Prevalence of microhematuria in renal colic and urolithiasis: a systematic review and meta-analysis

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Abstract

Background This systematic review and meta-analysis aims to investigate the prevalence of microhematuria in patients presenting with suspected acute renal colic and/or confirmed urolithiasis at the emergency department.

Methods A comprehensive literature search was conducted to find relevant data on prevalence of microhematuria in patients with suspected acute renal colic and/or confirmed urolithiasis. Data from each study regarding study design, patient characteristics and prevalence of microhematuria were retrieved. A random effect-model was used for the pooled analyses.

Results Forty-nine articles including 15,860 patients were selected through the literature search. The pooled microhematuria prevalence was 77% (95%CI: 73-80%) and 84% (95%CI: 80-87%) for suspected acute renal colic and confirmed urolithiasis, respectively. This proportion was much higher when the dipstick was used as diagnostic test (80% and 90% for acute renal colic and urolithiasis, respectively) compared to the microscopic urinalysis (74% and 78% for acute renal colic and urolithiasis, respectively).

Conclusions This meta-analysis revealed a high prevalence of microhematuria in patients with acute renal colic (77%), including those with confirmed urolithiasis (84%). Intending this prevalence as sensitivity, we reached moderate values, which make microhematuria alone a poor diagnostic test for acute renal colic or urolithiasis. Microhematuria could possibly still important to assess the risk in patients with renal colic.

1. Background

Renal colic is caused by the presence of stones in the urinary tract and it is characterized by sudden onset of severe loin pain, radiating to the flank, groin, and testes or labia majora [1]. Incidence amounts to 240 per 100,000 persons [2] with a prevalence up to 10%; men are commonly more affected than women with a ratio of 3-2:1 [3]. Lifetime risk is up to 19% in men and 9% in women [4], varying depending on geographic location and increasing constantly over last years [5]. Guidelines for the diagnostic pathway suggest assessing (micro)hematuria, while the gold standard of imaging is unenhanced multi-detector computed tomography (MDCT) [1]. As diagnostic tool the STONE Score was developed and validated; this score includes parameters as sex, duration of pain prior to presentation, race, nausea, vomiting and microhematuria [6]. Microhematuria prevalence in suspected renal colic has been studied in several trials, ranging from 55% [7] to 93% [8, 9]. In order to better understand the difference existing in prevalence range, we performed a meta-analysis of studies dealing with microhematuria by suspected acute renal colic and/or confirmed urolithiasis.

2. Methods

This systematic review and meta-analysis conforms to the statement on Preferred Reporting Items for Systematic reviews and Meta-Analyses [10].

2.1 Search strategy

A literature search of the electronic PubMed/MEDLINE database and Cochrane Central Register of Controlled Trials (CENTRAL), without language restriction, was carried out from inception to October 11, 2018. A search algorithm was established using a combination of the following terms: A) renal colic AND urolithiasis (Problem), B) urinalysis
(Intervention), C) microhematuria (Outcome). The final search query is reported in Appendix 1. Reference lists of the retrieved articles were also screened for additional studies.

2.2 Eligibility criteria

We included in this systematic review and meta-analysis studies which filled the following inclusion criteria: a) original article published in peer-reviewed journal; b) studies including adults only; c) patients presenting with acute renal colic at the emergency department; d) studies reporting data on microhematuria.

Exclusion criteria were: a) articles not within the field of interest of this review; b) review articles, letters or editorials; c) case reports or case series (less than 10 patients included); d) articles with possible patient data overlap.

2.3 Study selection

Titles and abstracts of the retrieved studies were independently reviewed by two researchers (MP, GT), applying the inclusion and exclusion criteria mentioned above. Articles were rejected if they were clearly ineligible. The full texts of the potentially eligible articles were reviewed independently by the same researchers to confirm or exclude their eligibility for inclusion. Disagreements were resolved in a consensus meeting.

2.4 Data extraction

For each included study, one author (MP) manually extracted data relevant to the review aims using a customized form. Information regarding basic study data (authors, year of publication, country of origin, type of study), patient characteristics (number of patients, mean age, gender), methods (microhematuria test, microhematuria definition) and outcomes (number of patients with microhematuria, microhematuria prevalence) were retrieved. The number of patients with microhematuria and microhematuria prevalence were also extracted for patients with confirmed urolithiasis, where available. Diagnostic methods for detection of stones were also retrieved. One other author (GT) independently checked all extracted data.

2.5 Outcome measures

The primary outcome was the percentage of microhematuria among patients presenting with suspected acute renal colic at the emergency department. The secondary outcome was the percentage of microhematuria among patients presenting with acute renal colic and confirmed urolithiasis at the emergency department.

2.6 Quality assessment

The overall quality of the studies included in the systematic review was critically appraised based on the revised “Quality Assessment of Diagnostic Accuracy Studies” tool (QUADAS-2). This tool comprises four domains: patient selection, index test, reference standard, and flow and timing. Each domain was assessed in terms of risk of bias, and the first three domains were also assessed in terms of concerns regarding applicability. Two authors have performed the risk of bias assessment (GT and MP) reaching a consensus.

2.7 Statistical analysis

Microhematuria prevalence was defined as the ratio between the number of patients with suspected acute renal colic with microhematuria detected by urinalysis or dipstick and the total number of patients with suspected acute
renal colic who underwent the analysis. This proportion was calculated also for patients presenting with acute renal colic and confirmed urolithiasis.

Pooled analyses of the proportion of microhematuria detected by urinalysis or dipstick were performed using data retrieved from the selected studies. When microhematuria was assessed using both urinalysis and dipstick, the test with the better outcome was chosen. Subgroup analyses taking into account the microhematuria test were planned.

A random-effects model was used for statistical pooling of the data, taking into account the heterogeneity between studies. The different weight of each study in the pooled analysis was related to the different sample size. Pooled data were presented with their respective 95% confidence interval (95%CI) values, and data were displayed using plots.

Heterogeneity was estimated by using the I-square index ($I^2$), which describes the percentage of variation across studies that is due to heterogeneity rather than chance [11] and considered significant if I-square test was higher than 50%.

Publication bias was assessed through the Egger’s test [12].

Statistical analyses were performed using the StatsDirect software version 3 (StatsDirect Ltd., Cambridge, UK).

3. Results

3.1 Literature search

The literature search from PubMed/MEDLINE and Cochrane CENTRAL databases yielded a total of 1,377 records. After reviewing titles and abstracts, 77 were selected as potentially eligible articles. The full text was retrieved for all. Following eligibility’s assessment, 31 articles did not meet the inclusion criteria and were excluded from the systematic review. Within the selected articles, screening of the reference lists allowed to add 3 additional records. Finally, 49 studies [7-9, 13-58] including 15,860 patients were identified as potentially relevant and were selected for the systematic review and meta-analysis. All of the included studies except two [30, 50] were published in English. These studies covered the period from inception to October 11, 2018. Search results and articles’ selection are displayed in a PRISMA flow chart (Figure 1).

3.2 Selected studies

The characteristics of selected studies are reported in Table 1. The studies were conducted in different countries worldwide (Europe, North America, Asia, Africa). The sample size of the included trials ranged from 32 to 2,218 adults presenting to the emergency department or urology clinic with acute renal colic. Most of the studies were observational with a prospective (19) or retrospective (29) or mixed (1) design.

Microhematuria was tested by urinalysis in 32 studies, urine dipstick in 10 and both methods in 7. Definition of microhematuria was different among the included studies. Six studies included also patients presenting with macroscopic hematuria [14, 17, 19, 22, 26, 50]. Details on the microhematuria test are reported in Table 2.

3.3 Quality assessment
Overall quality assessment of the studies included in the systematic review according to QUADAS-2 tool is reported in Supplemental Figure 1.

3.4 Microhematuria prevalence and suspected acute renal colic

Primary outcome characteristics on microhematuria prevalence in patients with suspected acute renal colic are summarized in Table 2 and Figure 2.

Prevalence of microhematuria ranged from 35% to 94%, with a pooled estimate of 77% (95%CI: 73-80%) (Figure 2). The heterogeneity among the included studies was significant ($I^2 = 96\%$). A publication bias was detected by Egger’s test ($p < 0.0001$).

Performing sub-group analyses taking into account different microhematuria tests, the pooled prevalence of microhematuria using urinalysis or urine dipstick was 74% (95%CI: 69-78%) and 80% (95%CI: 74-86%) respectively, without significant difference between two groups.

3.5 Microhematuria prevalence and confirmed urolithiasis

Secondary outcomes regarding main findings on microhematuria prevalence in patients with acute renal colic and confirmed urolithiasis are summarized in Table 3 and Figure 3.

Prevalence of microhematuria ranged from 44% to 100%, with a pooled estimate of 84% (95%CI: 80-87%) (Figure 3). Heterogeneity among the included studies was significant ($I^2 = 93\%$). A publication bias was detected by Egger’s test ($p = 0.0008$).

Performing sub-group analyses taking into account different microhematuria tests, the pooled prevalence of microhematuria using urinalysis or urine dipstick was 78% (95%CI: 74-82%) and 90% (95%CI: 83-95%), respectively.

4. Discussion

Many studies have evaluated the prevalence of microhematuria in patients with suspected acute renal colic (Table 1); this meta-analysis pooled data reported in the published studies to derive a more precise assessment. Overall, this systematic review and meta-analysis revealed a high prevalence of microhematuria in patients with acute renal colic (77%), including those with confirmed urolithiasis (84%). However, intending this prevalence as sensitivity, we reached moderate values, which make microhematuria alone a poor diagnostic test for acute renal colic, respectively for urolithiasis. In our meta-analysis heterogeneity was high; indeed, we found a poor definition regarding urine analysis across studies (see positive microhematuria definition in Table 2), with different cells count on microscopy, but also with various dipstick brands. Argyropoulos et al. [8] carried out a microscopic urinalysis when the dipstick was in doubt or with blood traces; microhematuria was confirmed in all of these cases. Thus, the authors concluded that urinary dipstick test is not inferior to microscopy. Bataille et al. [59] compared the sensitivity of urinary dipstick with microscopy and flow cytometry on in vitro contaminated human urine with human blood of volunteers at different concentrations. Urinary dipstick reached the best sensitivity, probably due to the ability to detect red blood cells after lysis, and was suggested as preferred test for screening of hematuria. Same results were previously reported by Kobayashi et al. [40] and Press et al. [52]. De facto we detected a trend toward a higher pooled prevalence of microhematuria by using urine dipstick compared to microscopic urinalysis. Some studies analyzed the characteristics of patients with renal colic and negative microhematuria, the most
without correlation between size, location or composition of the stones, or grade of the obstruction [44, 52, 55, 57]. Kobayashi et al. [40] found a relation between hematuria and pain onset, with the highest incidence of negative hematuria on day 3 and 4. Kim et al. [13] found negative microhematuria in patients with lower stones or elevated serum blood urea nitrogen (BUN). Mefford et al. [18] showed an increased prevalence of hydronephrosis in patients with urolithiasis and negative microhematuria. As hydronephrosis is easy to screen with ultrasonography, Daniel et al. [60] developed the STONE PLUS Score with addition of point-of-care ultrasound of the kidney to the original STONE Score. Presence of hydronephrosis improved the specificity up to 98% and helped to identify patients requiring urological intervention, without remarkably increasing risk stratification.

Considering the moderate sensitivity of microhematuria in patients with renal colic, Xafis et al. [31] suggested to perform a MDCT without urinalysis as a prerequisite. This approach seems to show the best diagnostic accuracy; however, it would increase the number of MDCT with more costs and radiation exposure. Therefore, the focus should be placed in complicated urolithiasis (e.g., obstructive pyelonephritis) or dangerous alternative diagnosis. Rucker et al. [61] reported numerous diseases mimicking urolithiasis. Moore et al. [6] found a lower likelihood of a dangerous alternative diagnosis (< 2%) by using high STONE scores and suggested for this group the possibility to initially avoid compute tomography because till 90% of stones < 7 mm will pass through spontaneously [62]. With the same approach the American College of Emergency Physicians (ACEP) suggests in the Choosing Wisely group to avoid ordering computed tomography of the abdomen and pelvis in young except healthy emergency department patients (age <50) with known histories of kidney stones, or ureterolithiasis, presenting with symptoms consistent with uncomplicated renal colic [63]. In fact, taking all studies together, the prevalence of patients with renal colic having effectively urolithiasis was 66% (median, IQR 52-76), which means a higher pre-test probability in the studied population and so a good discerning capacity of the treating physicians. Anyway, alternative diagnosis mimicking renal colic have to be taken into account. Commons diagnosis are pyelonephritis, appendicitis, diverticulitis, adnexal cysts/tumor, cholecystitis, lumbago/sciatica. Rarer pneumonia, lymphoma or aortic dissection/aneurysm. However CT scan negative rate reach till 31% [42] and Zwank et al. [27] could show that CT scan didn't change management when providers did not expect it would. Finally, alternative diagnosis mimicking renal colic could be found by ultrasonography at least in one study with the same accuracy as MDCT [64].

Some limitations and biases of our meta-analysis should be taken into account. We have no registered a protocol of the systematic review on a database such as PROSPERO. We included some retrospective studies because of the good data quality. Heterogeneity among studies may represent a potential source of bias in a meta-analysis. This heterogeneity is likely to arise through baseline differences among patients in the included studies (Table 1), or diversity in methodological aspects between different studies (Table 2). Unfortunately, we detected a significant heterogeneity in our meta-analysis. We believe that, beyond the various microhematuria tests (urinalysis vs dipstick), the most important source of heterogeneity could be the different definitions of microhematuria (Table 2). Finally, we found presence of publication bias.

In conclusion, microhematuria searched with urine dipstick showed higher diagnostic sensitivity and should be used in this setting as a “gold standard”; it is needed to calculate the STONE score, which can help to identify patients with decreased likelihood of a differential diagnosis, reducing costs and radiation exposure of MDCT. Finally, the concomitant use of ultrasound could increase the specificity till 98% by hydronephrosis, identify patients requiring urological intervention and help to find alternative diagnosis in each risk group. Especially for searching differential diagnosis with ultrasound in patients with suspected renal colic, further studies should be undertaken. Larger prospective multicenter validation study of the STONE score could provide more definitive evidence.
Declarations

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Availability of data and materials
Not applicable

Competing interests
No competing interests to declare

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Authors’ contribution
Concept: BM, AS. Literature search: MP, GT. Statistical analysis: MP, GT. Data interpretation: MP, GT, BM, AS. Manuscript writing: MP, GT, BM, AS. Critical review and final approval: all authors.

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Tables
Table 1: Basic study and patient characteristics. Patients presenting with acute renal colic at the emergency department.
| Authors                      | Year | Country      | Study design                  | No. of patients | % Male | Mean age ± SD (years) |
|------------------------------|------|--------------|-------------------------------|-----------------|--------|----------------------|
| Kim *et al.* [13]            | 2018 | South Korea  | Retrospective, observational  | 798             | 68.6   | 48.2 ± 13.3          |
| Desai *et al.* [14]          | 2018 | USA          | Retrospective, observational  | 350             | NR     | NR                   |
| Turk and Un [15]*            | 2017 | Turkey       | Prospective, observational    | 516             | 60.5   | 37 ± 20.3            |
| Shrestha *et al.* [16]*       | 2017 | Nepal        | Retrospective, observational  | 201             | 55.2   | 29 ± 13.5            |
| Odoemene *et al.* [17]*      | 2017 | Nigeria      | Prospective, observational    | 69              | 76.8   | 40.4 ± 2.9           |
| Mefford *et al.* [18]        | 2017 | USA          | Retrospective, observational  | 393             | 69     | 45.6 ± 12.55         |
| Rapp *et al.* [19]           | 2016 | USA          | Retrospective, observational  | 613             | 47     | 49 ± 0.6             |
| Park *et al.* [20]           | 2016 | South Korea  | Prospective, RCT              | 103             | 66     | 45.6 ± 12.55         |
| Hernandez *et al.* [21]      | 2016 | USA          | Retrospective, observational  | 536             | 56     | 45.9 ± 16.3          |
| Fukuhara *et al.* [22]*      | 2016 | Japan        | Retrospective, observational  | 491             | 70.5   | 51.8 ± 15            |
| Dorfman *et al.* [23]        | 2016 | USA          | Retrospective, observational  | 339             | 55.5   | 46.8 ± 16.5          |
| Yan *et al.* [24]            | 2015 | Canada       | Prospective cohort study      | 565             | 62.8   | 46.6 ± 14.4          |
| Lee *et al.* [25]            | 2015 | South Korea  | Retrospective, observational  | 2,218           | 71     | 43.3 ± 14.2          |
| Hall *et al.* [26]*          | 2015 | UK           | Retrospective, observational  | 513             | 57.1   | 45 ± 23.3           |
| Zwank *et al.* [27]          | 2014 | USA          | Prospective, observational    | 93              | NR     | 39 ± NR              |
| Abdel-Gawad *et al.* [28]*   | 2014 | UAE          | Retrospective, observational  | 939             | 87.9   | 37.9 ± 11            |
| Ince *et al.* [7]            | 2013 | Turkey       | Retrospective, observational  | 83              | 42.2   | 42.1 ± 14.4          |
| Lallas *et al.* [29]         | 2011 | USA          | Prospective, observational    | 32              | NR     | NR                   |
| Perez *et al.* [30]*         | 2010 | Spain        | Prospective, multicentre, cross-sectional case-control | 146             | 57.53  | 51.34 ± NR          |
| Xafis *et al.* [31]*         | 2008 | Switzerland  | Retrospective, observational  | 638             | NR     | 44.3 ± 14.6          |
| Seriniken *et al.* [32]*     | 2008 | Turkey       | Retrospective, observational  | 235             | 75.7   | 31.1 ± 7             |
| Cupisti *et al.* [33]        | 2008 | Italy        | Retrospective, observational  | 696             | 54     | NR                   |
| Matani and Al-Ghazo [34]*    | 2007 | Jordan       | Retrospective, observational  | 75              | 61.3   | 42.2 ± NR            |
| Kartal *et al.* [35]*        | 2006 | Turkey       | Prospective, observational    | 227             | 64.8   | 38.4 ± 14            |
| Kirpalani *et al.* [36]      | 2005 | Canada       | Retrospective, observational  | 299             | NR     | NR                   |
| Gaspari and Horst [37]       | 2005 | USA          | Prospective, observational    | 110             | NR     | NR                   |
| Argyropoulos *et al.* [38]   | 2004 | Greece       | Retrospective, observational  | 609             | 63.2   | 49.2 ± 15.9          |
| Ural *et al.* [39]*          | 2003 | Turkey       | Prospective, observational    | 137             | 55     | 38 ± NR              |
| Tack *et al.* [40]           | 2003 | Belgium      | Prospective, observational    | 106             | 50     | 45 ± NR              |
| Kobayashi *et al.* [41]      | 2003 | Japan        | Retrospective, observational  | 537             | 78     | 46.6 ± 14            |
| Eray *et al.* [41]           | 2003 | Turkey       | Prospective, observational    | 65              | 60     | 38.8 ± 13.5          |
| Lucus *et al.* [42]          | 2002 | USA          | Retrospective, observational  | 587             | NR     | NR                   |
| Hamm *et al.* [43]           | 2002 | Germany      | Prospective, observational    | 109             | 69.7   | 49 ± NR              |
| Li *et al.* [44]*            | 2001 | USA          | Retrospective, observational  | 397             | 73     | 47 ± 15              |
| Hamm *et al.* [45]           | 2001 | Germany      | Prospective, observational    | 125             | 72     | 55 ± 17              |
| Richards and *et al.* [46]   | 1999 | USA          | Retrospective, observational  | 185             | NR     | NR                   |
| Study               | Year | Location   | Design                        | Participants | Hematuria | Other Findings   |
|---------------------|------|------------|-------------------------------|--------------|-----------|------------------|
| Christman [46]      | 1999 | USA        | Retrospective, observational  | 195          | NR        | NR               |
| Bove et al. [47]    | 1998 | Singapore  | Prospective, observational    | 122          | 93        | 39.7 ± NR        |
| Ooi et al. [9]*     | 1998 | Singapore  | Prospective, observational    | 125          | 80        | 39.2 ± NR        |
| Ghali et al. [48]*  | 1998 | Saudi Arabia | Prospective, observational | 125          | 80        | 39.2 ± NR        |
| Eskelinen et al. [49]| 1998 | Finland    | Prospective, observational    | 57           | NR        | NR               |
| Gimondo et al. [50]*| 1996 | Italy      | Retrospective, observational  | 76           | 60.5      | 47 ± NR          |
| Boyd and Gray [51]  | 1996 | UK         | Prospective, observational    | 52           | NR        | NR               |
| Press and Smith [52]| 1995 | USA        | Retrospective, observational  | 109          | NR        | NR               |
| Chia et al. [53]    | 1995 | Singapore  | Prospective, observational    | 294          | 72.5      | 43.5 ± NR        |
| Elton et al. [54]*  | 1993 | USA        | Retrospective / prospective, observational | 275 | 71.2 | 46.2 ± 15.7 |
| Stewart et al. [55] | 1990 | USA        | Retrospective, observational  | 160          | 76.9      | NR               |
| Freeland [56]       | 1987 | Northern Ireland | Retrospective, observational | 134          | NR        | NR               |
| Dunn et al. [57]    | 1985 | USA        | Retrospective, observational  | 76           | NR        | 42.7 ± NR        |
| Bishop [58]         | 1980 | UK         | Prospective, observational    | 50           | NR        | NR               |

Abbreviations (alphabetical order): IQR = interquartile range; NR = not reported; RCT = Randomized controlled study; SD = standard deviation; UAE = United Arab Emirates; UK = United Kingdom; USA = United States of America.

Note: *Enrolled also children.

**Table 2**: Data on microhematuria in patients presenting with suspected acute renal colic at the emergency department.
| Authors         | Microhematuria test | Type of hematuria | Positive microhematuria definition | No. patients with microhematuria | Microhematuria prevalence |
|-----------------|---------------------|-------------------|------------------------------------|---------------------------------|--------------------------|
| Kim et al. [13] | Urinalysis          | Microscopic       | Presence of 4 or more RBCs/HPF     | 750                             | 750/798 (94%)            |
| Desai et al. [14] | Urinalysis          | Microscopic or macroscopic | Positive urinalysis for RBCs or for blood | 245                             | 245/350 (70%)           |
| Türk and Ün [15] | Urinalysis          | Microscopic       | NR                                 | 432                             | 432/516 (83.7%)        |
| Shrestha et al. [16] | Urinalysis          | Microscopic       | Presence of 3 or more RBCs         | 70                              | 70/201 (34.8%)          |
| Odoemene et al. [17] | Urinalysis          | Microscopic or macroscopic | NR                                 | 62                              | 62/69 (89.9%)          |
| Mefford et al. [18] | Urinalysis          | Microscopic       | Presence of 4 or more RBCs/HPF     | 321                             | 321/393 (81.7%)        |
| Rapp et al. [19] | Urinalysis          | Microscopic       | Presence of 4 or more RBCs/HPF     | 412                             | 412/613 (67.2%)        |
| Park et al. [20] | Urinalysis          | Microscopic       | NR                                 | 90                              | 90/103 (87.4%)         |
| Hernández et al. [21] | Urine dipstick     | Microscopic       | Hematuria on urine dipstick        | 332                             | 332/536 (61.9%)        |
| Fukuhara et al. [22] | Urinalysis or urine dipstick | Microscopic or macroscopic | Occult blood in urine             | 352                             | 352/491 (71.7%)        |
| Dorfman et al. [23] | Urinalysis          | Microscopic       | Presence of 5 or more RBCs/HPF     | 254                             | 254/339 (74.9%)        |
| Yan et al. [24] | Urinalysis          | Microscopic       | NR                                 | 451                             | 451/565 (79.8%)        |
| Lee et al. [25]  | Urinalysis          | Microscopic       | NR                                 | 1,980                           | 1,980/2,218 (89.3%)    |
| Hall et al. [26] | Urinalysis          | Microscopic       | Scores of 1+ to 3+ on urine dipstick or documented frank hematuria | 391                             | 391/513 (76.2%)        |
| Zwank et al. [27] | Urinalysis          | Microscopic       | RBCs present                       | 66                              | 66/93 (71%)            |
| Abdel-Gawad et al. [28] | Urinalysis          | Microscopic       | Presence of 4 or more RBCs/HPF     | 835                             | 835/939 (88.9%)        |
| Inci et al. [7]  | Urinalysis          | Microscopic       | Presence of 5 or more RBCs/HPF     | 46                              | 46/83 (55.4%)          |
| Lallas et al. [29] | Urinalysis          | Microscopic       | Presence of 4 or more RBCs/HPF     | 18                              | 18/32 (56.3%)          |
| Urine dipstick  | Microscopic         | Trace or scores of 1+ to 4+ on urine dipstick | 21                              | 21/32 (65.6%)            |
| Perez et al. [30] | Urine dipstick      | Microscopic       | NR                                 | 132                             | 132/146 (90.4%)        |
| Xafis et al. [31] | Urinalysis          | Microscopic       | Presence of 5 or more RBCs/HPF     | 396                             | 396/638 (62.1%)        |
| Serinken et al. [32] | Urinalysis          | Microscopic       | Presence of 5 or more RBCs/HPF     | 194                             | 194/235 (82.6%)        |
| Cupisti et al. [33] | Urine dipstick      | Microscopic       | NR                                 | 592                             | 592/696 (85.1%)        |
| Study Authors                                      | Test Type     | Method       | Criteria                                             | Positive % | Total/
|--------------------------------------------------|---------------|--------------|------------------------------------------------------|------------|----------|
| Study | Method | Microscopic | Criteria | Count | Count/Total (%) |
|-------|--------|-------------|----------|-------|-----------------|
| Chia *et al.* [53] | Urinalysis | Microscopic | Presence of 6 or more RBCs/HPF in males or of 10 or more RBCs/HPF in females | 181 | 181/294 (61.6%) |
| Elton *et al.* [54] | Urinalysis | Microscopic | Presence of 4 or more RBCs/HPF | 194 | 194/275 (70.5%) |
| Stewart *et al.* [55] | Urinalysis | Microscopic | Presence of 3 or more RBCs/HPF | 132 | 132/160 (82.5%) |
| Freeland [56] | Urine dipstick | Microscopic | Trace or scores of 1+ to 3+ on urine dipstick | 102 | 102/134 (76.1%) |
| Dunn *et al.* [57] | Urinalysis | Microscopic | Presence of 3 or more RBCs/HPF | 62 | 62/76 (81.6%) |
| Bishop [58] | Urine dipstick | Microscopic | Positive urine dipstick | 44 | 44/50 (88%) |

Abbreviations (alphabetical order): NR = not reported; HPF = High power Field; RBC = Red Blood Cell.

**Table 3:** Data on microhematuria in patients presenting with confirmed urolithiasis at the emergency department.
| Authors            | Microhematuria test | N. patients with microhematuria | Microhematuria prevalence | Diagnostic test for urolithiasis                  |
|--------------------|---------------------|--------------------------------|---------------------------|--------------------------------------------------|
| Kim *et al.* [13]  | Urinalysis          | 750                            | 750/798 (94%)             | Unenhanced MDCT                                  |
| Desai *et al.* [14]| Urinalysis          | 231                            | 231/282 (81.9%)           | Non-contrast CT                                  |
| Türk *et al.* [15] | Urinalysis          | 344                            | 344/388 (88.7%)           | Non-contrast complete abdominal CT                |
| Shrestha *et al.* [16]| Urinalysis     | 27                             | 27/61 (44.3%)             | Renal US                                         |
| Odoemene *et al.* [17] * | Urinalysis | 62                             | 62/69 (89.9%)             | Abdominal US, IVU, CT                            |
| Mefford *et al.* [18] | Urinalysis     | 321                            | 321/393 (81.7%)           | Non-contrast abdominal or pelvic CT               |
| Rapp *et al.* [19] * | Urinalysis      | 177                            | 177/222 (79.7%)           | Non-contrast CT                                  |
| Fukuhara *et al.* [22] * | Urinalysis or urine dipstick | 323                           | 323/358 (90.2%)          | Plain abdominal X-ray, helical contrast enhanced or non-contrast CT |
| Dorfman *et al.* [23] | Urinalysis     | 254                            | 245/339 (74.9%)           | Abdominal CT                                     |
| Hall *et al.* [26] * | Urinalysis      | 193                            | 193/233 (82.8)            | Non-enhanced CT                                  |
| Zwank *et al.* [27] | Urinalysis          | 52                             | 52/62 (83.9)              | CT                                              |
| Abdel-Gawad *et al.* [28] | Urinalysis | 835                            | 835/939 (88.9)            | Color doppler or gray-scale US, abdomen X-ray, helical CT |
| Inci *et al.* [7]   | Urinalysis          | 46                             | 46/83 (55.4)              | Unenhanced MDCT                                  |
| Lallas *et al.* [29] | Urinalysis          | 18                             | 18/32 (56.3)              | US, Abdomen X-ray, IVU, CT                       |
|                     | Urine dipstick      |                                 | 21                        | Urinalysis                                      |
| Xafis *et al.* [31] | Urinalysis          | 341                            | 341/507 (67.3)            | Unenhanced MDCT                                  |
| Kartal *et al.* [35] | Urinalysis          | 121                            | 121/176 (68.8)            | IVU, US, spiral CT, stone passage                |
| Gaspari and Horst [37] | Urinalysis    | 54                             | 54/58 (93.1)              | US, CT                                          |
| Argyropoulos *et al.* [8] | Urine dipstick | 539                            | 539/564 (95.6)            | Abdomen X-ray, US                               |
| Unal *et al.* [38]  | Urinalysis          | 92                             | 92/114 (80.7)             | US, excretory urography, non-enhanced helical CT |
| Tack *et al.* [39]  | Urinalysis or urine dipstick | 37                           | 37/38 (97.4)              | Excretory urography, non-enhanced helical MDCT    |
| Kobayashi *et al.* [40] | Urine dipstick | 346                            | 346/452 (76.5)            | Abdomen X-ray, US, CT                           |
|                     | Urinalysis          | 317                            | 317/452 (70.1)            |                                                 |
| Eray *et al.* [41]  | Urinalysis          | 37                             | 37/54 (68.5)              | Abdomen X-ray, spiral CT, stone passage          |
| Luchs *et al.* [42] | Urinalysis          | 492                            | 492/587 (83.8)            | CT, stone passage                                |
| Hamm *et al.* [43]  | Urinalysis          | 53                             | 53/80 (66.3)              | Unenhanced low dose helical CT                    |
| Li *et al.* [44]    | Urinalysis or urine dipstick | 360                          | 360/397 (90.7)            | CT, IVP                                          |
| Study            | Method                     | Sensitivity | Specificity | Imaging Method          |
|------------------|----------------------------|-------------|-------------|-------------------------|
| Hamm et al. [45] | Urinalysis                 | 76          | 76/91 (83.5)| Helical CT              |
| Richards and     | Urinalysis                 | 88          | 88/98 (89.8)| IVU                     |
| Christman [46]   |                            |             |             |                         |
| Bove et al. [47] | Urine dipstick             | 70          | 70/87 (80.5)| CT                      |
|                  | Urinalysis                 | 77          | 77/95 (81.1)|                         |
|                  | Urinalysis or Urine dipstick| 82          | 82/95 (86.3)|                         |
| Ooi et al. [9]   | Urine dipstick             | 62          | 62/65 (95.4)| Abdomen X-ray, IVU      |
|                  | Urinalysis                 | 46          | 46/65 (70.8)|                         |
| Ghali et al. [48]| Urinalysis                 | 64          | 64/82 (78)  | Abdomen X-ray, IVU, US  |
| Gmondo et al.    | Urine dipstick             | 29          | 29/29 (100)| US                      |
| [50]*            |                            |             |             |                         |
| Boyd and Gray    | Urine dipstick             | 29          | 29/29 (100)| Abdomen X-ray, IVU      |
| [51]             |                            |             |             |                         |
| Press and Smith  | Urinalysis                 | 78          | 78/109 (71.6)| IVU                    |
| [52]             |                            |             |             |                         |
| Stewart et al.   | Urinalysis                 | 132         | 132/160 (82.5)| IVP                   |
| [55]             |                            |             |             |                         |
| Freeland [56]    | Urine dipstick             | 72          | 72/76 (94.7)| IVU or stone passage    |
| Dunn et al. [57] | Urinalysis                 | 62          | 62/76 (81.6)| IVU or stone passage    |
| Bishop [58]      | Urine dipstick             | 33          | 33/35 (94.3)| IVU                     |

Abbreviations (alphabetical order): CT = computed tomography; HFU = High-power field; IVU = Intravenous Urography; MDCT = multidetector CT; NR = not reported; RBC = Red Blood Cell; SD = standard deviation; US = ultrasound

* This study included also patients with gross hematuria

**Figures**
**Figure 1**

PRISMA flow chart of the retrieved, excluded and analyzed studies.
Figure 2

Plots of individual studies and pooled prevalence of microhematuria in patients with acute renal colic, including 95% confidence intervals (95%CI).
Figure 3

Plots of individual studies and pooled prevalence of microhematuria in patients with confirmed urolithiasis, including 95% confidence intervals (95%CI).

Supplementary Files

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