Urolithiasis (2013) 41:523–530
DOI 10.1007/s00240-013-0598-z

ORIGINAL PAPER

A comparison among four tract dilation methods of percutaneous nephrolithotomy: a systematic review and meta-analysis

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Received: 12 May 2013 / Accepted: 5 August 2013 / Published online: 23 August 2013

Abstract The purpose of this study was to evaluate the efficacy and safety of the Amplatz dilation (AD), metal telescopic dilation (MTD), balloon dilation (BD), and one-shot dilation (OSD) methods for tract dilation during percutaneous nephrolithotomy (PCNL). Relevant eligible studies were identified using three electronic databases (Medline, EMBASE, and Cochrane CENTRAL). Database acquisition and quality evaluation were independently performed by two reviewers. Efficacy (stone-free rate, surgical duration, and tract dilatation fluoroscopy time) and safety (transfusion rate and hemoglobin decrease) were evaluated using Review Manager 5.2. Four randomized controlled trials and eight clinical controlled trials involving 6,820 patients met the inclusion criteria. The pooled result from a meta-analysis showed statistically significant differences in tract dilatation fluoroscopy time and hemoglobin decrease between the OSD and MTD groups, which showed comparable stone-free and transfusion rates. Significant differences in transfusion rate were found between the BD and MTD groups. Among patients without previous open renal surgery, those who underwent BD exhibited a lower blood transfusion rate and a shorter surgical duration compared with those who underwent AD. The OSD technique is safer and more efficient than the MTD technique for tract dilation during PCNL, particularly in patients with previous open renal surgery, resulting in a shorter tract dilatation fluoroscopy time and a lesser decrease in hemoglobin. The efficacy and safety of BD are better than AD in patients without previous open renal surgery. The OSD technique should be considered for most patients who undergo PCNL therapy.

Keywords Percutaneous nephrolithotomy · Tract dilation · Renal surgery · Systematic review · Meta-analysis

Abbreviations

PCNL	Percutaneous nephrolithotomy
OSD	One-shot dilation
AD	Amplatz dilatation
MTD	Metal telescopic dilatation
BD	Balloon dilatation
RR	Risk ratio
OR	Odds ratio
MD	Mean difference
CI	Confidence interval

Introduction

Percutaneous nephrolithotomy (PCNL) was first reported more than 35 years ago by Fernström et al. [1]. In 1976, PCNL was widely used and became a technique for removing renal calculi. Currently, the technique has almost completely replaced open surgical procedures for the management of various types of renal stone disease and has become the gold standard [2]. Although it is a minimally invasive surgical procedure, tract dilation, one of the central procedures of PCNL, is also one of the most complicated. Furthermore, tract dilation is one of the major cost factors in PCNL [3, 4]. Normally, there are three standard

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tract dilation techniques for PCNL: Amplatz fascial dilation (AD) [5], metal telescopic dilation of the Alken type (MTD) [6], and balloon dilation (BD) [7].

However, improvements in tract dilation techniques have led to the introduction of some innovative dilation techniques. One-shot dilation (OSD) was first introduced by Frattini et al. [8]. Among these methods, BD is regarded as the most effective and safe, and it decreases the tract dilatation fluoroscopy time for patients and operators [9, 10]. In contrast, some scholars have reported that OSD is more effective and safer [11–13].

As a result, the better method for tract dilation during PCNL is controversial. Most reports relevant to dilation during PCNL come from clinical observational studies [10, 16–20, 27, 28]. Each of the four types of surgical methods has its own advantages and disadvantages and has been selected by different surgeons. Generally, the choice depends on surgeon experience. Therefore, we considered it necessary to perform a systematic review and meta-analysis to compare the efficacy and safety of the four tract dilation methods used during PCNL.

Materials and methods

Search strategy

Medline, EMBASE, and Cochrane central register of controlled trials (CENTRAL) were searched by two cooperators independently (Cao DH and Liu LR). The retrieval deadline was 10th January 2013. The search was performed from the following medical subject heading terms: (Percutaneous Nephrostomy or Nephrostomies, Percutaneous or Percutaneous Nephrostomies or Nephrolithotomy, Percutaneous or Nephrolithotomies, Percutaneous or Percutaneous Nephrolithotomies or Percutaneous Nephrolithotomy) and (tract dilation or tract dilatation or tract creation or nephrostomy tract or nephrostomy access or standard tract or one step or one-stage or one-shot or single increment dilation or Amplatz dilatation or Amplatz dilator or metal telescopic dilation or telescopic technique or balloon dilatation or balloon dilator or fascial dilator). Studies that compared the above-mentioned tract dilatation methods among patients who underwent PCNL for the treatment of kidney stones were eligible for inclusion. There were no language restrictions. A database search was performed and the reference lists of the identified articles and other publications were manually searched. All articles were searched independently by two reviewers, and titles and abstracts were screened by Cao DH and Liu LR, respectively. Discrepancies were resolved in consultation with Wei Q.

Our main outcomes were the stone-free rate, hemoglobin decrease, tract dilation fluoroscopy time, transfusion rate, and surgical duration. The stone-free rate was defined as all residual fragments of stone with a maximum diameter of <5 mm as evaluated by ultrasonography or kidney–ureter–bladder radiography after the first postoperative visit. Tract dilatation fluoroscopy time was defined as the number of seconds of X-ray exposure that elapsed from the time of insertion of the guidewire until placement of the sheath. Hemoglobin decrease was defined as the change in hemoglobin from before the surgical procedure to 12–24 h after surgery. Stone burden was defined as the maximum diameter of the stone on ultrasonography or plain radiography.

Quality assessment

The relevant data from the included studies were extracted by two independent reviewers (Cao DH and Liu LR). When the relevant data were missed, we attempted to contact the study authors to obtain more information; otherwise, lost data were calculated by estimation. The quality of the included randomized controlled trials was assessed independently by Cao DH and Liu RL using the Cochrane Collaboration's tool [14] by recording the assessment of sequence generation, allocation concealment, blinding, incomplete outcome data, free of selective reporting, and other bias. Clinically controlled trials were assessed using a modification of the Newcastle–Ottawa Scale [15]. Review scores ranged from 0 to 9 points for each trial. Scores ranging from 0 to 4 were defined as low-quality scores, while those ranging from 5 to 9 were defined as high-quality scores. Discrepancies were resolved in consultation with Wei Q.

Analysis

Statistical analysis was performed using Review Manager (RevMan) software version 5.2 (Cochrane Collaboration, Oxford, UK). The χ^2 test with *N-1* degree of freedom and I^2 statistic were used to assess the heterogeneity, with a P value of 0.05 and an α of 0.10 used for the I^2 statistic and statistical significance. A P value of <0.05 was considered to be statistically significant. When the I^2 value was <60 %, heterogeneity was acceptable. In trials with a lack of heterogeneity, a fixed-effect model was used for the meta-analysis, or a random effects model was used. The odds ratio (OR) or relative risk (RR) was used to evaluate the dichotomous data, and the mean difference (MD) was used to evaluate the continuous data. For comparison of stone-free and transfusion rates between the OSD and MTD groups, the RR with a 95 % confidence interval (CI) was used. For comparison of blood transfusion rates between the BD and AD groups and between the BD and MTD groups, an OR with a 95 % CI was used. For hemoglobin decrease, tract dilatation fluoroscopy time, and surgical duration, the MD was calculated with a 95 % CI. Sensitivity analysis was implemented to explain the existence of significant heterogeneity.

Results

Study characteristics

After a study assessment, four randomized controlled trials [8, 11–13] and eight clinically controlled trials [10, 16–20, 27, 28] involving 6,820 patients met the inclusion criteria from the electronic databases and manual searches. The included literature screening process is summarized in Fig. 1. Three of the included studies [11–13] compared the OSD with MTD methods; four [10, 17–19] compared the BD and AD methods; one [8] compared the MTD, BD, and OSD methods; three [16, 27, 28] compared the MTD and BD methods; and one [20] compared the AD and MTD methods. Basic features and quality assessments of the included studies are summarized in Table 1.

Efficacy

Stone-free rate

Four studies [8, 11–13] involving 346 patients compared postoperative stone-free rates after tract dilation during PCNL. The pooled result of the meta-analysis demonstrated no statistically significant differences between the OSD and MTD groups (fixed-effect model; RR = 0.97; 95 % CI = 0.89–1.05; $P = 0.44$). Statistical heterogeneity was not indicated in the pooled analysis ($P = 0.53$; $I^2 = 0$ %; Fig. 2a).

Surgical duration

Three studies [10, 17, 18] involving 504 patients compared the surgical duration between the BD and AD groups. No statistically significant differences were observed between the BD and AD groups (fixed-effect model; MD = −7.10; 95 % CI = −14.86–0.66; $P = 0.07$). No statistical heterogeneity difference was indicated in the meta-analysis ($P = 0.57$; $I^2 = 0$ %; Fig. 2b). After deleting the data of Gönen et al. [18], the sensitivity analysis demonstrated a statistically significant difference in surgical duration between the BD and AD groups (fixed-effect model; MD = −9.80; 95 % CI = −19.03 to −0.56; $P = 0.04$; $I^2 = 0$ %). This shows that the meta-analysis was affected by the studies.

Tract dilatation fluoroscopy time

Four studies [8, 11–13] involving 346 patients compared the tract dilatation fluoroscopy time between the OSD and MTD groups. A meta-analysis of four studies showed that OSD was associated with a significantly shorter tract

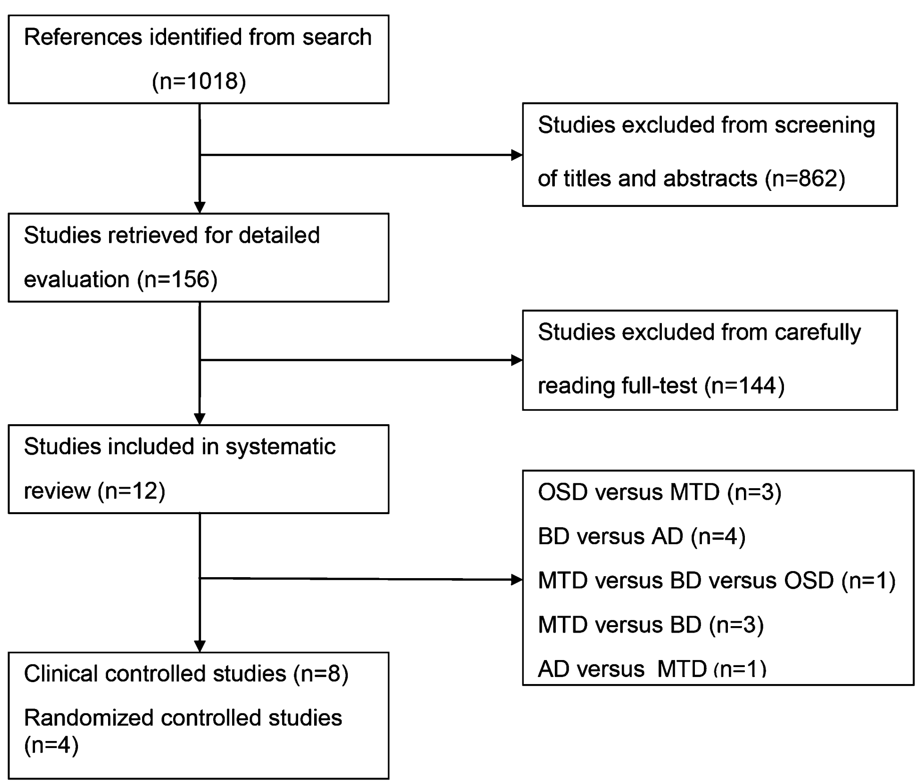

Fig. 1 The literature screening process

Table 1 Basic features and quality assessment of included studies

Study	Intervention	I/C M:F	Mean age (years)	SB (cm)	SS (right: left)	Staghorn calculi (n)	PORS (I/C)	Design	Sheath size (F)	Summary assessments of the risk of bias or total score
Amjadi et al. [11]	OSD VS MTD	10:7/12:2	42/44	3.7/3.2	8:9/6:8	41/29	22/9	RCT	28/28	Low risk
Falahatkar et al. [12]	OSD VS MTD	56:46/62:50	57/51	3.9/3.4	52:50/68:44	ND	23/14	RCT	30/30	Low risk
Aminsharifi et al. [13]	OSD VS MTD	19:10/9:10	44/42	2.7/3.1	11:18/8:11	5/6	0/0	RCT	30/30	Low risk
Frattini et al. [8]	MTD VS BD VS OSD	15:12/8:17/17:9	54/52/59	2.9/2.1/2.3	14:13/11:14/15:11	ND	0/0/0	RCT	34/34/34	Low risk
Wezel et al. [16]	MTD VS BD	61:39/46:54	51.5/52	2.6/2.1	40:60/49:51	ND	11/40	CCT	30/30	5
Davidoff et al. [10]	BD VS AD	50/100	47/47	ND	ND	ND	ND	CCT	34/34	4
Safak et al. [17]	BD VS AD	59:36/18:12	42.7/46.2	ND	ND	ND	0/0	CCT	32/32	4
Gönen et al. [18]	BD VS AD	28:14/121:66	45.2/49.4	3.7/3.4	ND	ND	8/23	CCT	34/34	5
Kalpee et al. [19]	AD VS BD	10/10	55.9/48.8	2.0/2.0	ND	4/4	ND	CCT	30/33	4
Ozok et al. [20]	AD VS MTD	24:43/57:64	47/49	2.9/3.0	24:43/60:61	ND	5/10	CCT	30/30	5
Lopes et al. [27]; Yamaguchi et al. [28]	BD VS MTD	1234:1043/1881:1379	50.8/48.8	ND	ND	706/825	ND	CCT	<14–30	4

I/C intervention group/control group, *M:F* male: female, *SB* stone burden, *SS* stone side, *PORS* previous open renal surgery, *ND* not depicted, *OSD* one-shot dilatation, *MTD* metal telescopic dilatation, *BD* balloon dilatation, *AD* Amplatz dilatation, *VS* versus, *RCT* randomized controlled trial, *CCT* clinical controlled trial

dilatation fluoroscopy time compared with MTD (fixed-effect model; MD = −41.69; 95 % CI = −43.50 to −39.87; $P < 0.00001$); statistical heterogeneity was acceptable ($P = 0.07$; $I^2 = 58$ %; Fig. 2c).

Safety

Blood transfusion rate

Four studies [8, 11–13] involving 346 patients have compared blood transfusion rates between the OSD and MTD groups. Although not statistically significant, the result of the meta-analysis showed that the OSD group was associated with a lower transfusion rate (fixed-effect model; RR = 0.62; 95 % CI = 0.20–1.96; $P = 0.42$). Statistical heterogeneity was not indicated in the pooled analysis ($P = 0.91$; $I^2 = 0$ %; Fig. 3a).

Three studies [10, 17, 18] involving 504 patients compared blood transfusion rates between the BD and AD groups. Although not statistically significant, the results of the meta-analysis showed that the BD group was associated with a lower transfusion rate (fixed-effect model; OR = 0.61; 95 % CI = 0.35–1.07; $P = 0.08$). Statistical heterogeneity was not indicated in pooled analysis ($P = 0.34$; $I^2 = 8$ %; Fig. 3b). After deleting the data of Gönen et al. [18], sensitivity analysis showed that there was a statistically significant difference between the BD and AD groups (fixed-effect model; OR = 0.47; 95 % CI = 0.23–0.98; $P = 0.04$; $I^2 = 20$ %). This indicated that the meta-analysis was influenced by the studies.

Four studies [8, 16, 27, 28] involving 5,789 patients compared blood transfusion rates between the BD and MTD groups. The result of meta-analysis showed that BD was associated with a significantly higher transfusion rate (fixed-effect model; OR = 1.51; 95 % CI = 1.21–1.89; $P = 0.0003$). Statistical heterogeneity was not indicated in the pooled analysis ($P = 0.32$; $I^2 = 12$ %; Fig. 3c).

Hemoglobin decrease

Three studies [8, 11, 13] involving 132 patients compared hemoglobin decrease between the OSD and MTD groups.

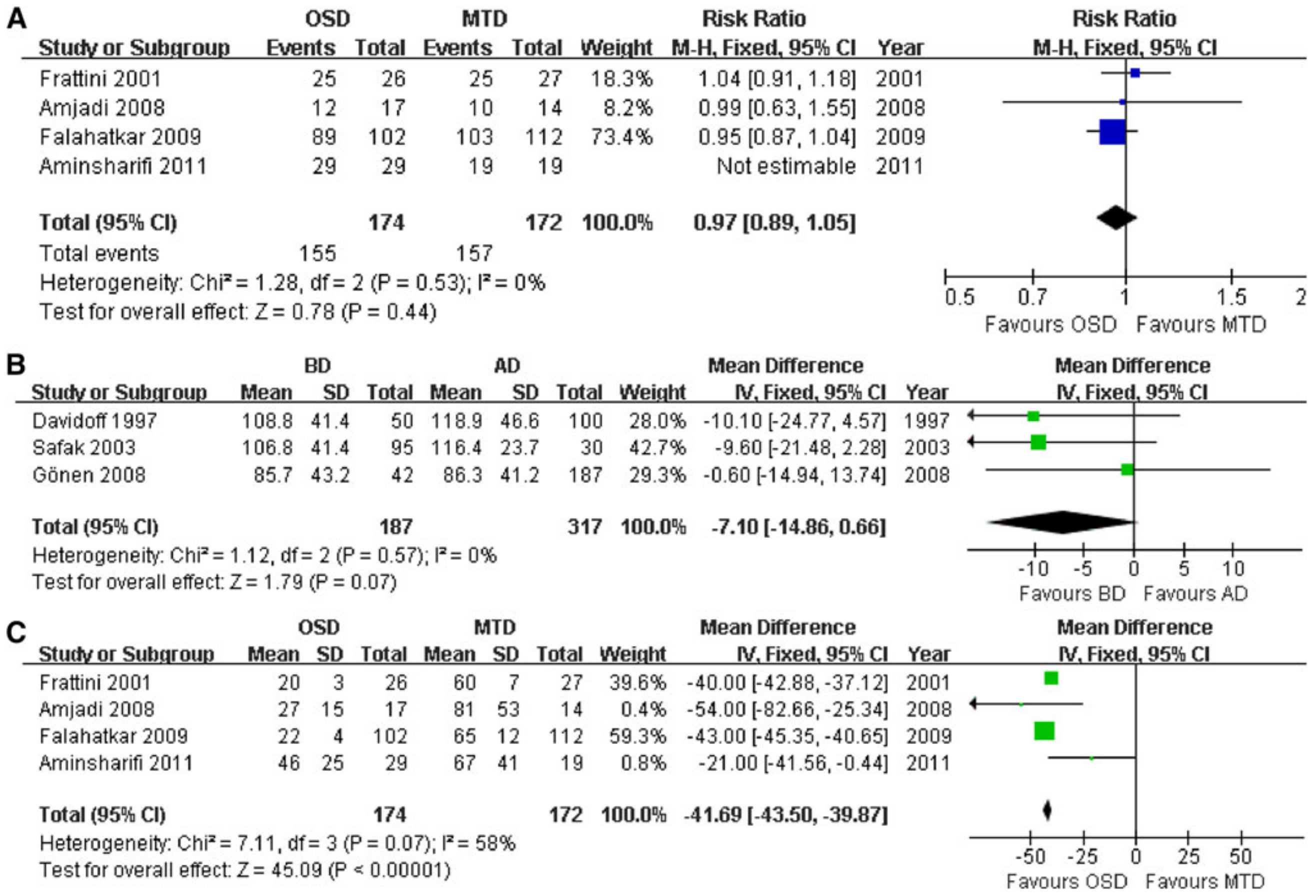

Fig. 2 **a** Pooled estimate of stone-free rate between OSD and MTD using fixed-effect model. **b** Pooled estimate of surgical duration between BD and AD using fixed-effect model. **c** Pooled estimate of tract dilatation fluoroscopy time between OSD and MTD group using fixed-effect model

The result of the meta-analysis showed a lower decrease in the OSD groups than in the MTD groups (fixed-effect model; MD = −0.34; 95 % CI = −0.67 to −0.00; $P = 0.05$). No heterogeneity was observed in the pooled analysis ($P = 0.93$; $I^2 = 0$ %; Fig. 3d).

Two studies [10, 18] involving 379 patients compared hemoglobin decrease between the BD and AD groups. Although not statistically significant, the result of the meta-analysis showed that BD was associated with a lower decrease in hemoglobin (fixed-effect model; MD = −0.30; 95 % CI = −0.65–0.05; $P = 0.10$). No statistical heterogeneity was indicated in the pooled analysis ($P = 1.00$; $I^2 = 0$ %; Fig. 3e).

Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis evaluating the efficacy and safety of four tract dilation methods used during PCNL. In our systematic review and meta-analysis, we included all relevant eligible studies to decrease the confounding variables, decrease bias, and extract data in the most effective manner. After evaluating the studies identified from the databases, four randomized controlled trials [8, 11–13] met the inclusion criteria. We are aware of the many limitations in performing randomized controlled trials of surgical procedures, and common surgical procedures are less likely to be based on this evidence [21, 22]. To enlarge the populations of the included studies, eight assessed clinical controlled trials [10, 16–20, 27, 28] met the inclusion criteria.

The main findings of our meta-analysis were that OSD can significantly decrease tract dilatation fluoroscopy time and lower the hemoglobin decrease compared with MTD, particularly in patients with a history of previous open nephrolithotomy. In other words, our results indicate that OSD is effective and safe for patients who have previously undergone open nephrolithotomy. The results clearly showed that there were no significant differences in stone-free and blood transfusion rates between the two groups. The results are consistent with other previous studies [11, 12]. Although rare, conditions for OSD was reportedly unsuited, which can be divided into two main types: kidney

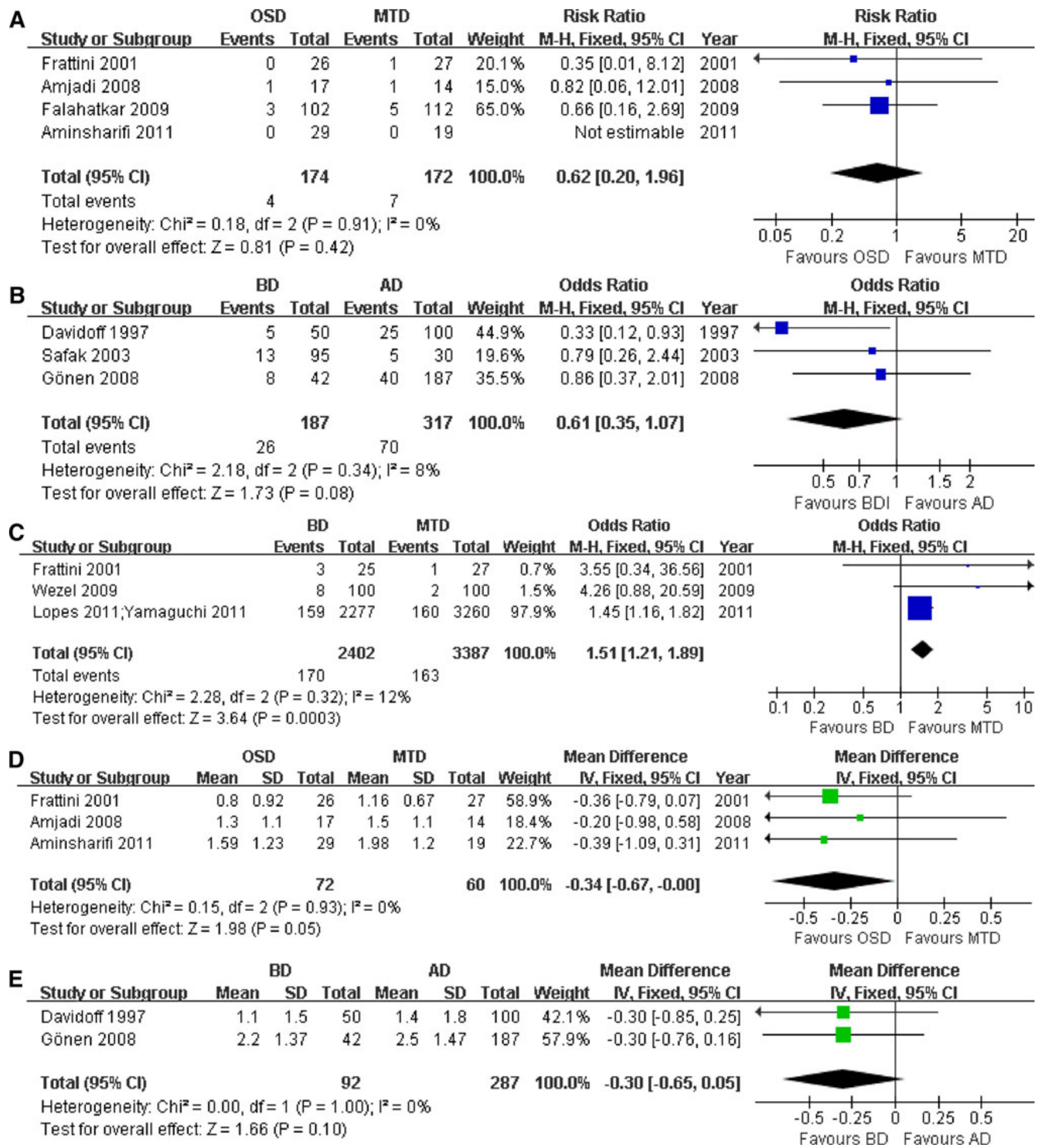

Fig. 3 **a** Pooled estimate of blood transfusion rate between OSD and MTD using fixed-effect model. **b** Pooled estimate of blood transfusion rate between BD and AD using fixed-effect model. **c** Pooled estimate of blood transfusion rate between BD and MTD using fixed-effect model. **d** Pooled estimate of hemoglobin decrease between OSD and MTD using fixed-effect model. **e** Pooled estimate of hemoglobin decrease between BD and AD using fixed-effect model

hypermobility, which led to avulsion of the entire tissue because of the strength exerted on the vessel pedicle, and heavy resistance of the densely scarred tissue in a previous open renal surgery that prevented the OSD process, necessitating excessive force to dilate the fascia and resulting in kidney bleeding [8]. However, according to our meta-analysis, showed OSD did not lead to more hemorrhages. OSD was clearly proven to be more effective and safer than MTD, even in patients with previous open renal surgery.

Some studies reported that BD was associated with a shorter surgical duration, a lower blood transfusion rate, and a lower hemoglobin decrease compared with AD [10, 17, 23]. They considered the following reason for these findings. An inflated balloon supports sustained pressure and tamponades the small vessels that are usually injured during procedures. Significant bleeding may happen frequently during the sequential exchange of AD, but the tamponade effect of the inflated balloon cannot occur with AD [19]. In addition, the tract can be dilated quickly using BD in one step; therefore, BD requires a shorter surgical duration, results in less blood loss, and is less traumatic to the tract [10, 24, 25]. In our meta-analysis, although not statistically significant, the BD groups exhibited a shorter surgical duration, a lower blood transfusion rate, and a lower hemoglobin decrease compared with the AD groups. To our surprise, after deleting the study data of Gönen et al. [18], which enrolled patients with a history of previous open nephrolithotomy, a statistically significant difference was found between the BD and AD groups. The BD group was associated with a shorter surgical duration and a lower blood transfusion rate. That is to say, efficacy and safety were decreased in patients with prior open renal surgery who underwent BD during PCNL. The result was confirmed by the study [26]. The reason for this finding is that patients with a previous history of open renal surgery exhibited serious resistance of fascial layers, which prevented BD passage. Therefore, BD was more effective than AD in patients without previous open renal surgery.

BD is also reported to be associated with a lower blood transfusion rate compared with MTD [29]. However, the results of the meta-analysis showed that BD was associated with a significantly greater blood transfusion rate compared with MTD. In addition, results of the Global PCNL Study involving 5,537 patients also showed a greater transfusion rate in the BD group than in the MTD group [27, 28]. Differences in results may be influenced by patient heterogeneity, including a history of previous open renal surgery, in addition to the number of staghorn stones, stone burden, and stone location, which are all more frequently associated with BD.

By and large, OSD was safe and effective in all the patients. BD was much safer and more effective than AD and MTD in patients without previous open renal surgery. That is, the effectiveness and safety of BD were lower than those of AD and MTD in patients with densely scarred tissue. The advantages of MTD are that it is an effective dilator, and it can dilate even if severe perirenal fibrosis is present after previous surgery. The disadvantages of MTD are that it can cause considerable damage and bleeding. The advantages of AD are that trauma to the renal collecting system is theoretically less likely with this procedure than with MTD; however, the disadvantage is that hemorrhage may occur each time a dilator is withdrawn [30]. Because of the limited number of studies available, differences between AD and MTD were not calculated in this meta- analysis. There was only one study comparing the difference between the two groups [20], and further research is required to clarify these differences.

Our review also has some limitations. The evaluation of quality was compromised by the lack of sufficient information in publications or the presence of methodology differences between studies. Several studies did not report the stone-free rate, the blood transfusion rate, etc. These studies did not provide sufficient statistical data and we were unable to obtain relevant data by contacting authors, which may have led to a risk of bias. However, we used sensitivity analysis to explore the influencing factors, which did not significantly change the conclusion. Nonetheless, the statistical heterogeneity and the risk of bias still existed and may have skewed the results. The differences in results may be influenced by patient heterogeneity, including previous open nephrolithotomy, the number of stones treated, stone location, stone burden, rate of staghorn calculi, small sample size, and other factors.

Nonetheless, a large number of multicenter randomized controlled trials of high quality are still required to explore the differences among OSD, MTD, BD, and AD.

Conclusions

Our meta-analysis showed that OSD was safer and more effective than MTD for tract dilation during PCNL, particularly in patients with previous open renal surgery, resulting in a shorter tract dilatation fluoroscopy time and a lower hemoglobin decrease. The efficacy and safety of BD were better than AD in patients without previous open renal surgery. OSD should be considered for most patients who undergo PCNL therapy. However, multicenter randomized controlled trials are needed to confirm the outcomes of this study.

Acknowledgments The authors would like to thank their colleagues and staff in the Chinese Cochrane Centre for their support and help. This research was funded by the National Natural Science Foundation of China (Grant No. 81200551).

Conflict of interest No competing financial interests exist.

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