 | −     | 0.402−0.559 |
| McClung et al\textsuperscript{19} | 757/7,815 | 219/1,187 | 0.532 | 0.0238−11.928 |
| Gourgios et al\textsuperscript{22} | 0/5  | 3/23 | 0.0105 | 0.0003−0.283 |
| Hammer and Santucci\textsuperscript{15} | 0/47 | 2/4  | 0.398−0.552 | <0.001 |
| Total (fixed effects) | 757/7,914 | 224/1,239 | 0.205 | 0.0259−1.628 | 0.134 |
| Total (random effects) | 757/7,914 | 224/1,239 | 0.468 | 0.398−0.552 | <0.001 |

Test for heterogeneity: $Q=5.1336$, $P=0.0768$

Figure 15 Mortality in high-grade penetrating trauma.

Note: The OR was not calculated when the results at the univariate analysis were not statistically significant; this is represented with “−” and consequently there is no 95% CI.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.

| Reference | NOM | OM | OR   | 95% CI | P-value |
|-----------|-----|----|------|--------|---------|
| Moolman et al\textsuperscript{18} | 4/47 | 1/25 | 2.233 | 0.236−21.130 |
| Gourgios et al\textsuperscript{22} | 5/5  | 10/23 | 14.143 | 0.700−285.58 |
| Starnes et al\textsuperscript{23} | 11/361 | 47/528 | 0.322 | 0.164−0.62 |
| Bjurlin et al\textsuperscript{24} | 2/39 | 1/58 | 3.081 | 0.270−35.20 |
| Shariat et al\textsuperscript{25} | 13/45 | 4/32 | 2.844 | 0.831−9.73 |
| Hammer and Santucci\textsuperscript{15} | 2/47 | 0/4  | 0.495 | 0.0204−11.97 |
| Total (fixed effects) | 37/544 | 63/670 | 0.730 | 0.461−1.157 | 0.180 |
| Total (random effects) | 37/544 | 63/670 | 1.565 | 0.422−5.802 | 0.503 |

Test for heterogeneity: $Q=16.5166$, $P=0.0055$

Figure 16 Morbidity in high-grade penetrating trauma.

Abbreviations: CI, confidence interval; NOM, nonoperative management; OM, operative management; OR, odds ratio.
even for high-grade blunt or penetrating RT, because it is associated to lower mortality rates and LOS, and similar morbidity rates.

**Disclosure**

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter discussed in this manuscript and report no conflicts of interest in this work.

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