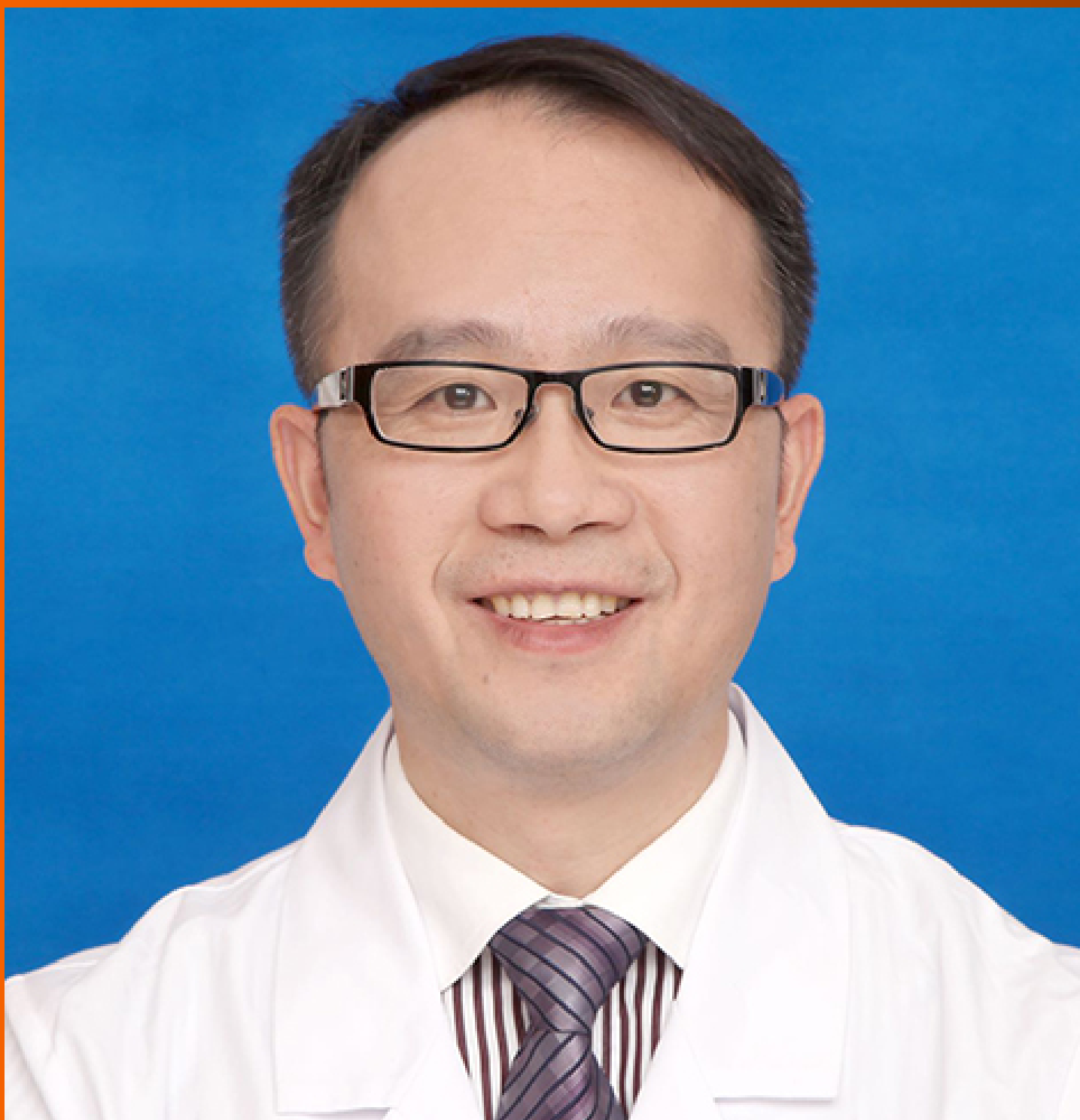


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Pulsed lavage in joint arthroplasty: A systematic review and meta-analysis

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Abstract

BACKGROUND

Knee and hip osteoarthritis affects millions of people around the world and is expected to rise even more in frequency as the population ages. Joint arthroplasty is the surgical management of choice in these articulations. Heterotopic ossification and radiolucent lines formation are two frequent problems faced in hip and knee replacements respectively. Some studies show that the usage of pulsed lavage may prevent their formation.

AIM

To compare pulsed lavage to standard lavage in joint arthroplasty.

METHODS

PubMed, Cochrane, and Google Scholar (page 1-20) were searched till December 2023. Only comparative studies were included. The clinical outcomes evaluated were the heterotopic ossification formation in hip replacements, radiolucent lines formation, and functional knee scores in knee replacements.

RESULTS

Four studies met the inclusion criteria and were included in this meta-analysis. Pulsed lavage was shown to reduce the formation of radiolucent lines ($P = 0.001$). However, no difference was seen in the remaining outcomes

CONCLUSION

Pulsed lavage reduced the formation of radiolucent lines in knee replacements. No difference was seen in the remaining outcomes. Furthermore, the clinical significance of these radiolucent lines is poorly understood. Better conducted randomized controlled studies and cost-effectivity studies are needed to reinforce these findings.

Key Words: Knee arthroplasty; Hip arthroplasty; Pulsed lavage; Syringe lavage; Heterotopic ossification; Radiolucent lines

Core Tip: Pulsed lavage may be important in total knee arthroplasty but has no added benefit in total hip arthroplasty.

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INTRODUCTION

With the advancements in medicine, people's average life expectancies are rising[1]. Between 2000 and 2050, there will be a 135% increase in the population above the age of 65[2]. The World Health Organization has identified four chronic musculoskeletal illnesses as conditions whose prevalence will increase as the population ages. Two of these conditions are osteoarthritis (OA) and rheumatoid arthritis (RA), which both affect millions of individuals worldwide[3]. When conservative treatment for RA and OA has failed and a person's overall quality of life is continuing to decline, total hip arthroplasty (THA) and total knee arthroplasty (TKA) is the surgical management of choice[4-10]. In fact, Joint arthroplasty is as an effective intervention to relieve pain and improve joint function[11-13]. Furthermore, gait is the most common activity to be affected in patients prior to undergoing joint replacement surgery[14-18]. Different prosthetic materials can be used in joint replacement which can also impact the gait and functional outcomes post-operatively, and can be assessed by computational simulation[19-23]. The By 2030, it is predicted that the United States would undertake over 3.5 million primary TKA procedures yearly and close to 600000 main THA procedures[1].

The lifespan of the implants depends on improvements in cement penetration and implant stability in hip and knee arthroplasty[24]. Pulsed lavage (PL) can be used to achieve this[24]. Radiolucent lines are a common observation at the cement-bone interface in TKA[25]. However, the clinical outcome does not appear to be impacted by the radiolucent lines, though[26]. The majority of radiolucent lines are 1 mm wide and have a radioopaque sclerotic border. Pathological radiolucent lines, on the other hand, are larger than 2 mm and have ill-defined edges[27]. Another problem in THA is the formation of heterotopic ossification (HO). PL may stop HO development by removing the nascent mesenchymal cells from the hip joint and gluteal muscles[28].

Despite numerous publications about the efficacy of PL in the field of surgery, there is no meta-analysis about its effectiveness in Joint Arthroplasty (JA). Therefore, this meta-analysis is designed to compare PL to standard lavage (SL) in JA.

MATERIALS AND METHODS

Search strategy

This study followed the PRISMA guidelines. PubMed, Cochrane, and Google Scholar (page 1-20) were searched updated to December 2023 for the qualified studies in order to study the efficacy of PL in JA using the following keywords and Boolean operators "puls*" AND "knee" OR "hip". Literature was also identified by tracking reference lists from papers and Internet searches. One investigator (MD) extracted the data, and another investigator (AS) confirmed the choice of the articles. The process is summarized in the PRISMA flowchart (Figure 1).

Inclusion criteria were: (1) Comparative studies: randomized controlled trails, retrospective comparative studies, prospective clinical trials; (2) patients operated with a total or partial knee or hip replacement; and (3) Pulsed lavage was used in the first group compared to standard lavage in another group. The studies with the following characteristics were excluded from this study: (1) Case reports, narrative or systematic reviews, theoretical research, conference report, meta-analysis, expert comment, and economic analysis; and (2) non-relevant outcomes.

Data extraction

Two reviewers determined the eligibility of the studies independently. Extraction of the analyzed data was made from the included studies and it consisted of two parts. The first part consisted of the basic information containing the name of the authors, the title, the publication year, the journal, the volume, the issue, the pages, the study design, the sample size along with the size of each group of management, and the different types of bias suspected in each study. The second part consisted of the clinical outcomes the formation of HO, radiolucent lines formation, and functional knee scores. Any arising difference between the investigators was resolved by discussion.

Risk of bias assessment

The Cochrane risk-of-bias tool was used by two writers (MD and AS) to independently assess the risk of bias. The following factors were taken into consideration when determining whether a trial had a high, low, or unclear risk of bias: Random sequence generation, allocation concealment, blinding of participants and study workers to the research

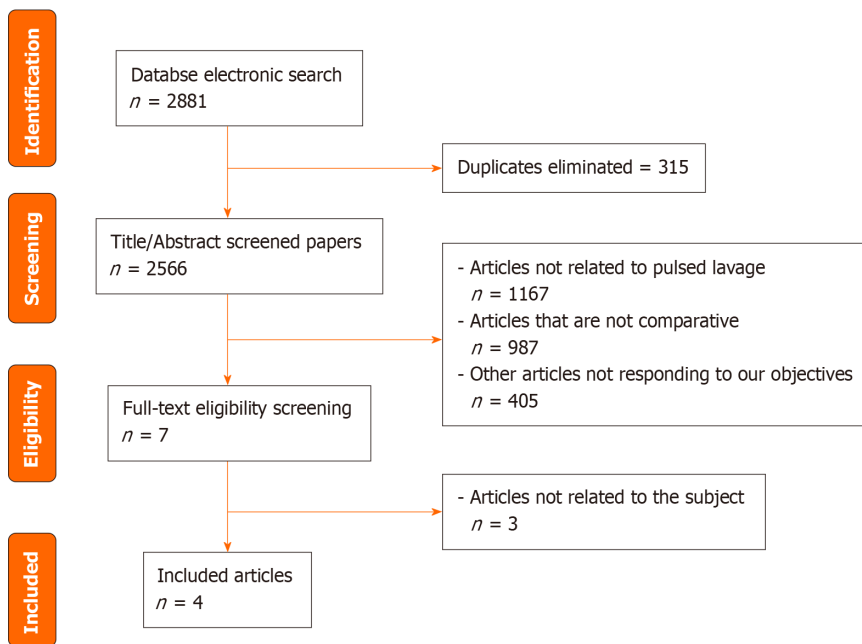


Figure 1 PRISMA flowchart for article selection process.

procedure, blinding of outcome assessment, inadequate outcome data, and selective reporting (Figure 2A and B). Trials that had a high risk of bias for more than one key domain were deemed to have a high risk of bias, while those that had a low risk of bias for every key domain were deemed to have a low risk of bias. If neither of these conditions were met, the trials were deemed to have an unclear risk of bias. For non-randomized studies, the ROBINS-I tool for assessing risk of bias in non-randomized studies of interventions was used[29]. Studies that had a critical risk of bias were excluded.

Statistical analysis

The statistical analysis was performed using Review Manager 5.4 (The Cochrane Collaboration, 2020). For continuous data, 95% confidence intervals (CI) and standardized mean differences were utilized, while risk ratio with 95% CI was used for dichotomous data. Q tests and I^2 statistics were used to evaluate heterogeneity indicating considerable heterogeneity if $P \leq 0.10$ or $I^2 > 50\%$. High levels of variability were handled by the use of the random-effects model. On the other hand, the fixed-effect model was chosen if $P > 0.10$ or $I^2 < 50\%$. Statistical significance threshold was chosen at $P = 0.05$.

RESULTS

Characteristics of the included studies

Four studies[24,28,30,31] met the inclusion criteria and were included in the meta-analysis with 2 randomized controlled trials and 1 prospective non-randomized study, and 1 retrospective comparative study. It involved 185 subjects in the PL group and 182 subjects in the SL group. The main characteristics of the included studies are summarized in Table 1.

Bias results

The risk of bias assessment is presented in Figure 2A and B and Table 2. There were no high bias risks, they were either low, moderate, or unclear.

Heterotrophic ossification

Two studies on 181 subjects (87 PL vs 94 SL) reported data on post-operative HO formation. The results showed no differences between PL and SL in overall HO formation (Odds ratio = 0.76; 95% CI = 0.42–1.36, $P = 0.35$, Figure 3A), Brooker grade 1 HO formation (Odds ratio = 1.02; 95% CI = 0.39–2.67, $P = 0.96$, Figure 3B), Brooker grade 2 HO formation (Odds ratio = 1.23; 95% CI = 0.49–3.08, $P = 0.65$, Figure 3C), Brooker grade 3 HO formation (Odds ratio = 0.36; 95% CI = 0.12–1.08, $P = 0.07$, Figure 3D), and Brooker grade 4 HO formation (Odds ratio = 0.76; 95% CI = 0.14–4.05, $P = 0.75$, Figure 3E).

Radiolucent lines

Two studies on 186 (98 PL vs 88 SL) subjects reported data on radiolucent lines formation. The results showed that when compared to SL, PL significantly reduces the formation of radiolucent lines (Odds ratio = 0.29; 95% CI = 0.14–0.61, $P = 0.001$, Figure 4).

Table 1 Main characteristics of the included studies

| Ref. | Methods | Participants | | Mean age (SD) | | Measured outcomes | Follow-up time |
|------------------------------------|---------------------------------------|--------------|----|---------------|--------|---|----------------|
| | | PL | SL | PL | SL | | |
| Abdeldayem <i>et al</i> [24], 2018 | Prospective randomized comparison | 44 | 42 | 64, NA | 64, NA | Knee society score, knee function score, radiolucent lines | 12 months |
| Clarius <i>et al</i> [30], 2009 | Prospective non-randomized comparison | 54 | 46 | 63, NA | 68, NA | Knee society score, knee function score, Oxford knee score, radiolucent lines | 22 months |
| Mellema <i>et al</i> [28], 2011 | Retrospective comparison | 39 | 48 | 62; 9 | 55; 10 | Rate of heterotopic ossification | 14 months |
| Sneath <i>et al</i> [31], 2001 | Prospective randomized comparison | 48 | 46 | 71, NA | 73, NA | Rate of heterotopic ossification | 12 months |

PL: Pulsed lavage; NA: Not available; SL: Standard lavage.

Table 2 Bias assessment of the included studies

| Studies | Confounding bias | Selection bias | Classification bias | Bias due to deviation from interventions | Bias due to missing data | Bias in measurement of outcomes | Bias in selection of reported results | Results |
|---------------------------------|------------------|----------------|---------------------|--|--------------------------|---------------------------------|---------------------------------------|---------------|
| Clarius <i>et al</i> [30], 2009 | Low risk | Low risk | Low risk | Low risk | Low risk | Moderate risk | Low risk | Moderate risk |
| Mellema <i>et al</i> [28], 2011 | Low risk | Low risk | Low risk | Low risk | Low risk | low risk | Low risk | Low risk |

Knee functional scores

Two studies on 186 subjects (98 PL *vs* 88 SL) reported data on knee functional scores. The results showed no difference between PL and SL in knee society score (Mean difference= -0.01; 95%CI = -4.85–4.84, $P = 1.0$, Figure 5A) and knee function score (Mean difference = 3.85; 95%CI -2.53–10.23, $P = 0.24$, Figure 5B).

DISCUSSION

Total joint arthroplasties are expected to increase over time due to the aging population and obesity. A commonly faced adverse events in such procedures is the formation of HO in hip replacements and radiolucent lines formation in knee replacements. The efficacy of PL and preventing such problems has been studied in JA. However, this is the first meta-analysis assessing the efficacy of PL in both knee and hip replacements. The outcomes of this meta-analysis can be divided into three section: HO formation, radiolucent lines, and knee functional scores. Pulsed Lavage reduced the formation of radiolucent lines. However, no differences were seen in the remaining outcomes.

Our results showed no difference in HO formation between PL and SL. A study by Mellema *et al* [28] showed a beneficial effect of PL in preventing Brooker grade 3–4 HO however this may be limited by the low numbers in such high HO grades. The etiology of this pathology is still unclear. It is said that it might be from the mesenchymal pluripotential stem cells that are released by the bone during the surgery acting as a stimulus [32,33]. If that was the case, then PL should have a beneficial effect on HO formation. The lack of correlation between HO formation and PL suggests another mechanism. Pellegrini *et al* [34] showed that a pre-operative radiotherapy directed at the soft tissue around the hip reduced the rate of HO formation which may draw the conclusion that the osteogenic precursors responsible of HO are derived from the soft tissue and not the bone debris.

No difference in knee functional scores were seen between SL and PL, however the latter reduced the formation of radiolucent lines in knee replacement. After cemented TKA, there are two types of tibial radiolucency that can be found. In the first year post-operatively, physiological radiolucency is a frequent but common observation [24]. It does not progress or compromise the stability of the implant. Physiologic radiolucency has a sclerotic border and a thickness of no more than 1 mm on radiographs. On the other hand, pathological radiolucency typically has edges that are not sclerotic and is thicker than 2mm. These radiolucent lines are signs of septic or aseptic loosening and influence implant stability because they progress over time [24]. Abdeldayem *et al* [24] and Clarius *et al* [30] showed that the cement penetration was deeper in the PL group which could explain the lower rate of radiolucency observed when PL was used. This can be explained by the cancellous bone becoming more porous following jet lavage and then becoming much more thoroughly penetrated by bone cement [24]. However, the clinical significance of these radiolucent lines is still poorly understood [26].

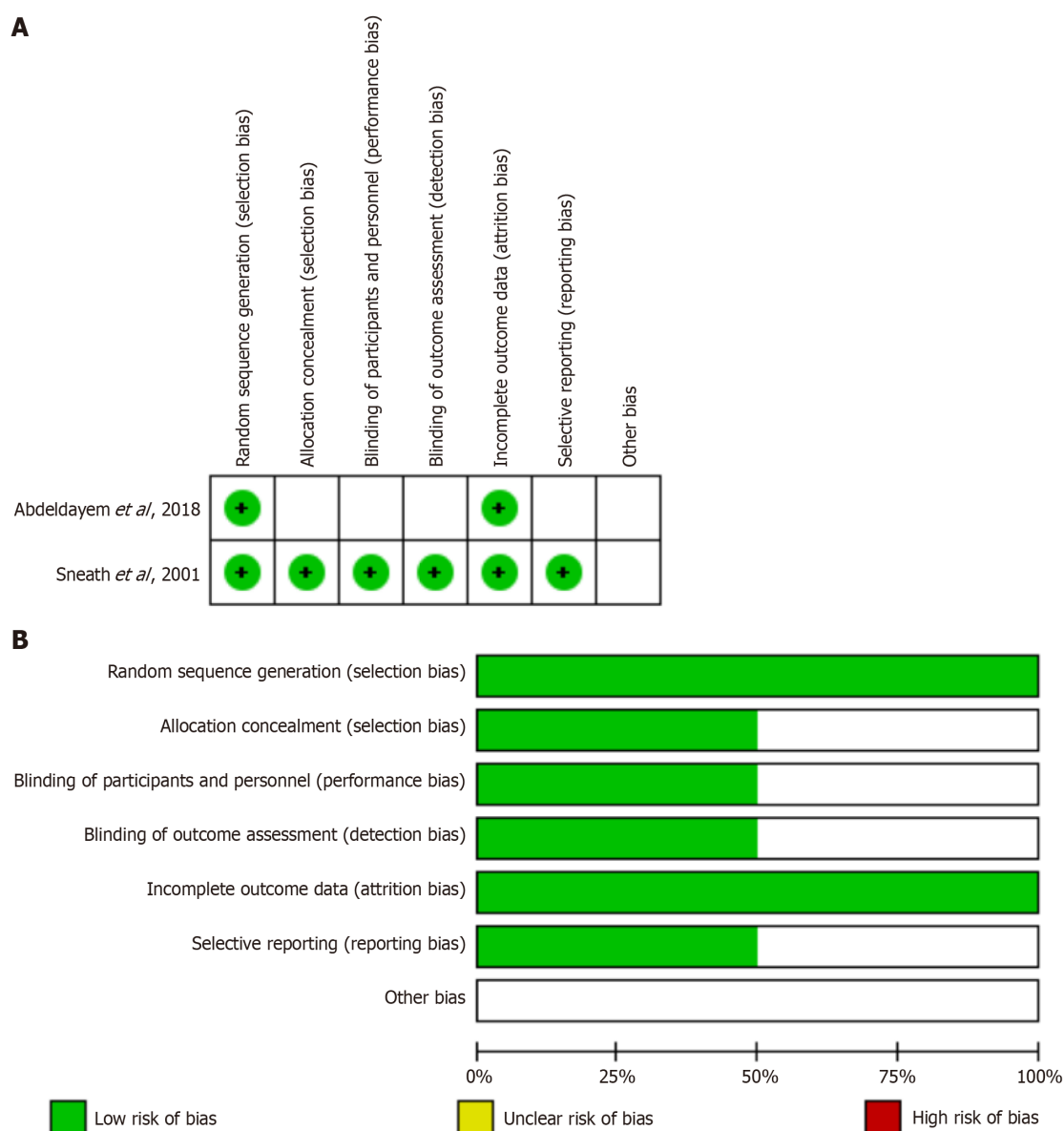


Figure 2 Risk of bias. A: Risk of bias summary: review authors' judgements about each risk of bias item for each included study; B: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

In fact, radiolucency is present in all loose knee implants, but not all implants that have radiolucency are loose[26]. And seeing that there are no differences in the functional scores, one might wonder about the benefit of using PL in knee replacement.

Strengths and limitations

This study has several strengths: It is the first meta-analysis comparing PL to SL in JA. Moreover, only comparative studies were included reducing the risk of operative and matching bias. Finally, the selection process was more selective. This makes the study less heterogenous and decreases the risk of bias. However, this study had also limitations: There weren't that many comparative studies in the literature to include; Inclusion and exclusion criteria for patients were different; the number of included studies is limited and the data used for analysis was pooled and individual patients' data were unavailable, and this could limit more comprehensive analyses.

CONCLUSION

This is the first meta-analysis comparing pulsed lavage to standard lavage in partial or total knee and hip arthroplasty. It showed that pulsed lavage reduced the formation of radiolucent lines in knee replacement. No difference was seen in the remaining outcomes when compared to standard lavage. The decrease in radiolucent lines formation may be associated to a better cement penetration however, the clinical significance of these lines is still questionable. Nevertheless, more randomized controlled studies and cost-effectivity studies are needed to confirm the benefits of this lavage technique.

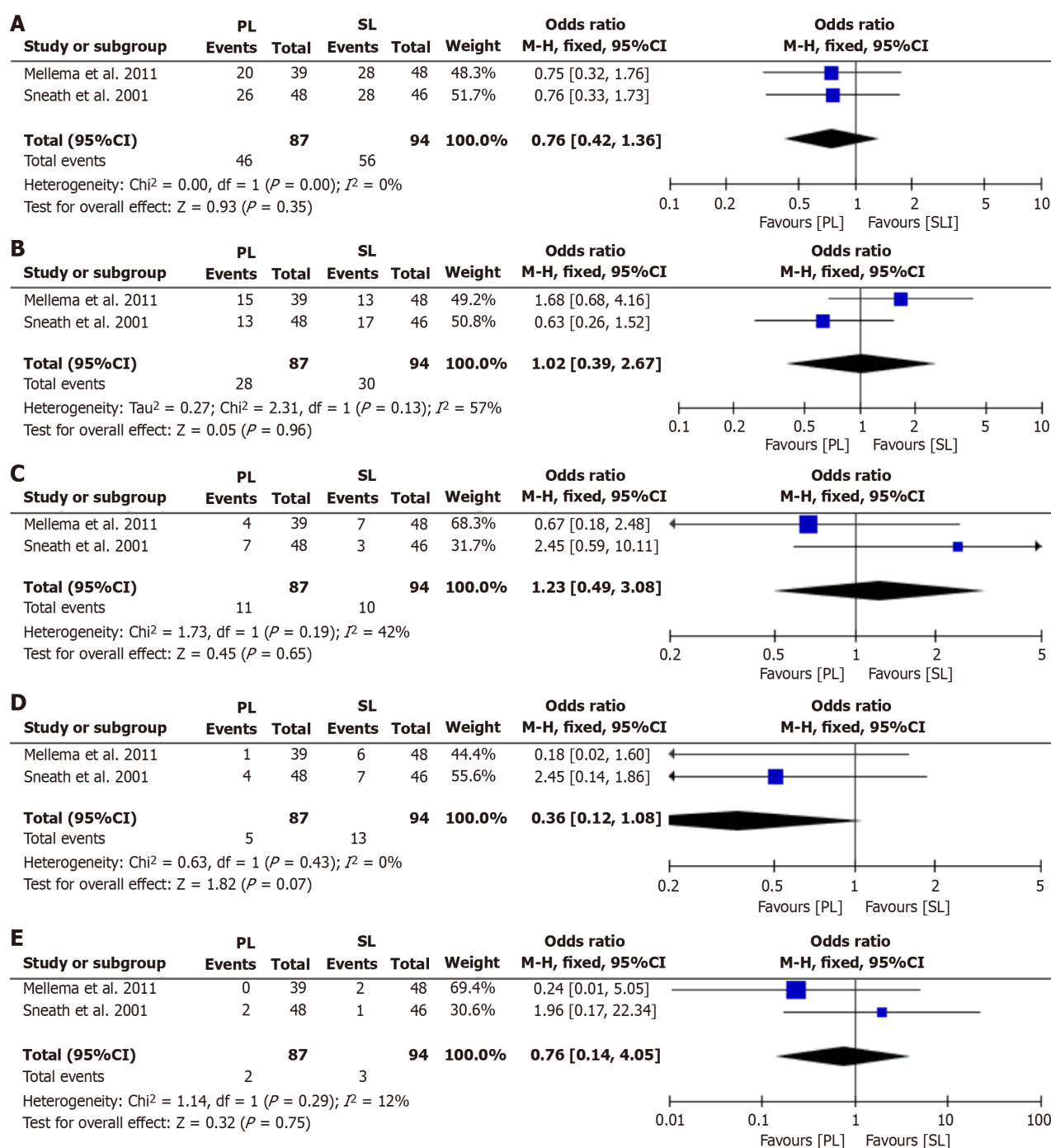


Figure 3 Forest plot. A: Forest plot showing the overall heterotopic ossification (HO) formation in pulsed lavage (PL) and standard lavage (SL); B: Forest plot showing the Brooker grade 1 HO formation in PL and SL; C: Forest plot showing the Brooker grade 2 HO formation in PL and SL; D: Forest plot showing the Brooker grade 3 HO formation in PL and SL; E: Forest plot showing the Brooker grade 4 HO formation in PL and SL.

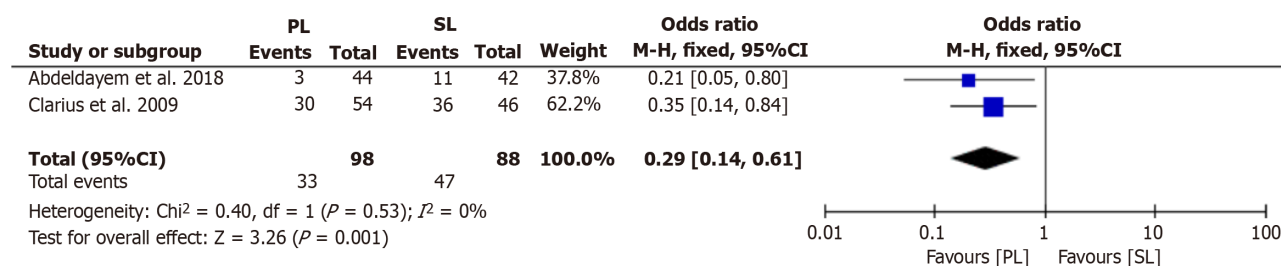


Figure 4 Forest plot showing the formation of radiolucent lines in pulsed lavage and standard lavage.

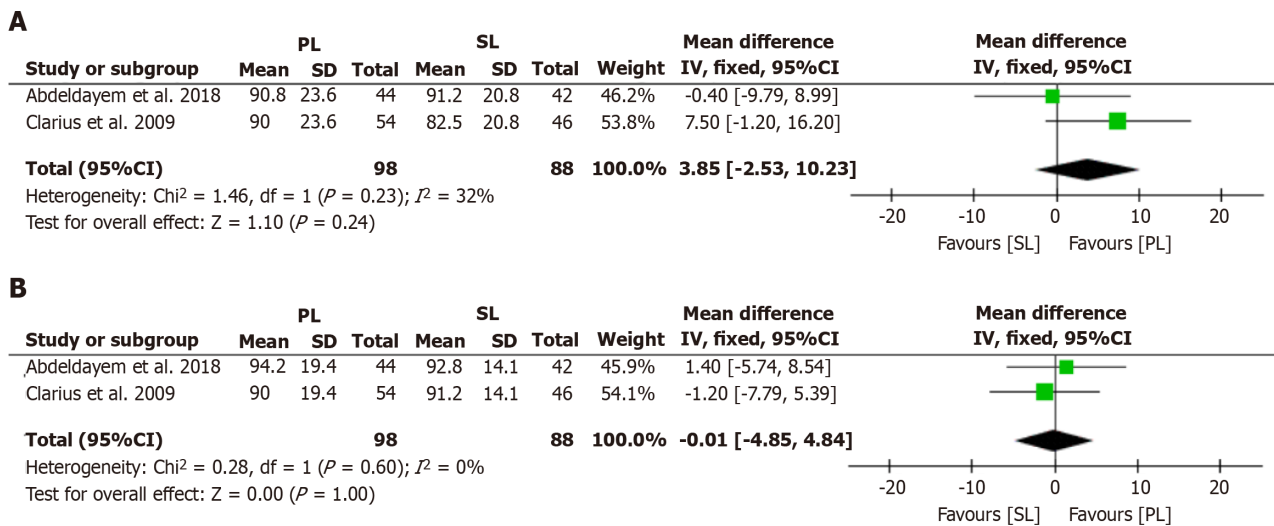


Figure 5 Forest plot. A: Forest plot showing the knee society score in pulsed lavage (PL) and standard lavage (SL); B: Forest plot showing the knee function score in PL and SL.

ARTICLE HIGHLIGHTS

Research background

Many studies compared pulse lavage to standard lavage in the setting of joint replacement but no meta-analysis is present to assess the overall utility of pulse lavage.

Research motivation

This study will be the first to assess the utility of pulse lavage in the setting of total hip and total knee replacements.

Research objectives

In the setting of hip replacement, we assessed the formation of heterotopic ossification whereas in knee replacement, we assessed the formation of radiolucent lines and functional outcomes.

Research methods

PubMed, Cochrane, and Google Scholar (page 1-20) were searched till December 2023 including only comparative studies comparing pulsed lavage to standard lavage in total knee or total hip replacements.

Research results

We found no difference in heterotopic ossification in hip replacement and no difference in functional outcomes in knee replacement. However, we found a reduction in the formation of radiolucent lines in total knee replacement.

Research conclusions

We conclude that pulsed lavage may be beneficial in the setting of total knee replacement but has no added benefit in total hip replacement.

Research perspectives

Future research should assess the costs/benefits of pulsed lavage in the setting of total joint replacement.

FOOTNOTES

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