

Comparison and outcomes of dusting versus stone fragmentation and extraction in retrograde intrarenal surgery: results of a systematic review and meta-analysis

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Citation: Gauhar V, Teoh J Y-C, Mulawkar PM, et al. Comparison and outcomes of dusting versus stone fragmentation and extraction in retrograde intrarenal surgery: results of a systematic review and meta-analysis. Cent European J Urol. 2022; 75: 317-327.

Article history

Submitted: July 19, 2022

Accepted: Aug. 21, 2022

Published online: Sept. 6, 2022

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Introduction Lithotripsy during retrograde intrarenal surgery (RIRS) can be achieved either by fragmentation and extraction or dusting with spontaneous passage. We aimed to perform a systematic review on the safety and stone-free rate after RIRS by comparing the techniques of dusting vs fragmentation/extraction.

Material and methods This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement. The inverse variance of the mean difference and 95% Confidence Interval (CI), Categorical variables were assessed using Cochran-Mantel-Haenszel Method with the random effect model and reported as Odds Ratio (OR) and 95% CI. Statistical significance was set at $p < 0.05$.

Results There were 1141 patients included in 10 studies. Stone size was up to 2.5 cm All studies used holmium laser for lithotripsy. Meta-analysis showed no significant difference in surgical time (MD -5.39 minutes 95% CI -13.92–2.31, $p = 0.16$), postoperative length of stay (MD -0.19 days 95% CI -0.60 – -0.22, $p = 0.36$), overall complications (OR 0.98 95% CI 0.58–1.66, $p = 0.95$), hematuria (OR 1.01 95% CI 0.30–3.42, $p = 0.99$), postoperative fever (OR 0.70 95% CI 0.41–1.19, $p = 0.19$) and sepsis (OR 1.03 95% CI 0.10–10.35, $p = 0.98$), immediate (OR 0.40 95% CI 0.13–1.24, $p = 0.11$) and overall stone-free rate (OR 0.76 95% CI 0.43–1.32, $p = 0.33$), and retreatment rate (OR 1.35 95% CI 0.57–3.20, $p = 0.49$) between the groups.

Conclusions This systematic review infers that urologists can safely use either option of fragmentation and basket extraction or dusting without extraction to achieve similar outcomes as both techniques are similar for efficacy and safety.

Key Words: kidney calculi <> lithotripsy <> laser <> retrograde intrarenal surgery <> dusting <> fragmentation

INTRODUCTION

Recent technological advances have led to greater utilization of retrograde intrarenal surgery (RIRS) for renal stones, because of its established efficiency and safety profile. Digital, disposable and miniaturized ureteroscopes with improved deflection, among other improvements, have turned RIRS into the commonest approach to treat kidney stone disease (KSD), with about 60% of the procedures performed by this route [1]. Although RIRS is an accepted modality for KSD management in both the European Association of Urology and American Urological Association guidelines [2, 3], there is still controversy on the best approach for managing fragments post-laser lithotripsy. Fragments can either be directly extracted with a basket ('basketing') or they can be turned into dust and left in situ so that they can be passed spontaneously as fine dust ('dusting'). Both procedures have pros and cons and no specific consensus exists on the best approach as shown by the Endourology Disease Group Excellence (EDGE) consortium study [4].

This study aimed to systematically review the safety and efficacy of RIRS by comparing the techniques of dusting vs fragmentation/extraction.

Evidence acquisition

Aim of the review

The present study aims to systematically review the safety (i.e. complications) and efficacy (i.e. stone-free rate) after RIRS using dusting lithotripsy as compared to RIRS using basketing devices (baskets) for kidney and upper ureteral stones. The primary outcome was to assess if there was any difference in the immediate and overall stone-free rate (SFR) and retreatment rate between the two procedures. The secondary outcome was to evaluate for differences in surgical time, length of stay, and postoperative complications between the two techniques.

Literature search

This review was performed according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. An extensive literature search was performed on 16th February 2022, using MEDLINE, EMBASE, and Cochrane Central Controlled Register of Trials (CENTRAL). Medical Subject Heading (MeSH) terms and keywords such as 'kidney or renal or ureter', 'stone or calculi', 'lithotripsy', 'laser or

holmium or shockwave or thulium' 'retrograde intrarenal surgery or RIRS or ureteroscopy', were used. The search was restricted to English papers only. No date limits were imposed. Animal and pediatric studies were also excluded. Appendix 1 (http://ceju.online/journal/2022/appendix_2230.pdf) shows the search strategy. The review protocol was submitted for registration in PROSPERO (registration CRD 42022311306).

Selection criteria

The PICOS (Patient Intervention Comparison Outcome Study type) model was used to frame and answer the clinical question. P: Adults with kidney and upper ureteral stones undergoing RIRS with laser lithotripsy; Intervention: stone fragmentation and extraction of fragments with baskets; Comparison: in situ dusting only; Outcome: surgical time, length of postoperative stay, overall complications, infection-related complications (fever defined as body temperature $>38^{\circ}\text{C}$, urinary tract infections, sepsis), the incidence of postoperative hematuria, immediate and overall stone-free rate, and retreatment rate; Study type: Randomized, prospective non-randomized, and retrospective studies. Patients were assigned to two groups according to the type of lithotripsy strategy (fragmentation/basketing vs in situ dusting).

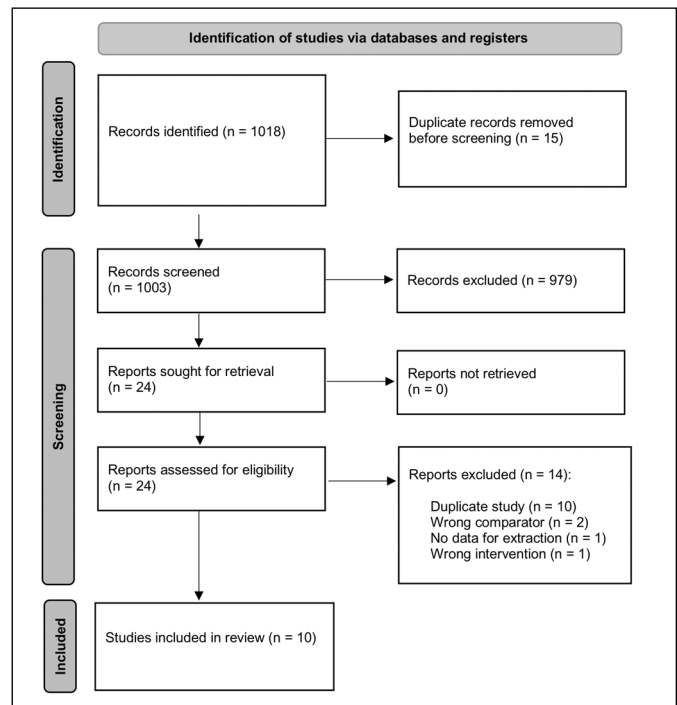


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study.

Study screening and selection

Two independent authors screened all retrieved records through Covidence Systematic Review Management® (Veritas Health Innovation, Melbourne, Australia). A third author solved discrepancies via mutual consensus. Studies were included based on PICOS eligibility criteria. Retrospective, prospective nonrandomized, and randomized studies were accepted. Meeting abstracts were also

included. Reviews, case reports, letters to the editor, and editorials were excluded. The full text of the screened papers was selected if found relevant to the purpose of this study.

Statistical analysis

Surgical time and postoperative length of stay were pooled using the inverse variance of the mean difference with a random effect, 95% Confidence Inter-

Table 1. Study characteristics

| | Type of study | Type of paper | Inclusion criteria | Exclusion criteria | Type of laser for dusting & extraction | Laser setting dusting | Laser setting extraction | Definition of SFR |
|----------------|----------------------------|------------------|---|---|--|-----------------------|--------------------------|--------------------------|
| Alkan 2016 | Prospective non-randomized | Meeting abstract | Stone size 1–4 cm | Not mentioned | Holmium | Not mentioned | Not mentioned | ≤4 mm |
| Bagadia 2017 | RCT | Meeting abstract | Stone size 1.5–2.5 cm | Not mentioned | Holmium | 0.2–0.4 J, 30–50 Hz | 1–2 J, 5–10 Hz | Not mentioned |
| El-Nahas 2019 | Retrospective | Full text | Stone size 1.5–2 cm | Not mentioned | Holmium | 0.3–0.5 J, 15–20 Hz | 1–1.2, 6–10 Hz | ≤4 mm |
| Elzayat 2020 | RCT | Meeting abstract | Symptomatic single primary proximal ureteric stone <2 cm | Pregnant women, children, and patients with coagulation disorders, medical problems that hinder anesthesia, recent active infection, urinary tract abnormalities and previous ureteric surgery | Holmium | 0.5J, 20 Hz | 2J, 5 Hz | Not mentioned |
| Gamal 2015 | RCT | Meeting abstract | Unilateral single stone in pelvis of 2 cm, age >18 | Not mentioned | Holmium | 0.2–0.4 J, 20–30 Hz | 1–2 J, 4–5 Hz | Not mentioned |
| Humphreys 2018 | Prospective non-randomized | Full text | Stone size 5–20 mm, age 18–80, location at the UPJ or above, ureteral stone if already present simultaneously | Prior ipsilateral upper urinary tract reconstruction, history of ipsilateral ureteral stricture, history abdominopelvic radiotherapy, spinal cord injury, neurogenic bladder, scheduled staged ureteroscopy | Holmium | Not mentioned | Not mentioned | No residuals of any size |
| Lee 2016 | Retrospective | Full text | Consecutive patients who underwent RIRS | Not mentioned | Holmium | Not mentioned | Not mentioned | <3 mm |
| Lee 2017 | RCT | Meeting abstract | Stone size <2 cm | Not mentioned | Holmium | Not mentioned | Not mentioned | |
| Multescu 2014 | Prospective non-randomized | Full text | Stone size <2 cm, age >18 | Not mentioned | Holmium | 0.5 J x 12 Hz | 1–1.2 J, 8–10 Hz | <1 mm |
| Zhong 2019 | RCT | Meeting abstract | Stone size <2 cm, age >18 | Not mentioned | Holmium | Not mentioned | 1–1.2 J, 8–10 Hz | Not mentioned |

RCT – randomized clinical trial; J – joule. Hz: Hertz; SFR – stone-free rate

vals (CI), and p-values. Incidence of overall complications, hematuria, fever, urinary infections, sepsis, retreatment rate, and SFR were assessed using Cochran-Mantel-Haenszel Method with the random effect model and reported as Odd Ratio (OR), 95% CI, and p-values. Analyses were two-tailed and the significance was set at $p < 0.05$ and a 95% CI. OR less than one indicates a lower risk in the dusting group. Study heterogeneity was assessed utilizing the I^2 value. Substantial heterogeneity was defined as an I^2 value $> 50\%$. Meta-analysis was performed using Review Manager (RevMan) 5.4 software by Cochrane Collaboration. The quality assessment of the included studies was performed using the Cochrane Risk of Bias tool, using RoB 2 for randomized studies and ROBINS-I for non-randomized ones [5, 6].

Evidence synthesis

The initial literature search retrieved 1018 papers. After removing 15 duplicates, 1003 studies were left for screening. Another 979 papers were excluded against the title and abstract screening because they were irrelevant to the purpose of this study. The full texts of the remaining 24 studies were screened and 14 papers were further excluded for lack of specificity of data or duplicate studies. Finally, 10 studies were accepted and included for meta-analysis. Figure 1 shows the PRISMA flow diagram.

Study characteristics and quality assessment

Ten studies compared dusting and basketing in RIRS for kidney and upper ureteral stones. There

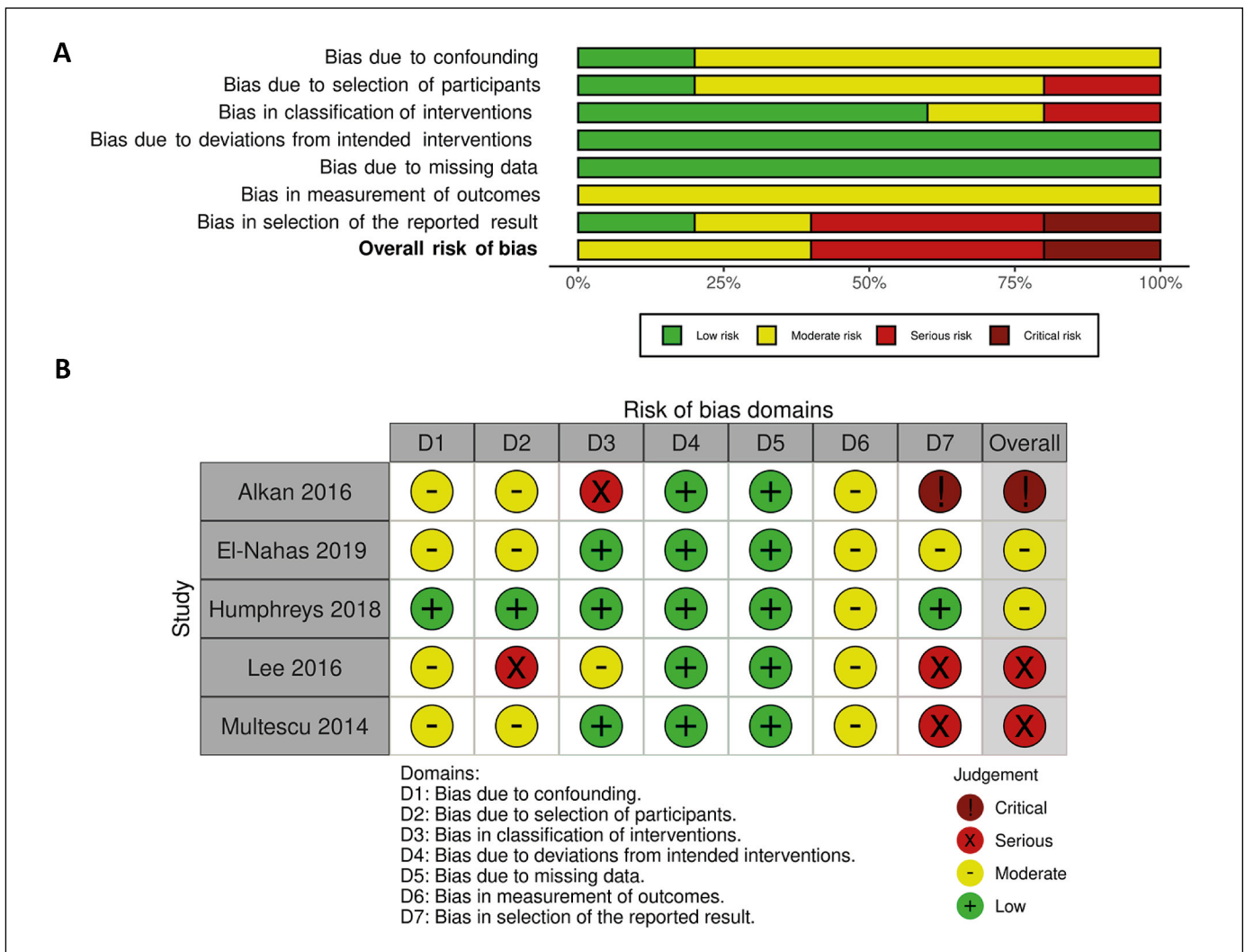


Figure 2. Risk of bias in non-randomized controlled trials (ROBINS-I). **A)** Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies. **B)** Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

were 3 prospective non-randomized studies [4, 7, 8], 2 retrospective studies [9, 10] and 5 randomized clinical trials [11–15].

Study characteristics are summarized in Table 1. There were 1141 patients included in 10 studies: 495 patients underwent dusting and 646 underwent basketing. Figure 2 shows the details of quality assessment in the retrospective and prospective non-randomized studies. One study showed a critical risk of bias, two studies a serious and the remaining two studies a moderate risk of bias. The most common reason for the risk of bias was in the measurement of outcomes, followed by risk in the selection of the reported results. Figure 3 shows the details of quality assessment in the prospective randomized studies. Three studies showed a low overall risk of bias and the remaining two had a moderate over-

all risk of bias. The most common reason for the risk of bias was in the measurement of outcomes, followed by risk from the randomization process.

Meta-analyses of surgical time and length of stay

Meta-analysis from 6 studies (408 cases in dusting and 559 cases in basketing group) showed no significant difference in surgical time between the groups (MD -5.39 minutes 95% CI -13.92–2.31, p = 0.16). Study heterogeneity was substantial (I² 94%) (Figure 4A).

Meta-analysis of 2 studies (119 cases in dusting and 138 cases in basketing group) showed no significant difference in postoperative length of stay between the groups (MD -0.19 days 95% CI -0.60 – -0.22, p = 0.36). Study heterogeneity was substantial (I² 91%) (Figure 4B).

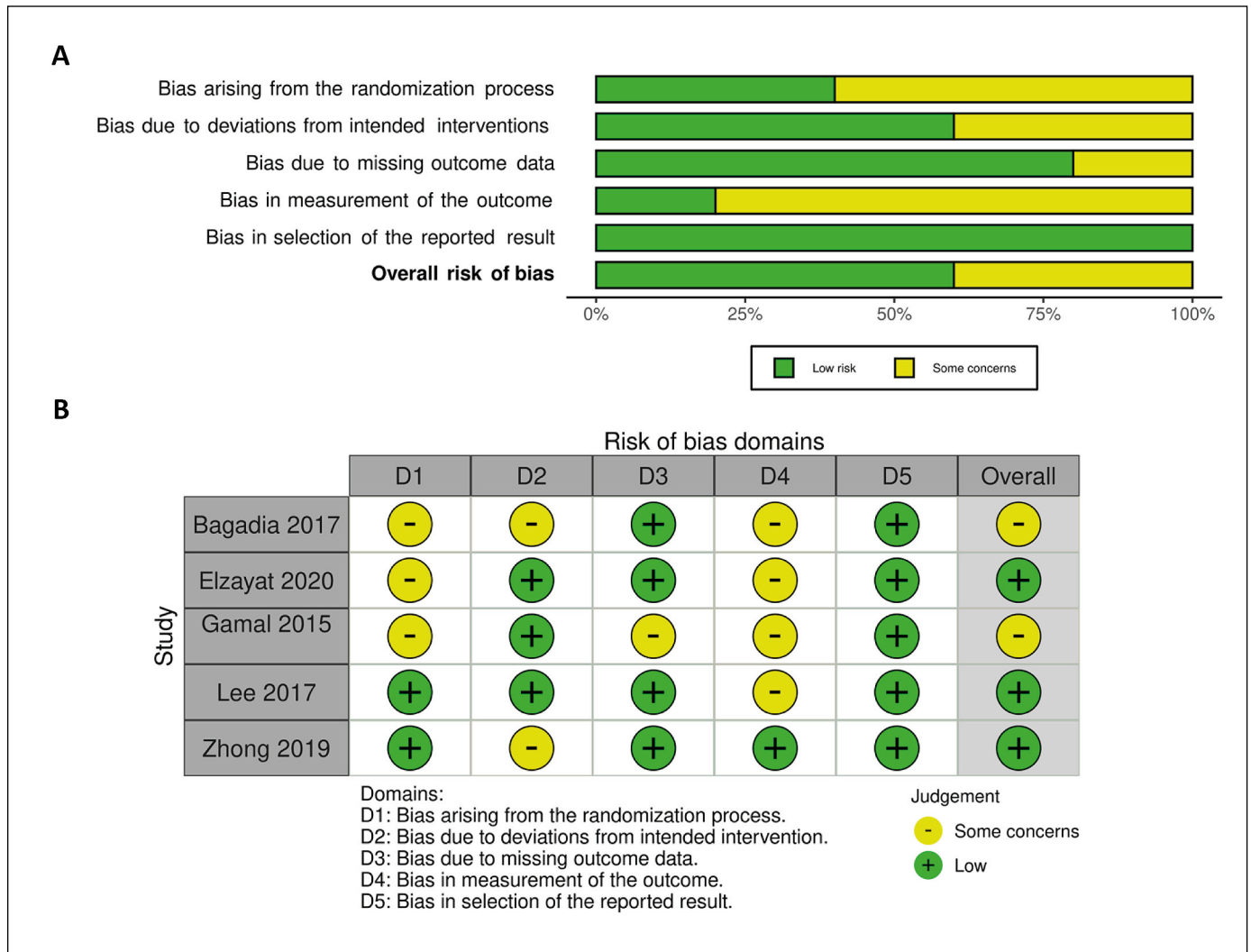


Figure 3. Risk of bias in randomized controlled trials (ROB-2). **A)** Risk of bias graph: review authors’ judgements about each risk of bias item presented as percentages across all included studies. **B)** Risk of bias summary: review authors’ judgements about each risk of bias item for each included study.

Meta-analysis of overall complications

Meta-analysis from 4 studies (241 cases in dusting and 340 cases in basketing group) showed that overall complications did not differ significantly between the groups (OR 0.98 95% CI 0.58–1.66, $p = 0.95$) Study heterogeneity was not significant ($I^2 0\%$) (Figure 5A).

Meta-analysis of postoperative hematuria

Meta-analysis from 6 studies (310 cases in dusting and 449 cases in basketing group) showed no significant difference in the occurrence of postoperative hematuria (OR 1.01 95% CI 0.30–3.42, $p = 0.99$). There was no significant heterogeneity among the studies ($I^2 0\%$) (Figure 5B).

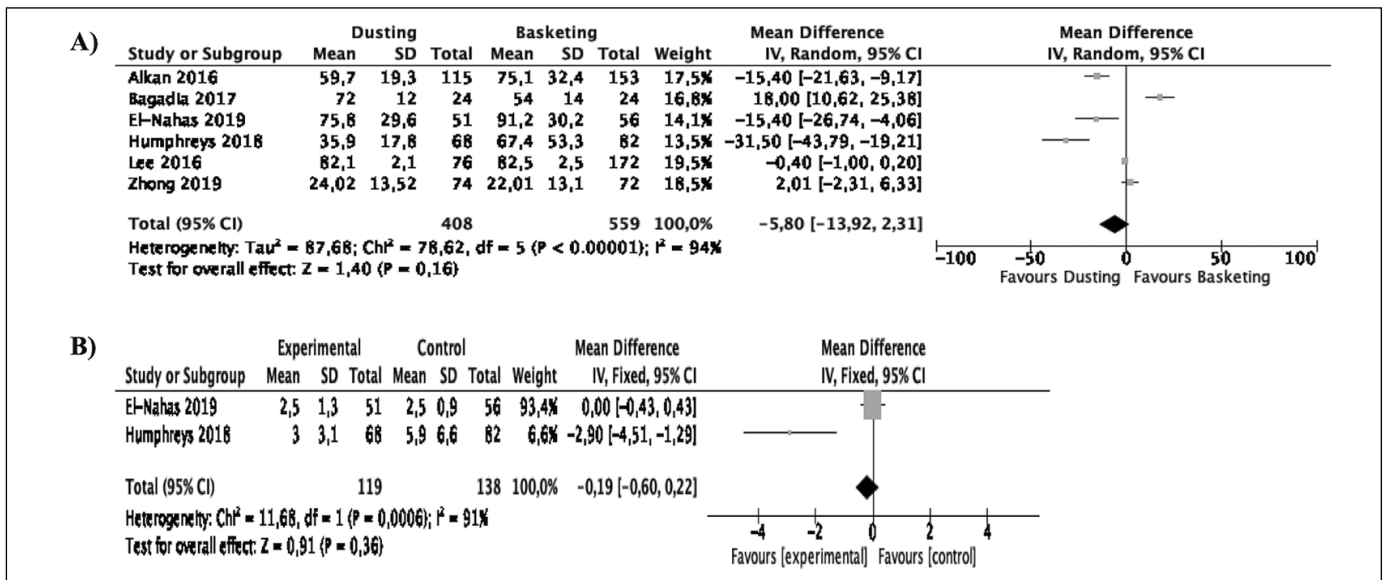


Figure 4. Meta-analysis of **A)** surgical time and **B)** postoperative stays in studies comparing dusting vs basketing in retrograde intrarenal surgery (RIRS).

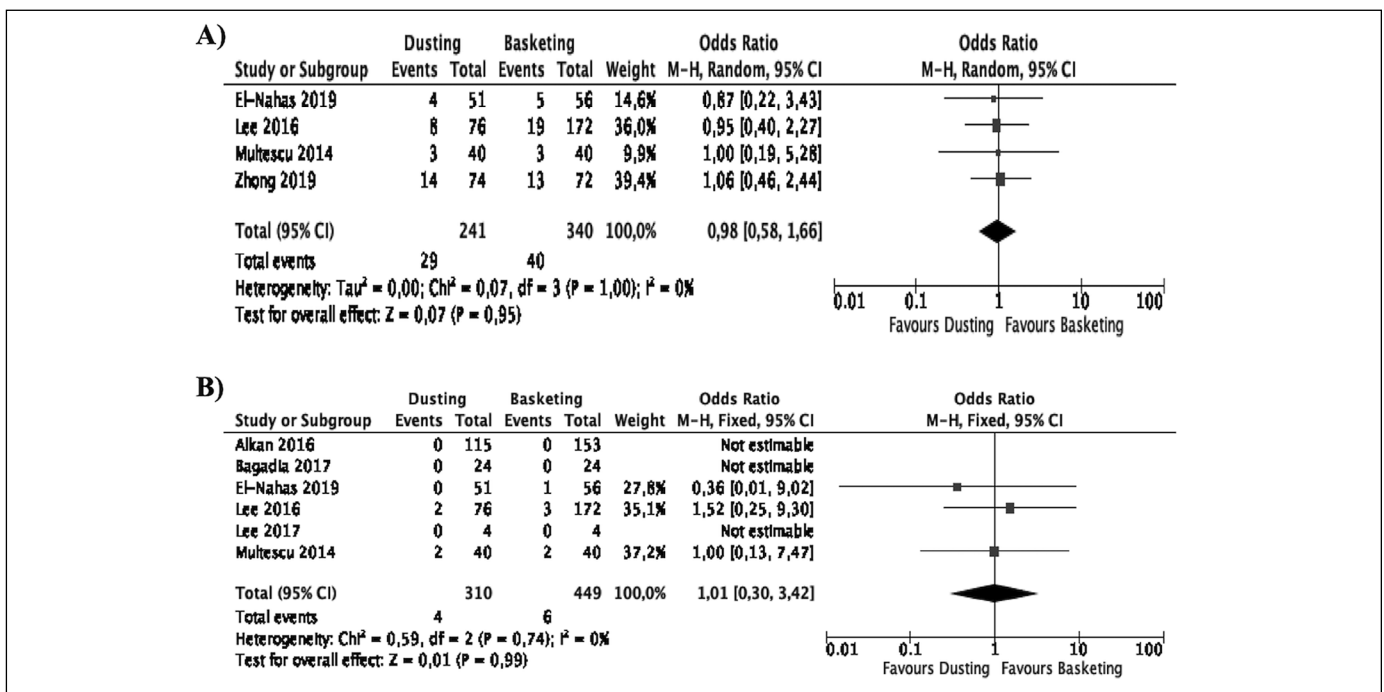


Figure 5. Meta-analysis of **A)** overall complications and **B)** hematuria in studies comparing dusting vs basketing in retrograde intrarenal surgery (RIRS).

Meta-analyses of infectious complications

Meta-analysis from 9 studies (470 cases in dusting and 614 cases in basketing group) showed that the incidence of postoperative fever did not differ significantly between the groups (OR 0.70 95% CI 0.41–1.19, $p = 0.19$). Study heterogeneity was substantial (I^2 54%) (Figure 6A).

Meta-analysis from 2 studies (125 cases in dusting and 128 cases in basketing group) showed that the incidence of postoperative sepsis did not differ between the groups (OR 1.03 95% CI 0.10–10.35, $p = 0.98$). There was no significant heterogeneity among the studies (I^2 2%) (Figure 6B).

There was only one study reporting postoperative urinary infections, making meta-analysis not feasible.

Meta-analyses of stone-free rate and retreatment rate

Meta-analysis from 3 studies (64 cases in dusting and 64 cases in basketing group) showed that immediate SFR did not differ significantly between the groups (OR 0.40 95% CI 0.13–1.24, $p = 0.11$). Study heterogeneity was not significant (I^2 0%) (Figure 7A).

Meta-analysis from 8 studies (474 cases in dusting and 582 cases in basketing group) showed that the overall SFR did not differ significantly between the groups (OR 0.76 95% CI 0.43–1.32, $p = 0.33$). Study heterogeneity was moderate (I^2 62%) (Figure 7B).

Meta-analysis from 3 studies (159 cases in dusting and 178 cases in basketing group) showed that the retreatment rate among patients who were not stone-free did not differ significantly between the groups (OR 1.35 95% CI 0.57–3.20, $p = 0.49$). Study heterogeneity was not significant (I^2 0%) (Figure 7C).

DISCUSSION

Technological advancements such as scope miniaturization, smaller ureteral access sheath (UAS), intraoperative fluid control devices, and high-power lasers are contributing to improvements in RIRS safety and efficiency [1]. Stone fragmentation and fragment removal has been utilized for decades for lithotripsy. New laser improvements such as Moses technology, and pulse modulation allow for a more efficient stone fragmentation using the least amounts of energy to complete lithotripsy [16]. Fragmentation requires fragment removal using a basket. This can help to improve SFR and allow

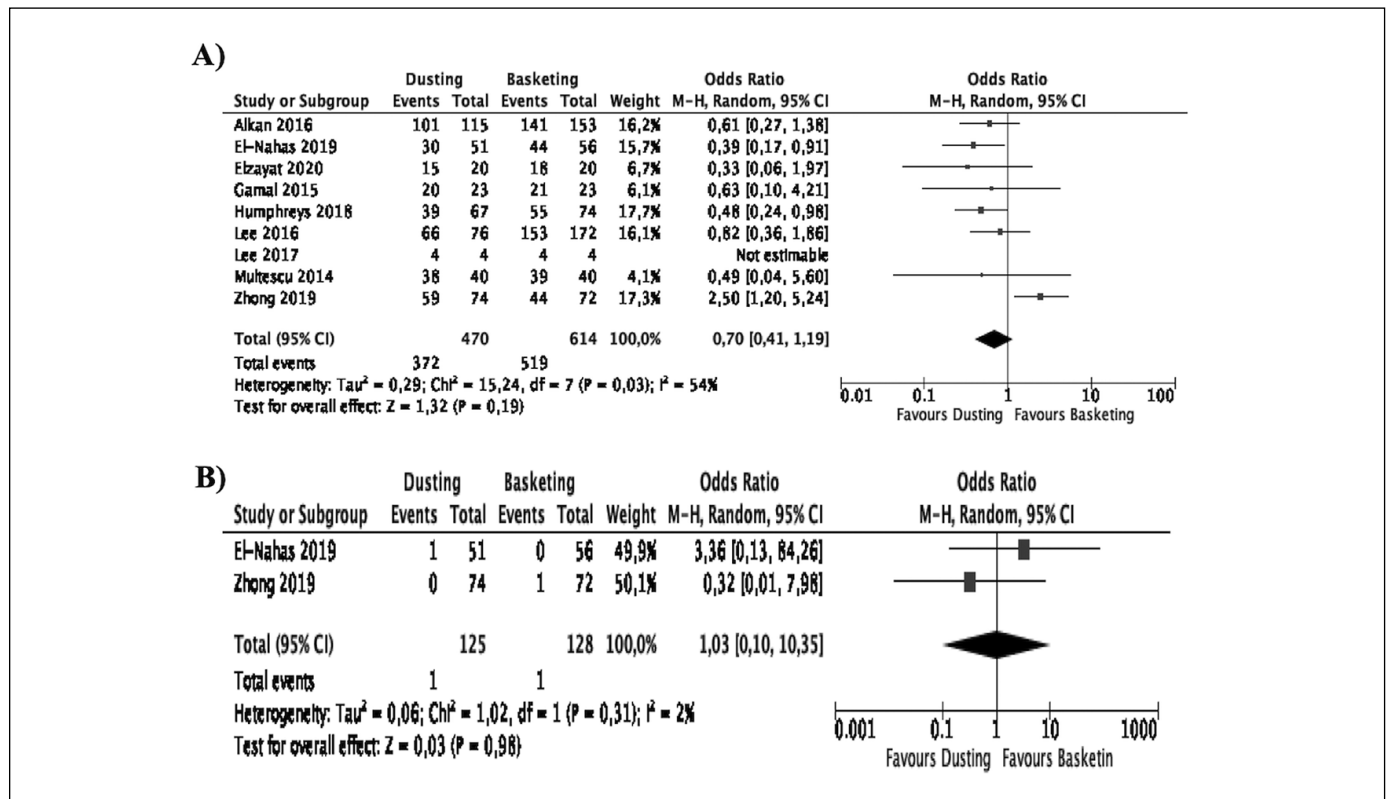


Figure 6. Meta-analysis of postoperative **A)** fever and **B)** sepsis in studies comparing dusting vs basketing in retrograde intrarenal surgery (RIRS).

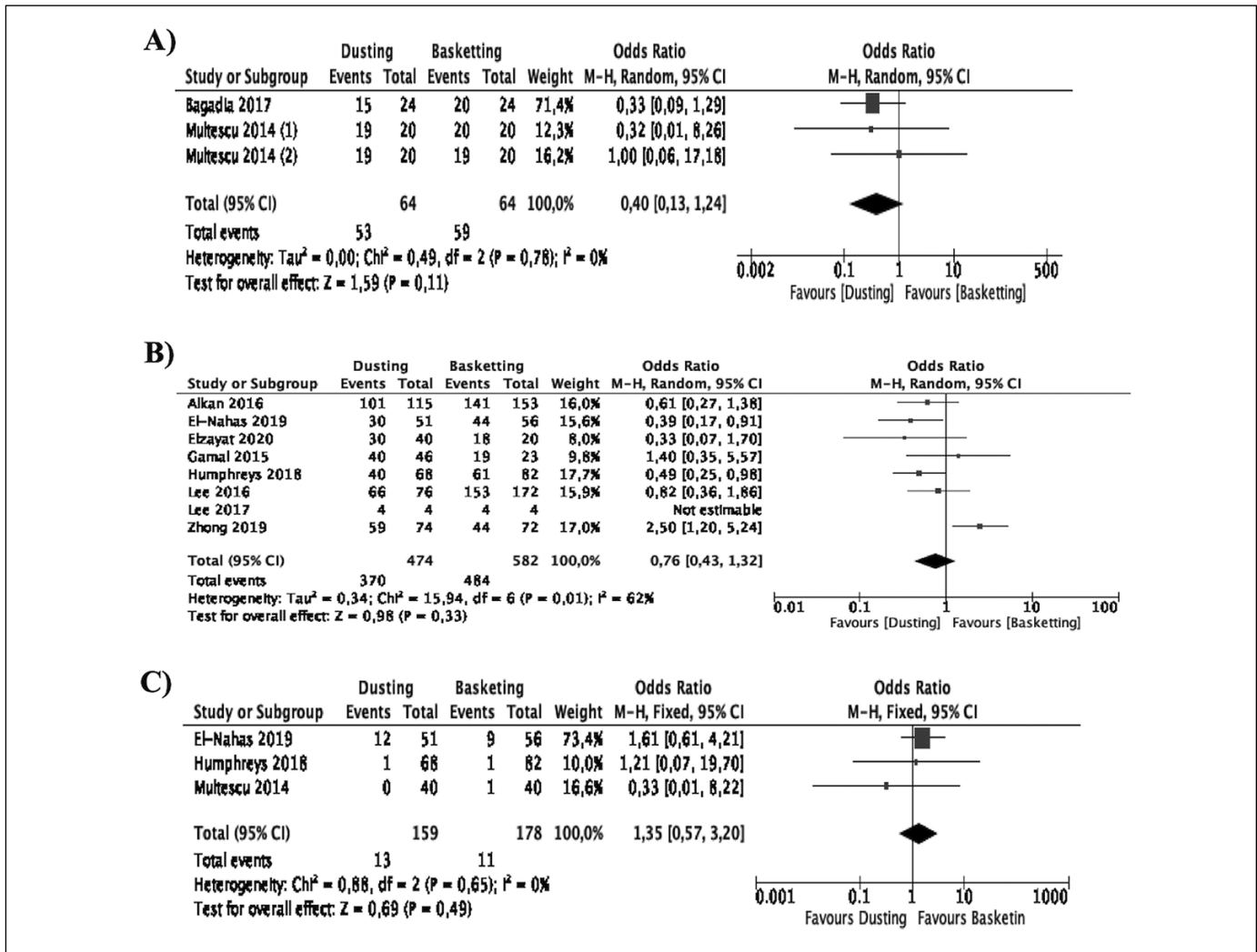


Figure 7. Meta-analysis of **A)** immediate and **B)** overall stone-free rate, and **C)** retreatment rate in studies comparing dusting vs basketting in retrograde intrarenal surgery (RIRS).

for stone analysis with the potential implementation of therapeutic strategies to prevent future episodes of nephrolithiasis [17]. In our review, the most common setting for fragmentation using the holmium laser was 1–2 J and 4–6 Hz. Pietropaolo et al. have shown how high-power Holmium lasers have brought to the endourology armamentarium the ability to select high-frequency laser pulses while working with low energy which is called ‘stone dusting’ [18].

The alternate options are pop-dusting and pop-corn-ing. Laser settings at lower pulse energy (0.2–0.6 Joule) and higher pulse frequency (50–80 Hz) reduce retro-pulsion and result in small dust-like particles, small enough to be spontaneously evacuated or actively aspirated [19].

The popular dusting setting in the studies included in our review was 0.2–0.5 J and 15–20 Hz. How-

ever, this was variable across different centers and reflected the personal practice. Dusting depends on gravity aided expulsion or active aspiration of dust post lithotripsy. Both dusting and fragmentation can be done using low and high power Holmium lasers by adjusting the energy, pulse, and frequency to derive the optimal power output. In our review, studies reported exclusively the use of Holmium lasers. Whether we dust or fragment in holmium laser lithotripsy, an understanding of laser settings is essential to optimize various techniques for lithotripsy. During contact laser lithotripsy, the use of high pulse/energy settings leads to a greater loss in stone mass and is an important variable when using a fragmentation approach. Low pulse/energy settings result in smaller fragments, and along with high frequencies, is the foundation for purposeful dusting [20]. Eventually, a balance should exist be-

tween total power output and irrigation flow while performing flexible ureteroscopy at all times to prevent high intrarenal pressure and temperature. This is even more important when using the newer super pulsed Thulium Fibre Laser (TFL) [21].

Despite the first reports about three decades ago, the definition of 'stone dust' has no consensus. D'yakonov et al., studying an in vitro model, concluded that the maximum size of particles should not exceed 200–400 μm in dusting [22]. Recently, Keller et al. proposed that dust particles should be a size limit of $\leq 250 \mu\text{m}$ because at this size, they spontaneously float during surgery, do not sediment fast, and are suitable for aspiration through the working channel of a 3.6 Fr flexible ureteroscope [23].

Newer technologies and lasers, like the Moses effect and TFL, provide a myriad of laser setting options by changing pulse widths/frequency/energy settings making both dusting and fragmentation with extraction equally attractive lithotripsy alternatives but pose a clinical dilemma as to which is the best choice for different stone locations and composition [24, 25, 26].

Dusting has fewer requirements for the use of retrieval baskets and graspers and may obviate the need for UAS, which potentially reduces the risk of ureteral trauma. In a recent meta-analysis, high power laser lithotripsy appears to require shorter operative time, with similar stone-free and complication rates as compared with low-power traditional lithotripsy in clinical practice [27, 28]. However, this advantage seems to be lost with higher stone burdens as was stated in experimental studies.

Irrespective of the type of laser or setting one must be extremely careful of complications due to increased intra-renal pressure and temperature at high laser frequencies and energies especially if a UAS is not used as was noted by Aldoukhi et al. [29]. Hence, the dogma on which modality is best for RIRS lithotripsy outcomes in renal and ureteric stones. In our review, only 2 studies included ureteral stones [4, 11] and the rest were for renal stones. The mean stone diameter ranged from 1 to 2.5 cm in the majority of the studies with only Alkan et al. including renal stones up to 4 cm [7].

Following flexible ureteroscopy, there are variable results regarding SFR of dusting and fragmentation techniques. In some studies, the fragmentation lithotripsy plus basketing technique has been shown to provide a better immediate SFR [9, 19]. However, in some pediatric studies, the SFR didn't differ between dusting vs fragmentation/extraction groups [30]. Our meta-analysis showed that both techniques are comparable regarding immediate (OR 0.40 95% CI 0.13–1.24, $p = 0.11$) and

overall stone-free rates (OR 0.76 95% CI 0.43–1.32, $p = 0.33$) which were assessed heterogeneously in the different studies included, ranging from 1 month to 3 months post-intervention by using a single or combination of imaging modalities. Danilovic et al. have recommended that if immediate endoscopic evaluation post-RIRS shows residual fragments $< 2 \text{ mm}$, a CT scan should be performed 3 months after surgery to assess the overall SFR [31].

Despite a lack of consensus on the definition of residual fragments and imaging protocol to evaluate patients after RIRS, our review showed that the need for reintervention following either technique was similar in the studies reporting a persistence of residual fragments (OR 1.35 95% CI 0.57–3.20). This reiterates that both methods are efficacious with a similar intraoperative time (MD -5.39 minutes 95% CI -13.92–2.31, $p = 0.16$). Most likely the time spent on basketing and extraction equates to the time a surgeon spends on carefully dusting the stones to avoid large residual fragments.

From our meta-analysis, it is clear that neither small residual fragments (between 2–4 mm) nor dust imposes the patient a significant risk of reoperation. Our data also supports that both techniques can be performed as outpatient surgery and there was no difference in the hospital stay. Hence, RIRS irrespective of the technique used, if executed safely, remains a day surgery procedure as long as there are no complications [32].

Infection is one of the most common complications after RIRS and can be associated with significant morbidity for patients. A recent review showed that the overall risk of sepsis following RIRS was 5% [33]. That study identified modifiable risk factors for sepsis such as preoperative stent placement, positive urine culture, and longer procedural time. We analyzed postoperative complications by comparing dusting versus basketing and found no difference in sepsis, postoperative fever, or post-operative hematuria between the two lithotripsy techniques. The most important factor to prevent postoperative urinary tract infection is to obtain a sterile urine culture before surgery [2]. Additionally, increased intrarenal pressure is one of the main reasons that the bacteria in a colonized collecting system enter the bloodstream via the pyelovenous backflow [34]. To prevent any unwanted infectious side-effects due to high intrarenal pressures, UASs are used to provide an efficient outflow and decrease intrarenal pressure [35]. In our review, the utility of UAS was mentioned in four studies for both cohorts. The overall complication rates were similar for both groups with similar operative times. Therefore, our data support that both lithotripsy techniques

have the same safety profile and should not influence surgeon strategy when stratifying patients for RIRS. Akin to using a personalized stone approach in endoscopic combined intrarenal surgery, in RIRS too lithotripsy strategy should be decided as per the surgeon's experience, the technology available, the need for fragments for stone composition, and the patient's profile [36].

This study has some limitations. With a paucity of data for stone location and stone characteristics in the reported studies, no deductions could be made on which technique favors a particular stone type or location. All studies uniformly used Holmium laser with most studies clearly stating the preferences for laser settings. Although the risk of bias in the studies is acceptable, the definition of dusting and laser settings are all varied among the centers and even among surgeons within the same center, hence the pooled outcome of results from different studies will be less accurate unless individual patient data is put together and analyzed. Further, the heterogeneity in reporting of residual fragments size, and diversity in using imaging modality to determine SFR exposes the urgent need to populate consensus statements in guideline recommendations for RIRS so that prospective future studies have a uniform reporting of outcomes [37]. However, we have been able to highlight the utility of both techniques for

holmium lithotripsy alone. Whether the same will hold well with newer lasers like the TFL is yet to be seen. Furthermore, studies should also look at the cost analysis of different techniques to help urologists decide on the most cost and clinically effective technique [38].

CONCLUSIONS

Our meta-analysis infers that in RIRS with holmium laser lithotripsy at this point urologists can safely use either option of fragmentation and basket extraction or dusting alone without extraction to achieve similar outcomes for renal stones up to 2–2.5 cm as both techniques are similar for efficacy and safety. It is however possible that with newer and more powerful lasers, this balance may tilt in the future.

CONFLICTS OF INTEREST

Rodrigo Donalisio da Silva is a consultant for Lumenis. Jeremy Yuen-Chun Teoh had honorarium/lecture for: Astellas, Boston Scientific, Combat Medical, Ferring, Ipsen, Janssen, Olympus, Sanofi. Jeremy Yuen-Chun Teoh is a consultant for: Astellas, Combat Medical, Ferring, Janssen, MRI PRO. Jeremy Yuen-Chun Teoh had research grant from: Baxter, Janssen, Storz, Olympus, Bristol-Meyers Squibb, Merck Sharp & Dohme.

The remaining authors declare that they have no conflict of interest.

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