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Management of blunt force bladder injuries: A practice management guideline from the Eastern Association for the Surgery of Trauma

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The authors declare no conflict of interest.

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Abstract

Background: The diagnostic evaluation and clinical management of bladder injuries due to blunt force trauma is variable. We aim to formulate a practice management guideline using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.

Methods: The working group, PICO (Patient, Intervention, Comparator, Outcome), formulated four questions regarding the following topics: 1) diagnostic evaluation based on patient baseline risk of bladder injury (CT cystography vs. no imaging); 2) management of intraperitoneal bladder injuries (operative versus non-operative); 3) management of extraperitoneal bladder injuries based on complexity of injury (operative vs. non-operative); and 4) diagnostic follow-up of bladder injuries based on complexity of repair (cystography versus no cystography). A systematic review of the MEDLINE database for English language articles with adult patients was undertaken. RevMan 5 (Cochran Collaboration) and GRADEpro (Grade Working Group) software were utilized. Recommendations were voted on by working group members. Consensus was obtained for each recommendation.

Results: Three hundred and ninety-three articles were screened, resulting in a full-text review of 64 articles. Seventeen articles were used to formulate the recommendations of this guideline. Several recommendations are made. The need for initial CT cystography after trauma depends on characteristics of the trauma itself, but it is not recommended in patients without gross hematuria. In general, patients with intraperitoneal bladder ruptures should undergo operative repair. This is not routinely necessary in those with extraperitoneal ruptures unless the injury is complex. The need for follow-up cystography after bladder repair depends on the risk of urine leak. Those with low risk of urine leak do not require a follow-up study.

Conclusion: Using the GRADE process, the panel made nine recommendations based on 4 PICO questions concerning the evaluation and management of blunt force bladder injuries.

Level of evidence: Level III meta-analysis

Study type: Practice management guideline

Keywords: Genitourinary trauma; bladder injury; hematuria, cystography

Introduction:

Blunt external trauma, from either a direct blow to the abdomen or shearing forces from a pelvic fracture, accounts for the majority of bladder injuries presenting in emergency rooms. Bladder injuries are associated with multiple organ injuries making mortality rates associated with bladder injuries as high as 22%. Overall, roughly 60% of injuries are extraperitoneal, 30% intraperitoneal, and 10% occur concomitantly.(1)

The purpose of this practice management guideline was to evaluate critical clinical questions regarding the diagnosis and management of bladder trauma resulting from blunt abdominoperineal trauma. Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology was utilized to provide evidence-based guidance.(2) Throughout this guideline we define bladder injuries/ruptures as being full thickness bladder lacerations/injuries. Typically, these injuries are repaired in two layers with absorbable sutures due to their non-lithogenic property.

Objectives:

To develop this guideline, we assembled a panel composed of experts in the field of urology, traumatology, and GRADE methodology. We defined four population (P), intervention (I), comparator (C), and outcome (O) (PICO) questions *a priori* to the systematic review. These PICO questions were derived through a process panel deliberation:

PICO 1: In patients with blunt abdominal/pelvic trauma (P), should retrograde CT cystography (I) versus no imaging study, be used to diagnose bladder injuries (O)?

PICO 2: In patients sustaining blunt abdominopelvic trauma with intraperitoneal bladder rupture (P), should operative repair (I) versus non-operative management (C), be used to decrease complications from the bladder injury (O)?

PICO 3: In patients sustaining blunt abdominopelvic trauma with extraperitoneal bladder rupture (P), should operative repair (I) versus non-operative management (C), be used to decrease complications from the bladder injury (O)?

PICO 4: In patients who have undergone operative or non-operative management of bladder rupture (P), should cystography (I) versus no imaging study (C), be used to evaluate for bladder closure (O)?

Identification of References

With the assistance of a professional medical librarian, a systematic review of the medical literature was performed. The MEDLINE database was searched to identify English-language human studies published from January 1975 through July 2016 using the medical subject headings (MeSH) and keywords listed (see Figure, Supplemental Digital Content 1, http://links.lww.com/TA/B240). All randomized controlled trials, observational studies, and retrospective studies were considered. Studies of adult patients (age ≥ 18 years) sustaining blunt abdominal/pelvic trauma were included. Letters to the editor, book chapters, reviewed articles, studies on pediatric patients, penetrating trauma, and case series of less than 20 patients were excluded. Three authors performed the title and abstract review of the literature for each PICO question. One author (LLY) then performed the full text review of the remaining articles (Figure 1).

Outcome Measure Types

The relevant outcome measures for each PICO question were established *a priori*. This was a two-stage process. Panel members identified the most relevant outcomes relating to each PICO question. A 9-point scale, as described by the GRADE methodology, was then used by the panel to rate the outcomes in terms of importance.(3) Outcomes with scores of 7 to 9 were considered critical to the decision making process and were included in the review. For PICO 1, the critical outcomes were the true positives (patients with bladder rupture), true negatives (patients without bladder rupture) false negatives (patients incorrectly classified as not having bladder rupture), and false positives (patients incorrectly classified as having bladder rupture). For PICO 2, the critical outcomes were overall survival, successful bladder closure, and infectious complications. For PICO 3, the critical outcomes were overall survival, infectious complications, and need for operative repair. Infectious complications in PICO 2 and 3 included sepsis secondary to urinary tract infection, infected pelvic hardware, osteomyelitis, and peri-vesical space abscess formation. For PICO 4, the critical outcomes were the true positives (patients with urine leak), true negatives (patients without urine leakage), false negatives (patients incorrectly classified as not having urine leakage), and false positives (patients incorrectly classified as having urine leakage).

Data Extraction and Methodology

Data was extracted from each study performed using a standardized data collection sheet, which we pilot-tested. Data from each study were entered into Review Manager (RevMan, Cochrane Collaboration, version 5.3) for the meta-analysis. The primary author checked all entered data in duplicate to ensure accuracy. Forest plots were generated for each critical outcome and risk ratios were calculated as measures of effect for dichotomous outcomes. The I^2 statistic was used to determine the degree of heterogeneity between studies. All studies were analyzed using a random effects model.

We used the Newcastle-Ottawa Scale to assess the risk of bias for observational studies.(4) We used GRADE to assess the quality of evidence on a per outcome basis considering study limitations (risk of bias), inconsistency, indirectness, imprecision, and publication bias. The Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool was used to assess the quality of the diagnostic accuracy studies.(5)

Evidence profiles were created for each PICO using the GRADEpro GDT software (GRADEpro Guideline Development Tool, McMaster University, 2015, gradepro.org). All members of the committee voted on the proposed recommendations via teleconference.

The „evidence to decision" framework was utilized by the panel for each PICO. This took into consideration the quality of evidence, relationship of benefits and harms, patient values and preferences (as represented by panel participants) and resource utilization when arriving at a recommendation.

PICOs 1 and 4 are diagnostic questions so the recommendations are presented for low, moderate, and high-risk groups.

RESULTS FOR CT CYSTOGRAPHY VS. NO CYSTOGRAPHY (PICO 1):

Qualitative Synthesis

Radiographic detection of bladder injury can be performed by retrograde filling of the bladder with contrast followed by plain film imaging and post-drainage films (plain film cystography) or retrograde filling of the bladder with contrast followed by CT imaging (CT cystography). Four studies (two prospective cohort and two retrospective cohort) assessed the utility of retrograde CT cystography in diagnosing bladder rupture in patients sustaining blunt abdominopelvic trauma, and the data from these studies pooled to determine the overall sensitivity and specificity in diagnosing bladder injury.(6-9) In the prospective study by Quagliano et al., CT cystography was found to have equivalent sensitivity (95%) and specificity (100%) as plain film cystography at detecting the presence or absence of bladder injury.(7) Chan et al. performed a retrospective review and compared CT cystography to intraoperative findings, clinical follow-up, or both, and the sensitivity and specificity of CT cystography in diagnosing bladder rupture were each 100%.(9) Deck et al. performed a retrospective review of 316 patients who underwent CT cystography and compared the radiographic findings to operative findings.(6) The overall sensitivity and specificity of CT cystography in diagnosing bladder rupture was found to be 95% and 100%, respectively. In the prospective series by Peng et al., 55 patients with hematuria and blunt abdominal trauma were screened with CT cystography, and five were identified with bladder injuries that were confirmed intraoperatively.(8) The 50 patients with negative CT cystograms underwent conventional cystography and no other bladder injuries were diagnosed, giving CT cystography a sensitivity of 100% and specificity of 100% at diagnosing bladder injury.

Two studies (one retrospective cohort and one prospective cohort) were used to determine the incidence of bladder rupture in three groups of patients: low risk (pelvic fracture and microhematuria); medium risk (gross hematuria), and high risk, (gross hematuria and pelvic fracture) risk groups.(10, 11) The study performed by Morey et al., was a systematic review of a contemporary retrospective series of patients with blunt bladder trauma. The prevalence of bladder rupture in patients with pelvic fracture and microhematuria (low likelihood group) was 0.6%, while the prevalence of bladder rupture in patients with pelvic fracture and gross hematuria (high likelihood group) was 29%. In the study by Brewer et al., patients sustaining blunt abdominopelvic trauma with hematuria were prospectively evaluated, and the incidence of bladder rupture in patients with gross hematuria (moderate likelihood group) was 21%. The pooled sensitivity and specificity analysis for CT cystography was then applied to determine the utility of retrograde CT cystography for each of these likelihood groups.

Quantitative Synthesis

In the four studies (including a total of 817 patients) used to calculate the sensitivity and specificity of CT cystography, the pooled overall sensitivity was 0.965 (95% CI: 0.90-0.99) and specificity was 1.00 (95% CI: 0.99-1.00).(6-9) (Figure 2)

When the pooled sensitivity and specificity of CT cystography is applied to the low likelihood (0.6%) of bladder injury group, 6 out of 1000 people would be correctly diagnosed as having a bladder rupture (true positive). None of the patients would be incorrectly diagnosed as not having a bladder rupture (false negative), 994/1000 would be correctly diagnosed as not having a bladder rupture (true negative), and none of the patients would be incorrectly classified as having a bladder rupture (false positive) (see Figure, Supplemental Digital Content 1, http://links.lww.com/TA/B240).

For the moderate likelihood group (21.3%), 206 out of 1000 people would be diagnosed correctly as having a bladder rupture (true positive). Seven patients would be diagnosed incorrectly as not having a bladder rupture (false negative) and 787 out of 1000 would be diagnosed correctly as not having a bladder rupture (true negative).None of the patients would be classified incorrectly as having a bladder rupture (false positive) (see Figure, Supplemental Digital Content 2, http://links.lww.com/TA/B241).

For the high likelihood group (29%), 280 people out of 1000 would be diagnosed correctly as having a bladder rupture (true positive). Ten patients would be incorrectly diagnosed as not having a bladder rupture (false negative), 710 would be correctly diagnosed as not having a bladder rupture (true negative), and no patients would be incorrectly classified as having a bladder rupture (false positive) (see Figure, Supplemental Digital Content 3, http://links.lww.com/TA/B242).

Grading the Evidence

The QUADAS-2 evaluation form was used to assess the quality of the diagnostic accuracy study, and risk of bias for the studies was determined to be high.(5) This was because the reference standard test (intraoperative bladder evaluation) was not always interpreted without knowledge of the index test (CT cystography). Additionally, not all patients received the reference standard. The imprecision of the studies was rated as very serious due to the small sample sizes in the included studies. These factors led to the downgrading of the overall certainty of evidence to be very low (Figure 3).

Recommendations

Based on the evidence, the panel makes the following three recommendations based on three groups of patients with different baseline risks.

1A: In low risk patients (microscopic hematuria only), we conditionally recommend no radiography versus routine retrograde CT cystography to diagnose bladder rupture (conditional recommendation based on very low-quality evidence).

The panel judged that the low likelihood of bladder ruptures in this group did not warrant the additional radiation exposure and cost associated with performing CT cystography. The 95% confidence interval for the false positives in this group ranges from 0-5, meaning that up to 5 patients per 1000 could possibly be falsely diagnosed with a bladder rupture, which may result in an unnecessary operation.

1B: In moderate risk patients (gross hematuria) we recommend CT cystography versus no radiography to diagnose bladder rupture (strong recommendation for based on very low-quality evidence).

The panel makes this recommendation based on the higher likelihood of bladder rupture. Two hundred and six of 1000 patients would be diagnosed with a true bladder injury in the moderate-risk group, which would place many patients at risk for potential complications that can result from an undiagnosed bladder injury if imaging is not performed. The downside to imaging is minimal as 0 per 1000 patients would be incorrectly diagnosed with a bladder injury and only 7 per 1000 would be falsely diagnosed as not having a bladder injury.

1C: In high risk patients (gross hematuria and pelvic fracture), we recommend CT cystography versus no radiography to diagnose bladder rupture (strong recommendation based on very low-quality evidence).

The panel makes this recommendation based on the higher likelihood of bladder rupture. Two hundred and eighty out of 1000 patients would be diagnosed with bladder injury in the high-risk group, which would place many patients at risk for potential complications that can result from an undiagnosed bladder injury if imaging is not performed. The downside to imaging is minimal as 0 per 1000 patients would be incorrectly diagnosed with a bladder injury and only 10 per 1000 would be falsely diagnosed as not having a bladder injury.

CT cystography has the same sensitivity and specificity at detecting bladder injury as the gold standard plain film cystography. The committee recommends that the clinician may choose either imaging modality to diagnose bladder injury based on patient condition, imaging requirements for other associated injuries, and equipment availability. Interpreting CT cystography could be less affected by overlying bone fragments caused by pelvic fracture, spine boards, or military anti-shock trousers that may be present on the patient in the initial evaluation of the trauma patient.

RESULTS FOR OPERATIVE VS. NONOPERATIVE MANAGEMENT OF INTRAPERITONEAL BLADDER RUPTURE (PICO 2):

Qualitative Synthesis

Current practice patterns for the management of intraperitoneal bladder rupture after blunt abdominal trauma involves operative repair of the injury to prevent extravasation of urine into the peritoneal cavity that can lead to peritonitis, elevated serum creatinine, azotemia, and death.(12-14) While there are very small case series describing successful non-operative management of small intraperitoneal bladder ruptures (15, 16), the majority of the body of evidence advocates for repair of intraperitoneal bladder injuries to prevent complications related to the injury.

There were no direct comparative studies addressing PICO 2. However, two retrospective cohort studies were identified which contained a subset of patients who underwent surgical repair and had reported outcomes. (17, 18) Neither study reported on the critical outcomes of overall survival or infectious complications. Data reported for urine leak rates on the first follow-up cystogram were used as a surrogate for the critical outcome of successful bladder closure and were pooled to determine overall success rates. Significant limitations to the data existed due to lack of direct comparison groups, heterogeneity of the populations, non-standardized study designs, and incomplete reporting of complications. In the study by Corriere et al. (17), 34 out of 34 patients with intraperitoneal bladder rupture who underwent surgical repair had successful bladder closure at the time of the first follow-up cystogram. In Inaba et al.(18), 30 out of 30 patients with intraperitoneal rupture who underwent surgical bladder repair had successful bladder repair at the time of the follow-up cystogram. Thus, when an intraperitoneal bladder rupture was surgically repaired there was a 100% successful bladder repair rate.

Regarding non-operative management of intraperitoneal bladder injuries, four case reports that contained seven patients combined were identified (15, 16, 19, 20). All of the isolated intraperitoneal bladder injuries were managed successfully with catheter drainage.

While both operative and non-operative management strategies appear to have very high success rates, patients with bladder rupture can have high rates of morbidity. This has led to the current standard of practice to repair intraperitoneal bladder injuries to prevent the complications that can lead to mortality (21, 22).

Quantitative Synthesis

Meta-analysis was not possible due to lack of direct comparison between groups, heterogeneity of the populations, non-standardized study designs, and incomplete reporting of complications among the articles.

Grading the Evidence

The data addressing PICO 2 was derived from retrospective and observational studies that provided low quality evidence.(4) Significant limitations to the data existed due to lack of direct comparison groups, heterogeneity of the populations, non-standardized study designs, and incomplete reporting of complications. Additionally, the imprecision of the studies was rated very serious due to the small sample sizes in the included studies. These factors led to the downgrading of the overall certainty of evidence to be very low.

Recommendations

2: In patients sustaining blunt abdominopelvic trauma with intraperitoneal bladder rupture, we recommend operative management over non-operative management to decrease complications from the bladder injury (strong recommendation based on very low-quality evidence).

Despite the overall certainty of evidence being very low, this recommendation is based on the panel members‟ judgment that the benefits of treatment clearly outweigh the harms, patient values and preferences are well understood and are largely consistent (i.e., most patients would likely choose to undergo operative repair to prevent complications such as peritonitis, fistula formation, and infectious complications).

RESULTS FOR OPERATIVE VS. NONOPERATIVE MANAGEMENT OF EXTRAPERITONEAL BLADDER RUPTURE (PICO 3):

Qualitative Synthesis

Five retrospective studies fulfilled criteria for PICO 3.(18, 23-26) None of the included studies differentiated between simple and complex extraperitoneal bladder ruptures. Simple extraperitoneal bladder ruptures are defined as a single, full-thickness tear in the bladder wall resulting in spillage of urine into the extraperitoneal space, and any other concomitant bladder injury would be classified as a complex extraperitoneal bladder rupture. Wirth et al. (23) was the only paper that reported any infectious complications for the operative repair group. In the pooled group of patients across all studies, there were three patients in the operative group that developed a peri-vesical abscess after surgical repair of the bladder. In the pooled non-operative intervention group, four patients developed sepsis secondary to urinary tract infections, one patient developed a peri-vesical abscess, one patient developed infected pelvic hardware, and one patient developed osteomyelitis of the pubis.

Non-operative management of bladder injuries resulted in a low rate (2.4%) of ultimate operative intervention to repair the bladder. The harm in the operative group was the need for the operative intervention. Therefore, the vast majority of patients with a simple extraperitoneal bladder rupture may be able to avoid an operation to repair the bladder. In contrast, current guidelines on the management of complex extraperitoneal bladder injuries from the American Urological Association recommends that these injuries be surgically repaired.(27) This recommendation was derived from the observation from case series demonstrating that complications (i.e persistent bladder leak, abscess formation, fistula formation) from extraperitoneal bladder injuries that were managed non-operatively were present in patients with injuries characterized as complex (i.e. bone spicules protruding into bladder lumen, concomitant rectal or vaginal lacerations, or injuries involving the bladder neck).(18, 24, 28-30)

Quantitative Synthesis

Five retrospective studies met criteria for quantitative analysis, and the critical outcomes were analyzed (Figure 4). (18, 23-26). No studies reported on the critical outcome of overall survival. There was no difference in infectious complications between groups (risk ratio [RR], 1.14 [95% CI, 0.32-4.0; p=0.84]). The ultimate need for operative intervention to repair the bladder was significantly lower in the non-operative intervention group (RR, 0.05 [95% CI, 0.01-0.14; p <0.00001]). Heterogeneity was minimal in the analysis for infectious complications (I^2=0%) and moderate in the analysis for the ultimate need for operative intervention (I^2=39%).

Grading the Evidence

All of the data were from small retrospective case series and observational studies. Significant limitations to the data existed due to lack of direct comparison groups, heterogeneity of the populations, non-standardized study designs, and incomplete reporting of complications. Due to the small sample sizes and event rates in the included studies, the imprecision of the studies was rated very serious. These factors led to the downgrading of the overall certainty of evidence to be very low (Figure 5).

Recommendations

3A: In patients sustaining blunt abdominopelvic trauma with simple extraperitoneal bladder ruptures, we conditionally recommend non-operative management versus operative management to decrease complications from the bladder injury (conditional recommendation against based on very low-quality evidence).

Despite the overall certainty of evidence being very low, the panel members based this recommendation on their judgment that most patients would choose to avoid the possible complications associated with surgical repair if there was a high likelihood of spontaneous bladder healing. Only 2.4% of patients managed non-operatively ultimately required an operation to repair the bladder. However, if in the setting of orthopedic repair of the pelvis, the bladder is to be exposed, the surgeon may consider repairing the bladder injury in the same setting to minimize exposure of the orthopedic hardware to urine.

3B: In patients with complex extraperitoneal injuries, we conditionally recommend operative repair over non-operative management to decrease complications from the bladder injury (conditional recommendation based on very low-quality evidence).

The panel members made this recommendation based on their judgement that most patients would choose to avoid the more severe complications that can result from a persistent bladder leak from these complex injuries. This recommendation is consistent with recommendations from the American Urological Association to repair complex extraperitoneal bladder injuries to avoid prolonged sequelae from the injury.

RESULTS FOR CYSTOGRAPHY VS. NO IMAGING STUDY AFTER BLADDER REPAIR (PICO 4):

In patients who have undergone operative or non-operative management of bladder rupture (P), should cystography (I) versus no imaging study (C), be used to evaluate for bladder closure?

Qualitative Synthesis

The results of the initial follow-up cystogram were evaluated to determine the success of intervention for management of bladder ruptures. The presence or absence of a urine leak was the indicator of the success of bladder closure. Six retrospective studies were used to determine the incidence of urine leakage rates on initial follow-up imaging in low (simple extraperitoneal or intraperitoneal ruptures that are surgically repaired), medium (complex intraperitoneal ruptures that are surgically repaired), and high (simple extraperitoneal bladder rupture managed by catheter drainage) likelihood patient groups.(17, 18, 24-26, 31) Simple intraperitoneal injuries are defined as a single, full-thickness tear in the bladder wall resulting in spillage of urine into the intraperitoneal space, and any additional concomitant bladder injury would be classified as a complex intraperitoneal bladder injury. The pooled sensitivity and specificity for CT cystography from PICO 1 was then applied to each of these groups to determine the utility of retrograde CT cystography in detecting.

There was no standard time frame when the first follow-up cystogram was performed across studies. Time to first cystogram ranged from a mean of 8.6 days (31) to 10-14 days post injury(17, 24, 26).

Quantitative Synthesis

The critical outcomes were the true positives (patients with urine leak), false negatives (patients incorrectly classified as having urine leak), true negatives (patients without urine leak), and false positives (patients incorrectly classified as having urine leak).

For the simple extraperitoneal or intraperitoneal ruptures that are surgically repaired (low likelihood of leak on first follow-up imaging), 0/175 patients demonstrated a urine leak on the first follow-up imaging study. When the pooled sensitivity and specificity of CT cystography is applied to the low likelihood (0.1%) of urine leakage group, 1 person out of 1000 would be correctly diagnosed as having a urine leak (true positive). No patients would be diagnosed incorrectly as not having a urine leak (false negative) and 999 out of 1000 would be correctly diagnosed as not having a urine leak (true negative). No patients would be classified incorrectly as having a urine leak (false positive) (see Figure, Supplemental Digital Content 4, http://links.lww.com/TA/B243). Although no urine leaks were observed in the group on systematic review of the literature, the prevalence rate of 0.1% was used for calculation purposes in the evidence profile table.

For complex intraperitoneal ruptures that are surgically repaired (moderate likelihood of leak on first follow-up imaging), 2/22 patients demonstrated a urine leak on the first follow-up imaging study. When the pooled sensitivity and specificity of CT cystography is applied to the moderate likelihood (9%) of urine leakage group (1,000 people), 87 would be diagnosed correctly as having a urine leak (true positive); 3 would be incorrectly diagnosed as not having a urine leak (false negative); 910 would be diagnosed correctly as not having a urine leak (true negative), and no patients would be classified incorrectly as having a urine leak (false positive) (see Figure, Supplemental Digital Content 5, http://links.lww.com/TA/B244).

For simple extraperitoneal ruptures that are managed non-operatively with catheter drainage (high likelihood of leak on first follow-up imaging), 34/200 patients demonstrated a urine leak on the first follow-up imaging study. When the pooled sensitivity and specificity of CT cystography is applied to the group of patients with a high likelihood (17%) of urine leakage (1,000 patients), 164 would be correctly diagnosed as having a urine leak (true positive); 6 would be incorrectly diagnosed as not having a urine leak (false negative); 830 would be correctly diagnosed as not having a urine leak (true negative), and there would be no patients incorrectly classified as having a urine leak (false positive) (see Figure, Supplemental Digital Content 6, http://links.lww.com/TA/B245).

Grading the Evidence

All included studies were small, retrospective, and observational. The imprecision of the studies was rated very serious due to the small sample sizes and event rates in the included studies. These factors led to the downgrading of the overall certainty of evidence to be very low (Figure 6).

Recommendations

4A: In low risk patients (operative repair of simple intraperitoneal or extraperitoneal bladder ruptures), we conditionally recommend against routine follow-up cystography in the absence of clinical signs or symptoms concerning for urinary leakage (conditional recommendation against based on very low-quality evidence).

The panel makes this recommendation based on the very low prevalence of urine leak in this group. In this risk group, 999 of 1000 patients would unnecessarily undergo a follow-up cystogram to correctly diagnose one bladder leak.

4B: In patients at moderate risk of urine leak on follow-up cystography, (operative repair of complex intraperitoneal bladder ruptures), we recommend follow-up cystography versus no follow-up cystography to evaluate for successful bladder closure (strong recommendation based on very low-quality evidence).

In this risk group, routine follow-up cystography in 1000 patients would correctly diagnose 87 of 90 urinary bladder leaks with no false positive results but 3 false negatives. 910 patients would undergo imaging unnecessarily. The panel judged that follow-up cystography would likely result in a large net benefit by averting complications of undiagnosed postoperative leakage.

4C: In patients at high risk for urine leak on follow-up cystography, (non-operative management of simple extraperitoneal bladder ruptures), we recommend follow-up cystography to evaluate for successful bladder closure (strong recommendation based on very low-quality evidence).

In this risk group, routine follow-up cystography in 1000 patients would correctly diagnose 164 urinary bladder leaks with no false positive results but 6 false negatives. 830 patients would undergo imaging unnecessarily. The panel judged that follow-up cystography would likely result in a large net benefit by averting complications of undiagnosed postoperative leakage.

CT cystography has the same sensitivity and specificity at detecting bladder injury as the gold standard plain film cystography. The clinician may consider standard pain film cystography over CT cystography to diagnose urine leak on follow-up imaging due to decreased costs and radiation exposure.

Using these guidelines in clinical practice

These evidence-based guidelines were developed after a thorough review of the literature regarding the evaluation and management of bladder injuries resulting from blunt abdominoperineal trauma. The available evidence is of very low quality indicating that we are uncertain of the findings of the underlying report; future research is likely to change the reported estimates of effect. The GRADE approach provided a transparent process for the qualitative and quantitative of the body of evidence. These guidelines are intended to provide information to use in the decision-making process and should not replace clinical judgment.

Conclusion

Using the GRADE process, the panel makes nine recommendations based on 4 PICO questions concerning the evaluation and management of blunt force bladder injuries (Figure 7). Several recommendations are made. The need for initial CT cystography after trauma depends on characteristics of the trauma itself, but is not recommended in patients without gross hematuria. In general, patients with intraperitoneal bladder ruptures should undergo operative repair, while this is not routinely necessary in those with extraperitoneal ruptures, unless the injury is complex. The need for follow-up cystography after bladder repair depends on the risk of urine leak, with those having a low risk of urine leak not requiring a follow-up study.

Author Contribution

L.L.Y. and P.D. conceived the study.

L.L.Y. created the PICO questions. All listed authors assisted with finalizing the PICO questions and voted on the outcomes of interest for these PICO questions.

L.L.Y. and M.E. performed the entire literature search. L.L.Y., P.D., B.R., J.K.L., A.A.M., J.K., and J.J.C. read the abstracts and selected the articles for review. L.L.Y. reviewed and summarized the selected articles.

L.L.Y. and P.D. extracted the data from the selected articles. L.L.Y. and P.D. entered the extracted data into the RevMan and GRADEpro programs and evaluated the results for recommendations.

L.L.Y. wrote the manuscript. All authors participated in the critical review of all versions of this article.

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Conflict of Interest:

The authors declare no conflict of interest.

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Figure Legend

Figure 1- PRISMA Flow Diagram

Figure 2- Pooled sensitivity/specificity of CT cystography

Figure 3- Evidence Profile Table PICO 1

Figure 4- Meta-analysis PICO 3

Figure 5- Evidence Profile Table PICO 3

Figure 6- Evidence Profile Table PICO 4

Figure 7- Summary of Recommendations

SDC Legend

Table, Supplemental Digital Content 1- Search strategy

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Figure, Supplemental Digital Content 2- Moderate likelihood group PICO 1

Figure, Supplemental Digital Content 3- High likelihood group PICO 1

Figure, Supplemental Digital Content 4- Low likelihood group PICO 4

Figure, Supplemental Digital Content 5- Moderate likelihood group PICO 4

Figure, Supplemental Digital Content 6- High likelihood group PICO 4

Figure 1- PRISMA Flow Diagram

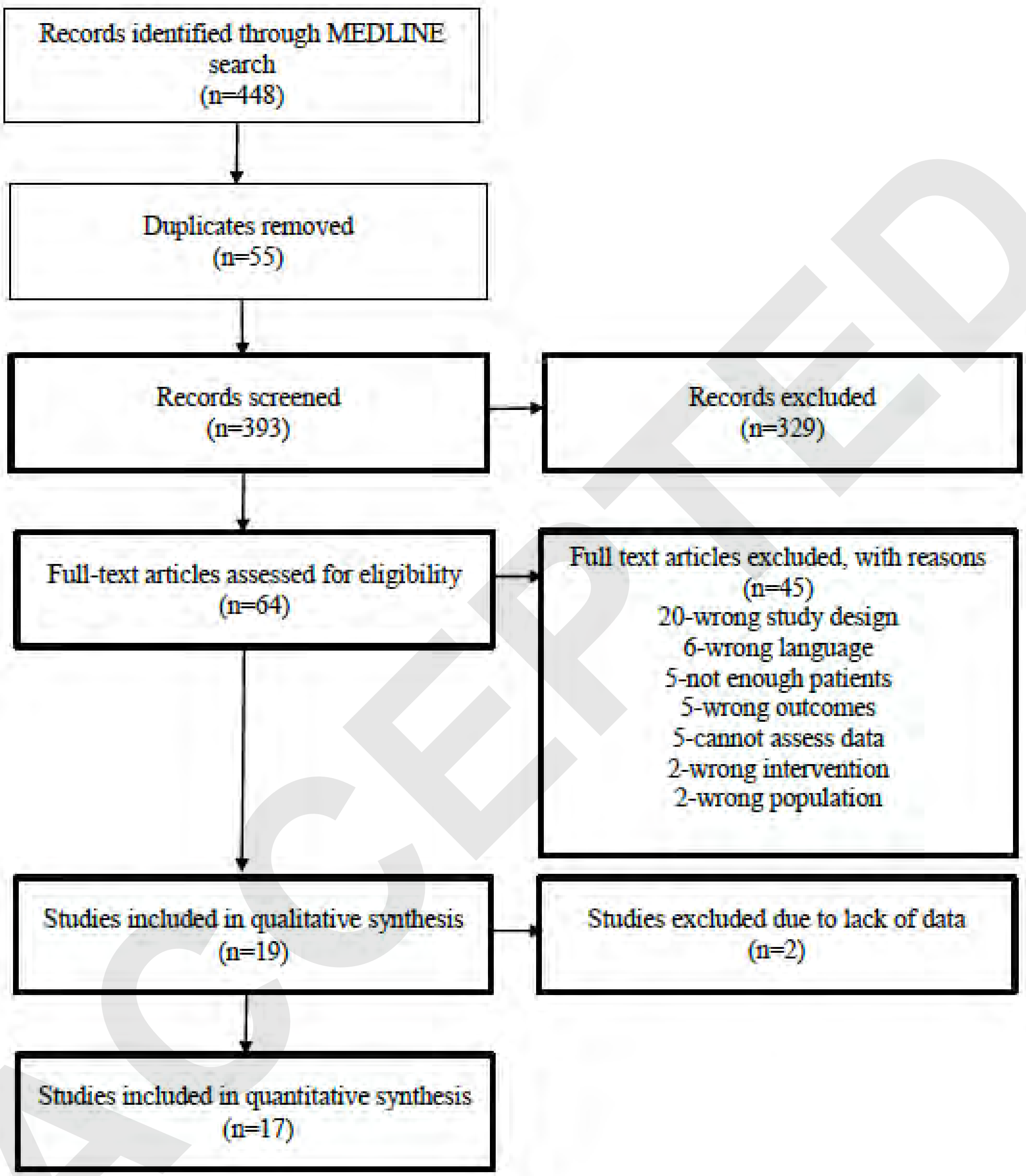


Figure 2- Pooled sensitivity/specificity of CT cystography

Summary Sensitivity

Study	Sens	[95% CI]	TP/(TP+FN)	TN/(TN+FP)
Chan 2006	1.000	0.815 - 1.000	18/18	216/216
Deck 2000	0.955	0.845 - 0.994	42/44	272/272
Peng 1999	1.000	0.478 - 1.000	5/5	50/50
Quagliano 2006	0.947	0.740 - 0.999	18/19	193/193
Pooled Sensitivity	**0.965**	**0.901 - 0.993**		

Heterogeneity chi-squared = 1.92 (d.f.= 3) p = 0.589

Inconsistency (I^2) = 0.0 %

No. studies = 4

Summary Specificity

Study	Spec	[95% CI]	TP/(TP+FN)	TN/(TN+FP)
Chan 2006	1.000	0.983 - 1.000	18/18	216/216
Deck 2000	1.000	0.987 - 1.000	42/44	272/272
Peng 1999	1.000	0.929 - 1.000	5/5	50/50
Quagliano 2006	1.000	0.981 - 1.000	18/19	193/193
Pooled Specificity	**1.000**	**0.995 - 1.000**		

Heterogeneity chi-squared = 0.00 (d.f.= 3) p = 1.000

Inconsistency (I^2) = 0.0 %

No. studies = 4

Figure 3- Evidence Profile Table PICO 1

Sensitivity	0.96 (95% CI: 0.90 to 0.99)
Specificity	1.00 (95% CI: 0.99 to 1.00)

Prevalences	0.6%	21.3%	29%

Outcome	№ of studies (№ of patients)	Study design	Factors that may decrease certainty of evidence					Effect per 1,000 patients tested			Test accuracy CoE
			Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias	pre-test probability of 0.6%	pre-test probability of 21.3%	pre-test probability of 29%	
True positives (patients with bladder rupture)	4 studies 817 patients	cross-sectional (cohort type accuracy study)	serious [a]	not serious	not serious	very serious [a]	none	6 (5 to 6)	206 (192 to 212)	280 (261 to 288)	⨁◯◯◯ VERY LOW
False negatives (patients incorrectly classified as not having bladder rupture)								0 (0 to 1)	7 (1 to 21)	10 (2 to 29)	
True negatives (patients without bladder rupture)	4 studies 817 patients	cross-sectional (cohort type accuracy study)	serious [a]	not serious	not serious	very serious [a]	none	994 (989 to 994)	787 (783 to 787)	710 (706 to 710)	⨁◯◯◯ VERY LOW
False positives (patients incorrectly classified as having bladder rupture)								0 (0 to 5)	0 (0 to 4)	0 (0 to 4)	

Explanations

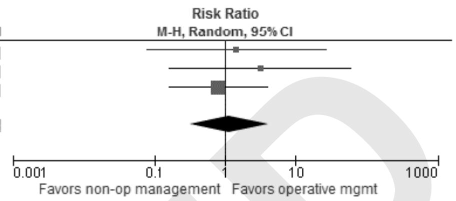
a. QUADAS-2 used to assess risk of bias. Unclear if consecutive patients were enrolled. Case-control design not avoided. Reference standard not interpreted without knowledge of the index test. All patients did not receive the same reference standard.

Figure 4- Meta-Analysis PICO 3

Outcome: Infectious complications

Study or Subgroup	non-operative management Events	non-operative management Total	operative management Events	operative management Total	Weight	Risk Ratio M-H, Random, 95% CI
Kotkin (1995)	2	27	0	7	18.3%	1.43 [0.08, 26.83]
Johnsen (2016)	3	56	0	24	18.4%	3.07 [0.16, 57.25]
Wirth (2010)	2	10	3	12	63.2%	0.80 [0.16, 3.88]
Total (95% CI)		**93**		**43**	**100.0%**	**1.14 [0.32, 4.01]**
Total events	7		3			

Heterogeneity: Tau² = 0.00; Chi² = 0.69, df = 2 (P = 0.71); I² = 0%
Test for overall effect: Z = 0.20 (P = 0.84)



Outcome: Need for operative bladder repair

Study or Subgroup	non-operative management Events	non-operative management Total	operative management Events	operative management Total	Weight	Risk Ratio M-H, Random, 95% CI
Inaba (2006)	0	37	2	2	12.1%	0.02 [0.00, 0.26]
Corriere (1986)	0	39	9	9	12.3%	0.01 [0.00, 0.21]
Wirth (2010)	0	10	12	12	12.7%	0.05 [0.00, 0.71]
Johnsen (2016)	1	56	24	24	25.6%	0.03 [0.01, 0.13]
Kotkin (1995)	3	27	7	7	37.4%	0.13 [0.05, 0.36]
Total (95% CI)		**169**		**54**	**100.0%**	**0.05 [0.01, 0.14]**
Total events	4		54			

Heterogeneity: Tau² = 0.59; Chi² = 6.55, df = 4 (P = 0.16); I² = 39%
Test for overall effect: Z = 5.50 (P < 0.00001)

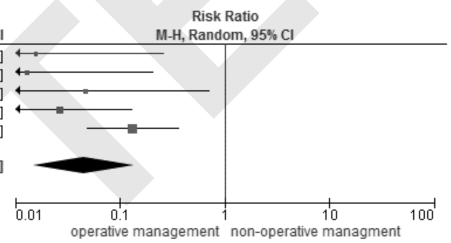


Figure 5. Evidence Profile Table PICO 3

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	non-operative management with urinary drainage	operative bladder repair	Relative (95% CI)	Absolute (95% CI)		
Need for operative bladder repair												
5	observational studies	serious [a]	not serious	not serious	very serious [a]	none	4/169 (2.4%)	54/54 (100.0%)	**RR 0.05** (0.01 to 0.14)	**950 fewer per 1,000** (from 860 fewer to 990 fewer)	⨁◯◯◯ VERY LOW	CRITICAL
Infectious complications												
3	observational studies	serious [a]	not serious	not serious	very serious [b,c]	none	7/93 (7.5%)	3/43 (7.0%)	**RR 1.14** (0.32 to 4.01)	**10 more per 1,000** (from 47 fewer to 210 more)	⨁◯◯◯ VERY LOW	CRITICAL

CI: Confidence interval; **RR:** Risk ratio

Explanations

a. Downgrade based on Newcastle Ottawa Scale used to assess risk of bias
b. Wide pooled confidence interval
c. Small number of events

Figure 6- Evidence Profile Table PICO 4

Sensitivity	0.96 (95% CI: 0.90 to 0.99)
Specificity	1.00 (95% CI: 0.99 to 1.00)

Prevalences	0.1%	9%	17%

Outcome	№ of studies (№ of patients)	Study design	Factors that may decrease certainty of evidence					Effect per 1,000 patients tested			Test accuracy CoE
			Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias	pre-test probability of 0.1%	pre-test probability of 9%	pre-test probability of 17%	
True positives (patients with urine leak)	6 studies 397 patients	case-control type accuracy study	serious a,b	not serious	not serious	very serious a,b	none	1 (1 to 1)	87 (81 to 89)	164 (153 to 169)	⊕◯◯◯ VERY LOW
False negatives (patients incorrectly classified as not having urine leak)								0 (0 to 0)	3 (1 to 9)	6 (1 to 17)	
True negatives (patients without urine leak)	6 studies 397 patients	cross-sectional (cohort type accuracy study)	serious a,b	very serious	not serious	very serious a,b	none	999 (994 to 999)	910 (905 to 910)	830 (826 to 830)	⊕◯◯◯ VERY LOW
False positives (patients incorrectly classified as having urine leak)								0 (0 to 5)	0 (0 to 5)	0 (0 to 4)	

Explanations

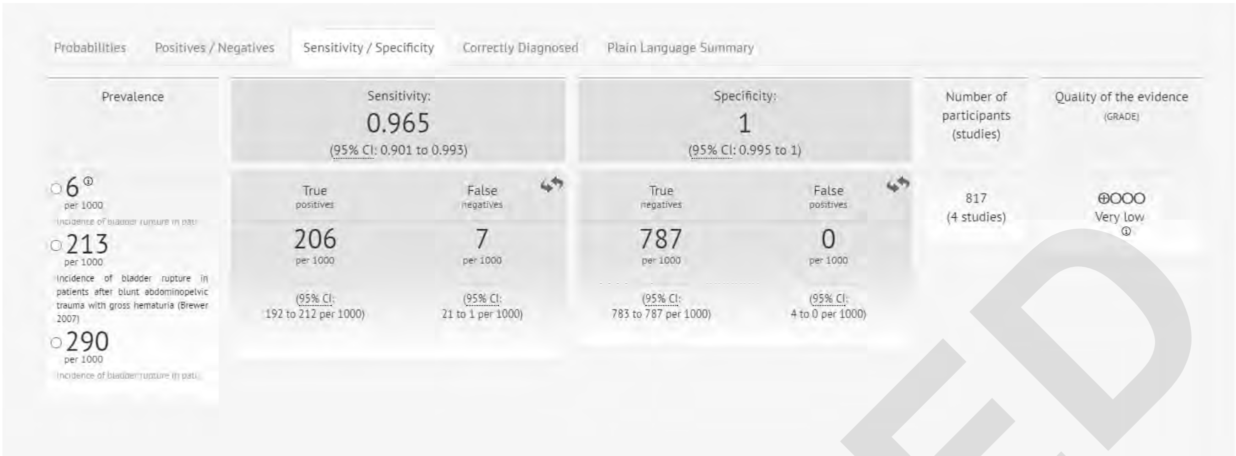
a. Downgrade based on Newcastle-Ottawa Scale used to assess risk of bias
b. Small number of events

Figure 7- Summary of Recommendations

Question	Recommendation
PICO 1	• In low risk patients (microscopic hematuria only), **we conditionally recommend** no radiography versus routine retrograde CT cystography to diagnose bladder rupture. • In moderate risk patients (gross hematuria) **we recommend** CT cystography versus no radiography to diagnose bladder rupture. • In high risk patients (gross hematuria and pelvic fracture), **we recommend** CT cystography versus no radiography to diagnose bladder rupture.
PICO 2	• In patients sustaining blunt abdominopelvic trauma with intraperitoneal bladder rupture, **we recommend** operative management over non-operative management to decrease complications from the bladder injury.
PICO 3	• In patients sustaining blunt abdominopelvic trauma with simple extraperitoneal bladder ruptures, **we conditionally recommend** non-operative management versus operative management to decrease complications from the bladder injury. • In patients with complex extraperitoneal injuries, **we conditionally recommend** operative repair over non-operative management to decrease complications from the bladder injury.
PICO 4	• In low risk patients (operative repair of simple intraperitoneal or extraperitoneal bladder ruptures), **we conditionally recommend against** routine follow-up cystography in the absence of clinical signs or symptoms concerning for urinary leakage. • In patients at moderate risk of urine leak on follow-up cystography, (operative repair of complex intraperitoneal bladder ruptures), **we recommend** follow-up cystography versus no follow-up cystography to evaluate for successful bladder closure. • In patients at high risk for urine leak on follow-up cystography, (non-operative management of simple extraperitoneal bladder ruptures), **we recommend** follow-up cystography to evaluate for successful bladder closure.

Figure, Supplemental Digital Content 1- Low likelihood group PICO 1

Figure, Supplemental Digital Content 2- Moderate likelihood group PICO 1

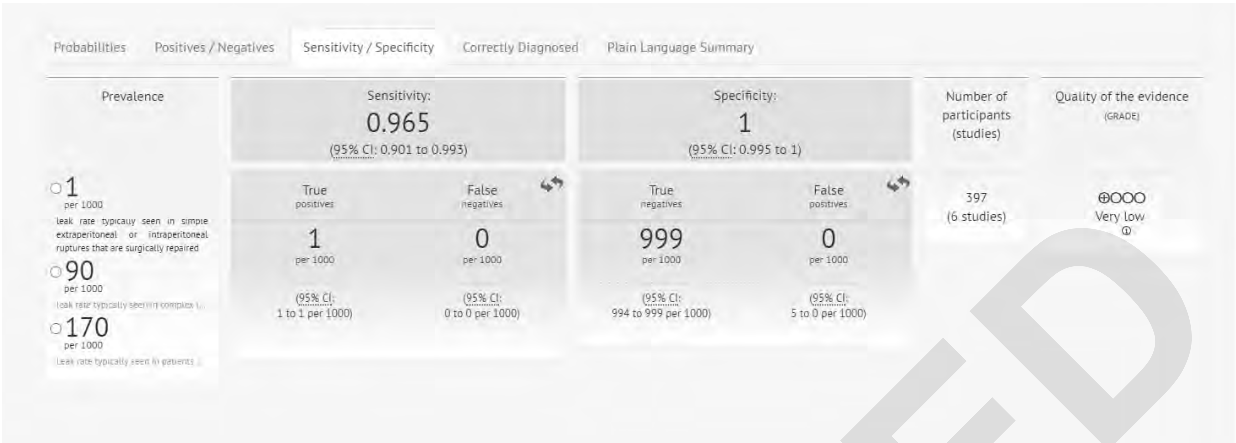


Figure, Supplemental Digital Content 3- High likelihood group PICO 1

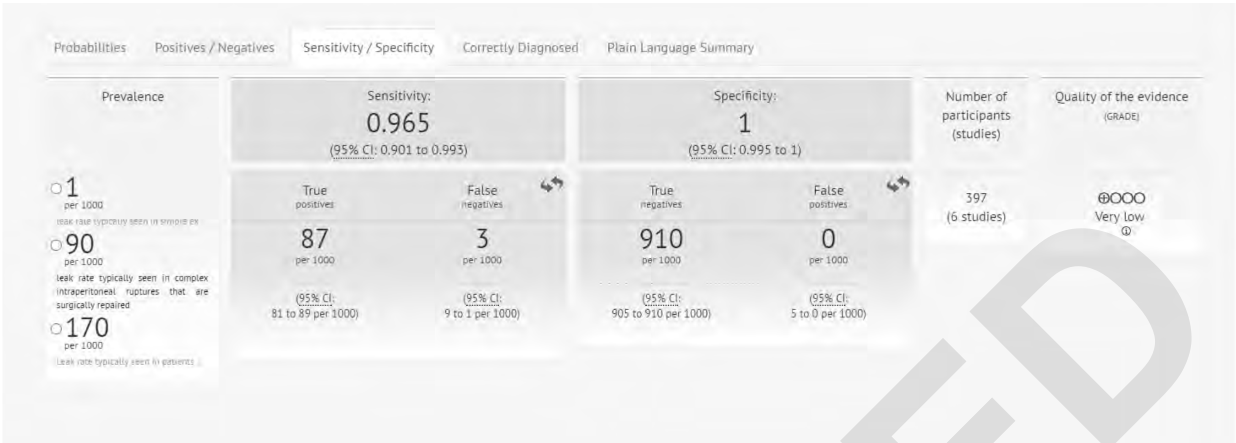
Probabilities | Positives / Negatives | Sensitivity / Specificity | Correctly Diagnosed | Plain Language Summary

Prevalence	Sensitivity: 0.965 (95% CI: 0.901 to 0.993)		Specificity: 1 (95% CI: 0.995 to 1)		Number of participants (studies)	Quality of the evidence (GRADE)
	True positives	False negatives	True negatives	False positives		
6 per 1000 Incidence of bladder rupture in pati 213 per 1000 Incidence of bladder rupture in pati 290 per 1000 Incidence of bladder rupture in patients after blunt abdominopelvic trauma with gross hematuria and pelvic fracture (Morey 2001)	280 per 1000 (95% CI: 261 to 288 per 1000)	10 per 1000 (95% CI: 29 to 2 per 1000)	710 per 1000 (95% CI: 706 to 710 per 1000)	0 per 1000 (95% CI: 4 to 0 per 1000)	817 (4 studies)	⊕○○○ Very low

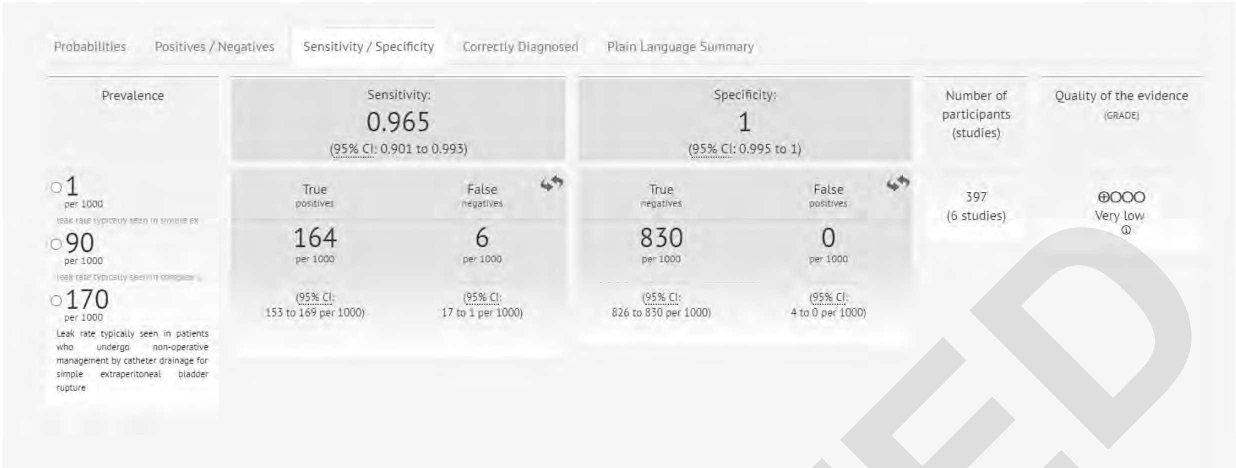
Figure, Supplemental Digital Content 4- Low likelihood group PICO 4



Figure, Supplemental Digital Content 5- Moderate likelihood group PICO 4



Figure, Supplemental Digital Content 6- High likelihood group PICO 4



Table, Supplemental Digital Content 1- Search strategy

PICO 1	"Wounds, Nonpenetrating"[Mesh] AND "Urinary Bladder/injuries"[Mesh]) OR ("bladder injury" OR bladder injuries") AND ("Diagnostic Imaging"[Mesh] OR ("Radiography"[Mesh] OR cystography[All Fields] OR cystogram AND retrograde [All Fields] AND "ct" [All Fields] OR "computed tomography"[All Fields])
PICO 2	((("Therapeutics"[Mesh] OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR ("surgery"[Subheading] OR "surgery"[All Fields] OR "surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND "procedures"[All Fields] AND "operative"[All Fields]) OR "operative surgical procedures"[All Fields] OR "surgery"[All Fields] OR "general surgery"[MeSH Terms] OR ("general"[All Fields] AND "surgery"[All Fields]) OR "general surgery"[All Fields])) OR "Surgical Procedures, Operative"[Mesh]) AND (("Urinary Bladder"[Mesh] AND "Rupture, Spontaneous"[MeSH Terms]) OR ("urinary bladder rupture"[All Fields] OR "bladder rupture"[All Fields]))) AND (intraperitoneal[All Fields] OR intra-peritoneal[All Fields] OR "intra peritoneal"[All Fields])
PICO 3	((("Therapeutics"[Mesh] OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR ("surgery"[Subheading] OR "surgery"[All Fields] OR "surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND "procedures"[All Fields] AND "operative"[All Fields]) OR "operative surgical procedures"[All Fields] OR "surgery"[All Fields] OR "general surgery"[MeSH Terms] OR ("general"[All Fields] AND "surgery"[All Fields]) OR "general surgery"[All Fields])) OR "Surgical Procedures, Operative"[Mesh]) AND (("Urinary Bladder"[Mesh] AND "Rupture, Spontaneous"[MeSH Terms]) OR ("urinary bladder rupture"[All Fields] OR "bladder rupture"[All Fields]))) AND (extraperitoneal[All

	Fields] OR extra-peritoneal[All Fields] OR "extra peritoneal"[All Fields])
PICO 4	(("Urinary Bladder/injuries"[Mesh] OR "urinary bladder injuries"[All Fields] OR "urinary bladder injury"[All Fields] OR "bladder injuries"[All Fields] OR "bladder injury"[All Fields]) AND ("Radiography"[Mesh] OR ("cystography"[MeSH Terms] OR "cystography"[All Fields]) OR (retrograde[All Fields] AND ("contraindications"[Subheading] OR "contraindications"[All Fields] OR "ct"[All Fields])))) AND (intraperitoneal[All Fields] OR intra-peritoneal[All Fields] OR "intra peritoneal"[All Fields]) (("Urinary Bladder/injuries"[Mesh] OR "urinary bladder injuries"[All Fields] OR "urinary bladder injury"[All Fields] OR "bladder injuries"[All Fields] OR "bladder injury"[All Fields]) AND ("Radiography"[Mesh] OR ("cystography"[MeSH Terms] OR "cystography"[All Fields]) OR retrograde[All Fields] AND "contraindications"[Subheading] OR "contraindications"[All Fields] OR "ct"[All Fields])))) AND (extraperitoneal[All Fields] OR extra-peritoneal[All Fields] OR "extra peritoneal"[All Fields])