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REVIEW

Surgical versus percutaneous catheter placement for peritoneal dialysis: an updated systematic review and meta-analysis

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Abstract

Background No consensus currently exists regarding the optimal approach for peritoneal dialysis catheter placement. We aimed to compare the outcomes of percutaneous and surgical peritoneal dialysis catheter placement.

Methods A systematic review of the literature was performed using the MEDLINE, Cochrane Library, and Scopus databases (end-of-search date: August 29th, 2020). We included studies comparing percutaneous (blind, under fluoroscopic/ultrasound guidance, and "half-perc") and surgical peritoneal dialysis catheter placement (open and laparoscopic) in terms of their infectious complications (peritonitis, tunnel/exit-site infections), mechanical complications (leakage, inflow/outflow obstruction, migration, hemorrhage, hernia, bowel perforation) and long-term outcomes (malfunction, removal, replacement, surgery required, and mortality).

Results Thirty-four studies were identified, including thirty-two observational studies (twenty-six retrospective and six prospective) and two randomized controlled trials. Percutaneous placement was associated with significantly lower rates of tunnel/exit-site infection [relative risk (RR) 0.72, 95% confidence interval (CI) 0.56–0.91], catheter migration (RR 0.68, 95% CI 0.49, 0.95), and catheter removal (RR 0.73, 95% CI 0.60–0.88). The 2-week and 4-week rates of early tunnel/exit-site infection were also lower in the percutaneous group (RR 0.45, 95% CI 0.22–0.93 and RR 0.41, 95% CI 0.27–0.63, respectively). No statistically significant difference was observed regarding other outcomes, including catheter survival and mechanical complications.

Conclusion Overall, the quality of published literature on the field of peritoneal dialysis catheter placement is poor, with a small percentage of studies being randomized clinical trials. Percutaneous peritoneal dialysis catheter placement is a safe procedure and may result in fewer complications, such as tunnel/exit-site infections, and catheter migration, compared to surgical placement.

Protocol registration PROSPERO CRD42020154951.

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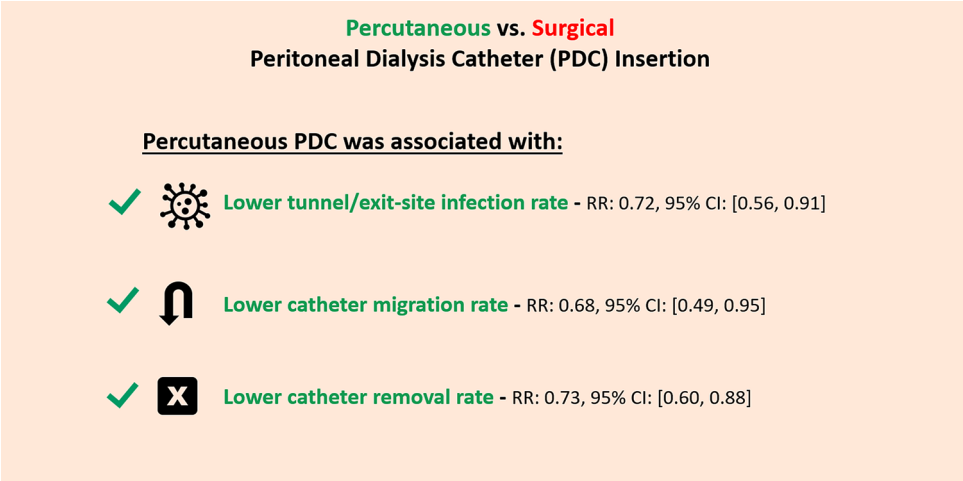
Graphic abstract



Keywords Percutaneous catheter placement · Open surgical catheter placement · Laparoscopic catheter placement · Peritoneal dialysis catheter

Background

Peritoneal dialysis (PD) is an important therapeutic option for the management of end-stage renal disease, with comparable short-term and long-term outcomes to hemodialysis [1, 2]. Access to the peritoneal cavity is achieved via the placement of a peritoneal dialysis catheter (PDC). A variety of techniques have been developed to facilitate PDC placement. The classic surgical approaches include open surgery or laparoscopy. The percutaneous approach, on the other hand, allows for a minimally-invasive placement of the catheter in the Interventional Radiology suite using the modified Seldinger technique, often under fluoroscopic/radioscopic guidance [3–5]. Patient comorbidities, expertise of the healthcare provider, resource availability and urgency for PD initiation are factors that often influence the choice between the different techniques [3].

Both infectious and mechanical complications directly related to the placement of the PDC are a primary cause of catheter failure and mortality in patients receiving PD [6–8]. The rate of complications varies with the placement technique due to inherent strengths and weaknesses associated with each. However, there is currently no consensus regarding the optimal technique for PDC placement. Previous meta-analyses on the subject have failed to provide a definitive answer and were often limited by small sample sizes [9–11]. Therefore, we sought to perform an updated systematic review and meta-analysis, aiming to compare the effects of surgical and percutaneous PDC placement techniques on catheter-related complications and catheter survival.

Materials and methods

Study design and inclusion/exclusion criteria

This systematic review and meta-analysis was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines (Online Resource 1) [12]. A protocol was developed and agreed upon by all authors prior to the beginning of this study and was made publicly available at the PROSPERO database (registration number CRD42020154951). An institutional review board approval was not required to conduct this study. We applied the PICO (Population/Participants, Intervention, Comparison, and Outcome) framework to define the study selection criteria as follows:

- P (Participants): Adult patients (age ≥ 18 years) of any sex or race undergoing peritoneal dialysis catheter placement, regardless of indication. Both first-time insertions and re-insertions were considered.
- I (Interventions): Percutaneous and surgical peritoneal dialysis catheter placement. Percutaneous techniques included catheter placement via the Seldinger technique, with or without fluoroscopic/ultrasound guidance, as well the newer "half-perc" techniques. Surgical techniques included catheter placement via open surgery, mini-laparotomy or laparoscopic surgery.

- C (Comparison): Studies were deemed eligible only if percutaneous catheter placement was directly compared to surgical catheter placement for the outcomes of interest.
- O (Outcomes): The primary outcome measures were the rates of 3-month and 1-year catheter survival, overall infectious complications, overall mechanical complications peritonitis, and tunnel/exit-site infection. The secondary outcome measures were the rates of leakage, inflow/outflow obstruction, catheter migration, post-procedural hemorrhage, hernia, bowel perforation, catheter malfunction, surgery required due to catheter-related causes, catheter removal, catheter replacement, post-procedural mortality and overall mortality.

Original clinical studies, including both randomized trials and non-randomized prospective/retrospective comparative studies, published in English, reporting on both surgical and percutaneous PDC placement for the outcomes of interest were deemed eligible for inclusion. The exclusion criteria were defined as follows: (1) articles published in any non-English language, (2) irrelevant articles, (3) animal and in vitro studies, (4) case reports, (5) narrative or systematic reviews and meta-analyses, (6) editorials, letters to the editors, perspectives, comments, errata that did not provide any primary patient data, (7) published abstracts without any published full text, and (8) non-comparative studies (1 study arm only). No search filters were applied.

All eligible studies were closely assessed for any partially or completely overlapping populations according to their author lists, study centers, recruitment dates and data collection dates. Among studies with overlapping populations, we selected those with the largest number of patients and/or data for the outcomes of interest.

Search strategy

Eligible studies were identified by searching through the MEDLINE (via PubMed), Scopus, and Cochrane Library databases (end-of-search date: August 29th, 2020) by two independent reviewers (S.M.E. and G.A.S.). The following search algorithm was used: peritoneal AND dialysis AND catheter AND (insert* OR placement). Any disagreements on article inclusion were resolved by a third independent reviewer (K.P.E.). The reference lists of the included studies were also searched for any missed but otherwise eligible articles, based on the "snowball" methodology [13].

Data extraction

Data tabulation and extraction was performed by two independent reviewers (S.M.E. and G.A.S) and using a standardized, pre-piloted form. Any disagreements were identified and resolved by reaching a consensus and/or discussion with a third reviewer (K.P.E.). The following data were extracted: (1) study characteristics (first author, year of publication, study design, study center, study period, number of patients, number of procedures, PDC type for each group) (2) patient characteristics (age in years, sex, number of prior abdominal surgeries, underlying comorbidities, primary renal disease, follow up period in months, break-in period in days) (3) primary outcomes (3-month and 1-year catheter survival rate, overall mechanical complication rate, overall infectious complication rate, peritonitis rate, and tunnel/exit-site infection rate), and (4) secondary outcomes (leakage rate, inflow/outflow obstruction rate, catheter migration rate, post-procedural hemorrhage rate, hernia rate, bowel perforation rate, catheter malfunction rate, surgical PDC revision rate, catheter removal rate, catheter replacement rate, post-procedural mortality rate and overall mortality rate). Additional data were recorded regarding early infectious and mechanical complications, occurring up to 2 weeks and 4 weeks following catheter placement.

The overall infectious complication rate was defined as the number of patients affected by at least one episode of peritonitis, tunnel infections and/or exit-site infection. The overall mechanical complication rate was defined as the number of patients affected by at least one episode of any non-infectious complication, including leakage, inflow/outflow obstruction, catheter migration, post-procedural hemorrhage, hernia, and bowel perforation. Catheter survival was defined as the number of catheters remaining in place after a specific time period following placement (3 months and 1 year), taking into account any censoring of patients due to death, transplantation or transfer to hemodialysis as applied by the authors. The catheter removal rate was defined as the number of catheters removed as a result of an infectious or mechanical complication divided by the total number of catheters; removals due to death, transplantation, switching to hemodialysis, and voluntary patient choice were not considered for this outcome. The rest of the outcomes were defined according to the International Society of Peritoneal Dialysis [14].

Quality of evidence assessment

We used the Newcastle–Ottawa scale (NOS) [15] to assess the quality of non-randomized studies; a score of ≥ 6 denoted high study quality. A 3-month duration and a 90% rate were a priori set as the cutoffs for the items assessing whether follow-up length and adequacy, respectively.

We used the Cochrane Collaboration's tool to assess the quality of randomized controlled trials (RCTs), which evaluates the following types of bias: selection, performance, detection, attrition, and reporting [16].

Statistical analysis

Frequencies and percentages were used to summarize categorical variables, while means and standard deviations (SDs) were used to summarize continuous variables. We applied the method proposed by Hozo et al. to estimate the means and SDs of continuous variables, whenever medians and ranges were provided instead [17]. We estimated all relative rates based on available data for each variable of interest. We handled all available data according to the principles stated in the Cochrane Handbook [18].

Meta-analysis was carried out to compare surgical and percutaneous PDC insertion for all primary and secondary outcomes. A subgroup analysis was performed according to the type of surgical PDC placement (open surgical, laparoscopic or both), as previous meta-analyses have shown differences in the outcomes between open surgical and laparoscopic PDC placement [19, 20]. An additional subgroup analysis was performed regarding patients with no previous abdominal operation history. Selection bias is often present in studies utilizing the percutaneous technique and patients with a previous abdominal surgery are often excluded or moved to the surgical group instead [21]. Thus, a history of previous abdominal operations may act as a confounder when comparing the two placement techniques. Based on extracted data, relative risks (RRs) and 95% confidence intervals (CIs) were calculated by means of 2×2 tables for each categorical outcome; RR greater than 1 indicated that the outcome was more frequently present in the percutaneous group. Continuity correction of 0.5 in studies with zero cell frequencies was adopted. Between-study heterogeneity was assessed through Cochran Q statistic and by estimating I^2. High heterogeneity was confirmed with a significance level of $P < 0.05$ and $I^2 \geq 50\%$. We used the random-effects model (DerSimonian-Laird) to calculate the pooled effect estimates for all outcomes, due to the significant between-study heterogeneity [22]. Publication bias was assessed via funnel plots and Egger's test for each outcome of interest; publication bias was determined to be present for any p value < 0.1 on Egger's test [23]. Statistical significance was set at 0.05 and all p values were two-tailed. Statistical analyses were performed using STATA IC 16.0 (StataCorp LLC, College Station, Texas).

Results

Study selection and characteristics

Through our systematic search, 1794 unique articles were retrieved, of which 110 underwent full-text evaluation for eligibility. Ultimately, 34 studies reporting on 6067 PDC placements (2946 percutaneous and 3121 surgical) fulfilled the inclusion criteria and were included in our meta-analysis [24–57] (Fig. 1). Detailed study and patient characteristics of the included studies are presented in Tables 1 and 2, respectively. More patients had a history of previous abdominal surgery in the surgical group (26.8%) compared to the percutaneous group (8.4%). The average break-in period was shorter in the percutaneous group (14.7 ± 24.8 days) compared to the surgical group (22.4 ± 31.7). The remaining baseline characteristics were similar among the two groups.

Study quality and publication bias assessment

Of the 34 included studies in this meta-analysis, 32 were non-randomized studies (26 retrospective and 6 prospective), and 2 were randomized controlled trials. The NOS was used to assess the quality of the 24 non-randomized studies, with a mean score of 6.4 ± 1.0 (Online Resource 2A).

Two randomized controlled trials were also included in the meta-analysis and were assessed separately using the Cochrane Collaboration's Tool. The risk of selection and attrition bias was low in both studies, while the risk of performance and detection bias was high in both cases. The risk of reporting bias was low in Voss et al. and high in Atapour et al., respectively (Online Resource 2B).

Egger's test revealed no publication bias in the funnel plots of any of the studied outcomes, with the exception of the 2-week tunnel and exit-site infection rate ($p = 0.084$).

Meta-analyses of primary outcomes

The results of the meta-analyses for all primary outcomes are summarized in Table 3. Forest plots of all primary outcomes are presented in Figs. 2, 3, 4 and 5.

Three-month catheter survival

The 3-month catheter survival rate was reported in 3 studies [24, 35, 42]. No statistically significant difference was found between the percutaneous group (74.9%; n = 250/334) and the surgical group (71.4%; n = 302/423) (RR 1.05, 95% CI 0.95–1.15; p = 0.33). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Fig. 2a).

One-year catheter survival

The 1-year catheter survival rate was reported in 5 studies [24, 26, 42, 50, 51]. No statistically significant difference was found between the percutaneous group (71.2%; n = 332/466) and the surgical group (62.8%; n = 446/710) (RR 1.02, 95% CI 0.97–1.07; p = 0.49). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Fig. 2b).

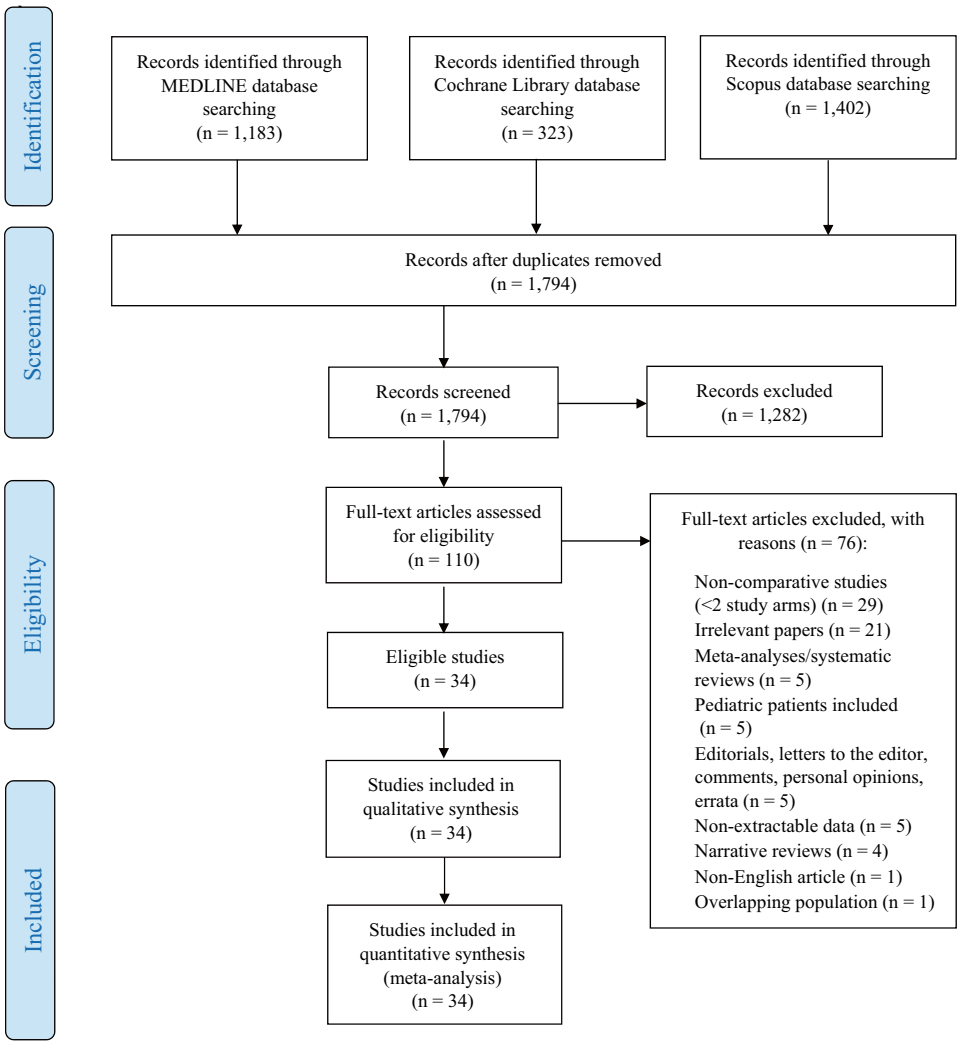


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram of the study selection process

Overall infectious complications

The overall infectious complication rate was reported in 5 studies [29, 30, 39, 43, 50]. No statistically significant difference was found between the percutaneous group (23.6%; n = 183/777) and the surgical group (28.5%; n = 163/573) (RR 0.82, 95% CI 0.60–1.11; p = 0.20). Statistical heterogeneity was low (I^2 = 47.9%) (Fig. 3a).

Overall mechanical complications

The overall mechanical complication rate was reported in 6 studies [28–30, 39, 43, 50]. No statistically significant difference was found between the percutaneous group (16.8%; n = 139/827) and the surgical group (16.7%; n = 126/753) (RR 1.00, 95% CI 0.72–1.38; p = 0.98). Statistical heterogeneity was low (I^2 = 45.7%) (Fig. 3b).

Peritonitis rate

The peritonitis rate was reported in 24 studies [24, 26–30, 32, 33, 35–38, 42, 44, 46–51, 54, 55, 57]. No statistically significant difference was found between the percutaneous group (15.7%; n = 321/2042) compared to the surgical group (15.2%; n = 334/2205) (RR 0.94, 95% CI 0.75–1.18; p = 0.60). Statistical heterogeneity was low (I^2 = 49.8%) (Fig. 4). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 1.10, 95% CI 0.78–1.56) or the open surgical group (RR 0.98, 95% CI 0.74–1.29).

Tunnel and exit-site infection rate

The tunnel and exit site infection rate was reported in 24 studies [24, 26–30, 32, 33, 36–38, 40, 43, 44, 46–51, 53–55, 57], and was significantly lower in the percutaneous

Table 1 Characteristics of the included studies

Author	Year	Country	Study Period	Type of Study	Catheters		Technique	
					Perc	Surg	Perc	Surg
Abdel Aal et al.	2018	USA	Jan 2005–Jun 2016	Retrospective cohort	50	190	Fluoroscopic/ultrasound-guided	Laparoscopic
Alkatheeri et al.	2015	Canada	Jul 2010–Oct 2013	Prospective cohort	20	10	Fluoroscopic-guided	Laparoscopic
Atapour et al.	2011	Iran	Jan 2009–Dec 2010	Randomized controlled trial	31	30	Blind	Open surgical
Borazan et al.	2006	Turkey	Apr 2003–Jul 2003	Prospective cohort	30	12	Blind	Laparoscopic
Brunier et al.	2010	Canada	Jan 2000–May 2007	Retrospective cohort	88	125	Fluoroscopic-guided	Open surgical
Chula et al.	2014	Brazil	Jun 2006–Jan 2008	Prospective cohort	79	42	Fluoroscopic-guided or Blind	Open surgical
Demiriz et al	2014	Turkey	2007–2012	Retrospective cohort	30	10	Blind	Laparoscopic
Dequidt et al.	2003	Belgium	Jan 1998–May 2002	Prospective cohort	60	78	Blind	Open surgical
Dinc et al.	2008	Turkey	2006–2008	Retrospective cohort	17	37	Blind	Laparoscopic
Gajjar et al.	2007	USA	N/A	Retrospective cohort	30	45	Blind	Laparoscopic
Glavinovic et al.	2019	Canada	Jan 2012–Dec 2017	Prospective cohort	94	203	Fluoroscopic/ultrasound-guided	Laparoscopic
Henderson et al.	2009	UK	Apr 1999–Mar 2008	Prospective cohort	283	150	Blind	Open surgical or Laparoscopic
Kang et al.	2020	South Korea	Mar 2011–Nov 2018	Retrospective cohort	144	105	Blind	Open surgical
Khositrangsikun et al.	2011	Thailand	Oct 2007–Oct 2010	Retrospective cohort	56	149	Blind	Mini-laparotomy
Kim et al.	2020	South Korea	Sep 2009–Feb 2012	Retrospective cohort	89	78	Blind	Open surgical
Liberek et al.	2003	Poland	Jan 1994–Apr 1996	Retrospective cohort	18	25	Blind	Open surgical
Maher et al.	2014	New Zealand	Sep 2004–Aug 2009	Retrospective cohort	133	153	Fluoroscopic-guided	Laparoscopic
Medani et al.	2012	Ireland	Jan 2003–Apr 2010[a], Jul 1998–Apr 2010[b]	Retrospective cohort	151	162	Blind	Open surgical
Melotte et al.	1993	UK	Oct 1988–May 1992	Retrospective cohort	50	180	Blind	Open surgical
Nicholas et al.	2014	UK	2000–2010	Retrospective cohort	369	244	Blind	Open surgical
Ozener et al.	2001	Turkey	Apr 1994–Apr 1999	Retrospective cohort	133	82	Blind	Open surgical
Park et al.	2014	South Korea	Sep 2009–Feb 2012	Retrospective cohort	89	78	Blind	Open surgical
Perakis et al.	2009	Greece	Jan 1990–Dec 2007	Retrospective cohort	86	84	Blind	Open surgical
Pico et al.	2000	Spain	Jan 1992–Dec 1996	Retrospective cohort	70	74	Blind	Open surgical
Rana et al.	2011	U.K	Jan 2005–Sept 2008	Retrospective cohort	69	51	Blind	Open surgical
Rosenthal et al.	2008	USA	Jan 1999–Nov 2004	Retrospective cohort	54	53	Fluoroscopic-guided	Open surgical or Laparoscopic
Roueff et al.	2002	France	Apr 1993–Mar 1996[a], Apr 1996–Mar 1999[b]	Retrospective cohort	57	47	Blind	Open surgical
Sampathkumar et al.	2008	India	Jan 2006–May 2007	Retrospective cohort	25	21	Blind	Open surgical
Sivaramakrishnan et al.	2016	India	Jan 2012–Dec 2012	Retrospective cohort	55	88	Blind	Open surgical or Laparoscopic
Stonelake et al.	2018	UK	Jan 2011–Dec 2016	Retrospective cohort	143	119	N/A	Open surgical
Sun et al.	2016	New Zealand	Aug 2009–Jul 2013	Retrospective cohort	69	140	Fluoroscopic-guided	Laparoscopic
Voss et al.	2012	New Zealand	Apr 1999–Aug 2004	Randomized controlled trial	51	56	Fluoroscopic-guided	Laparoscopic
Xie et al.	2020	China	Jan 2015–Dec 2016	Retrospective cohort	83	95	Blind	Open surgical
Zhang et al.	2020	China	Jan 2015–Jan 2018	Retrospective cohort	126	114	Half-perc	Open surgical
Total			1988–2017		2946	3121		

Perc percutaneous, *Surg* surgical, *N/A* not available

[a]Percutaneous group

[b]Surgical group

Table 2 Demographic characteristics and comorbidities of the patients included in this analysis

	Percutaneous (n = 2946)	Surgery (n = 3121)
Demographic characteristics		
Age (years)	55.1 ± 15.6	51.2 ± 20.3
Males/females	1467 (61.6)/914 (38.4)	1292 (55.0)/1058 (45.0)
BMI (kg/m^2)	25.7 ± 5.8	26.4 ± 5.9
Comorbidities		
Diabetes	413 (33.2)	399 (35.0)
Coronary artery disease	98 (22.1)	156 (20.8)
Cerebrovascular disease	47 (13.1)	51 (8.0)
Primary renal disease		
Diabetic nephropathy	499 (35.5)	441 (34.2)
Hypertensive nephropathy	129 (21.1)	110 (15.7)
Glomerulonephritis	284 (22.6)	262 (23.2)
Polycystic kidney disease	31 (4.0)	57 (6.9)
Previous abdominal operations	120 (8.4)	381 (26.8)
Follow up (months)	18.5 ± 19.9	17.3 ± 19.7
Break-in period (days	14.7 ± 24.8	22.4 ± 31.7

Values are given as mean ± SD or n (%)

group (10.2%; n = 191/1882) compared to the surgical group (12.8%; n = 263/2054) (RR 0.72, 95% CI 0.56–0.91; p = 0.01). Statistical heterogeneity was low ($I^2 = 24.5\%$) (Fig. 5). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.95, 95% CI 0.76–1.19), while the tunnel and exit-site infection rate was significantly lower in the percutaneous group compared to the open surgical group (RR 0.68, 95% CI 0.48–0.95).

Meta-analyses of secondary outcomes

The results of the meta-analyses for all secondary outcomes are summarized in Table 3. Forest plots of all secondary outcomes are presented in Online Resource 3.

Leakage

The leakage rate was reported in 28 studies [24–30, 32–34, 36–38, 40, 42–51, 53–55, 57]. No statistically significant difference was found between the percutaneous group (7.4%; n = 159/2148) and the surgical group (5.9%; n = 136/2321) (RR 1.29, 95% CI 0.95–1.76; p = 0.11). Statistical heterogeneity was low ($I^2 = 32.8\%$) (Online Resource 3A). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 1.05, 95% CI 0.63–1.76), while the leakage rate was significantly higher in the percutaneous group compared to the open surgical group (RR 1.67, 95% CI 1.15–2.44).

Inflow/outflow obstruction

The inflow/outflow obstruction rate was reported in 11 studies [28–30, 36, 38, 43, 44, 46, 47, 54, 57]. No statistically significant difference was found between the percutaneous group (8.4%; n = 88/1043) and the surgical group (8.5%; n = 76/891) (RR 0.86, 95% CI 0.64–1.15; p = 0.51). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3B). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.70, 95% CI 0.18–2.71) or the open surgical group (RR 0.85, 95% CI 0.48–1.52).

Catheter migration rate

The catheter migration rate was reported in 14 studies [25, 29–33, 36, 40, 43, 45, 46, 49, 51, 54], and was significantly lower in the percutaneous group (6.1%; n = 64/1058) compared to the surgical group (8.7%; n = 81/927) (RR 0.68, 95% CI 0.49–0.95; p = 0.02). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3C). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 1.36, 95% CI 0.36–5.17), while the migration rate was significantly lower in the percutaneous group compared to the open surgical group (RR 0.65, 95% CI 0.46–0.93).

Table 3 Summary of meta-analyses for all outcomes

Outcomes	Sum Perc	Sum Surg	RR	95% CI	p value	I^2 (%)	Egger's test	Result
Primary outcomes								
3-month catheter survival	250/334	302/423	1.05	[0.95, 1.15]	0.33	0.00	0.609	NS
1-year catheter survival	332/466	446/710	1.02	[0.97, 1.07]	0.49	0.00	0.448	NS
Overall infectious complications	183/777	163/573	0.82	[0.60, 1.11]	0.20	47.92	0.808	NS
Overall mechanical complications	139/827	126/753	1.00	[0.72, 1.38]	0.98	45.66	0.265	NS
Peritonitis	321/2042	334/2205	0.94	[0.75, 1.18]	0.60	49.81	0.918	NS
Tunnel/exit-site infections	191/1882	263/2054	0.72	[0.56, 0.91]	0.01	24.53	0.315	Favors percutaneous
Secondary outcomes								
Leakage	159/2148	136/2321	1.29	[0.95, 1.76]	0.11	32.76	0.579	NS
Inflow/outflow obstruction	88/1043	76/891	0.86	[0.64, 1.15]	0.51	0.00	0.917	NS
Catheter migration	64/1058	81/927	0.68	[0.49, 0.95]	0.02	0.00	0.012	Favors percutaneous
Post-procedural hemorrhage	45/1785	48/1864	1.09	[0.72, 1.66]	0.68	0.00	0.154	NS
Hernia	41/1128	70/1133	0.71	[0.49, 1.02]	0.06	0.00	0.381	NS
Bowel perforation	5/1323	1/1534	1.66	[0.62, 3.38]	0.40	0.00	0.933	NS
Catheter malfunction	107/854	180/1047	0.86	[0.67, 1.09]	0.20	0.00	0.255	NS
Catheter-related surgery required	40/395	46/463	1.03	[0.68, 1.55]	0.90	0.00	0.153	NS
Catheter removal	309/1418	330/1277	0.73	[0.60, 0.88]	< 0.001	23.64	0.900	Favors Percutaneous
Catheter replacement	47/546	74/566	0.78	[0.55, 1.11]	0.17	0.00	0.186	NS
Post-procedural mortality	0/597	6/440	0.42	[0.10, 1.87]	0.26	0.00	N/A	NS
Overall mortality	140/1105	171/1287	1.03	[0.73, 1.45]	0.86	51.18	0.557	NS
Secondary early outcomes								
2-week peritonitis	12/502	26/407	0.65	[0.31, 1.36]	0.25	0.00	0.619	NS
2-week tunnel/exit-site infections	6/566	42/780	0.45	[0.22, 0.93]	0.03	0.00	0.084	Favors Percutaneous
2-week leakage	2/214	8/296	0.71	[0.17, 2.97]	0.64	5.68	N/A	NS
4-week peritonitis	33/673	53/634	0.65	[0.39, 1.07]	0.09	15.55	0.263	NS
4-week tunnel/exit-site infections	31/557	52/533	0.41	[0.27, 0.63]	< 0.001	0.00	0.749	Favors Percutaneous
4-week leakage	42/492	39/560	1.38	[0.57, 3.34]	0.48	66.99	0.996	NS

Perc percutaneous, *Surg* surgical, *RR* risk ratio, *CI* confidence interval, *NS* non-statistically significant

Post-procedural hemorrhage rate

The post-procedural hemorrhage rate was reported in 21 studies [24, 26, 28–30, 32, 33, 36, 38, 40, 42, 43, 45–47, 49–51, 53, 54, 57]. No statistically significant difference was found between the percutaneous group (2.5%; n = 45/1785) and the surgical group (2.6%; n = 48/1864) (RR 1.09, 95% CI 0.72–1.66; p = 0.68). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3D). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.65, 95% CI 0.09–4.56) or the open surgical group (RR 1.14, 95% CI 0.72–1.80).

Hernia rate

The hernia rate was reported in 13 studies [24, 27, 29, 31, 32, 36, 38, 42, 43, 46, 47, 50, 53]. No statistically significant difference was found between the percutaneous group (3.6%; n = 41/1128) and the surgical group (6.2%; n = 70/1133) (RR 0.71, 95% CI 0.49–1.02; p = 0.13). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3E). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.83, 95% CI 0.48–1.41) or the open surgical group (RR 0.61, 95% CI 0.36–1.04).

Bowel perforation rate

The bowel perforation rate was reported in 18 studies [24, 27–31, 33, 34, 36, 40, 43, 44, 47, 49–51, 53, 56]. No statistically significant difference was found between the percutaneous group (0.4%; n = 5/1323) and the surgical group (0.1%; n = 1/1534) (RR 1.45, 95% CI 0.62–3.38; p = 0.40). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3F). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 1.55, 95% CI 0.34–7.16) or the open surgical group (RR 1.47, 95% CI 0.51–4.25).

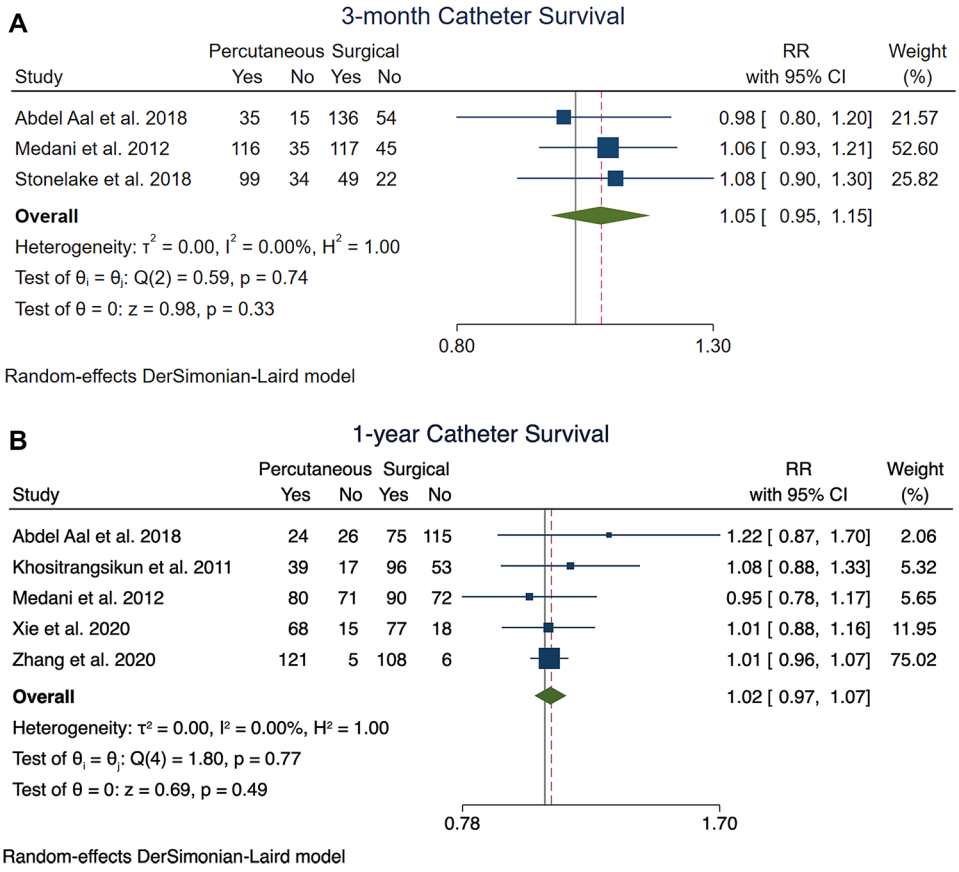


Fig. 2 Forest plots of 3-month catheter survival rate (**a**) and 1-year catheter survival rate (**b**)

Catheter malfunction rate

The catheter malfunction rate was reported in 11 studies [24, 27, 29, 32, 40, 48–51, 53, 56]. No statistically significant difference was found between the percutaneous group (12.5%; n = 107/854) and the surgical group (17.2%; n = 180/1047) (RR 0.86, 95% CI 0.67–1.09; p = 0.20). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3G). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.91, 95% CI 0.67–1.23) or the open surgical group (RR 0.81, 95% CI 0.50–1.33).

Catheter-related surgery required rate

The catheter-related surgery required rate was reported in 5 studies [30, 36, 42, 49, 56]. No statistically significant difference was found between the percutaneous group (13.1%; n = 40/395) and the surgical group (9.9%; n = 46/463) (RR 1.03, 95% CI 0.68–1.55; p = 0.90). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3H). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 1.08, 95% CI 0.55–2.12) or the open surgical group (RR 0.98, 95% CI 0.54–1.80).

Catheter removal rate

The catheter removal rate was reported in 12 studies [27, 29, 32, 33, 38–40, 43, 44, 46, 47, 56], and was lower in the percutaneous group (21.8%; n = 309/1478) compared to the surgical group (25.8%; n = 309/1418) (RR 0.73, 95% CI 0.60–0.88; p = < 0.001). Statistical heterogeneity was low ($I^2 = 23.6\%$) (Online Resource 3I). In the subgroup analysis, the catheter removal rate was lower in the percutaneous group, when compared against the laparoscopic group (RR 0.66, 95% CI 0.45–0.99) and the open surgical group (RR 0.71, 95% CI 0.53–0.94).

Catheter replacement rate

The catheter replacement rate was reported in 6 studies [28, 29, 32, 40, 42, 43]. No statistically significant difference was found between the percutaneous group (8.6%; n = 47/546) and the surgical group (13.1%; n = 74/566) (RR 0.78, 95% CI 0.55–1.11; p = 0.17). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3J).

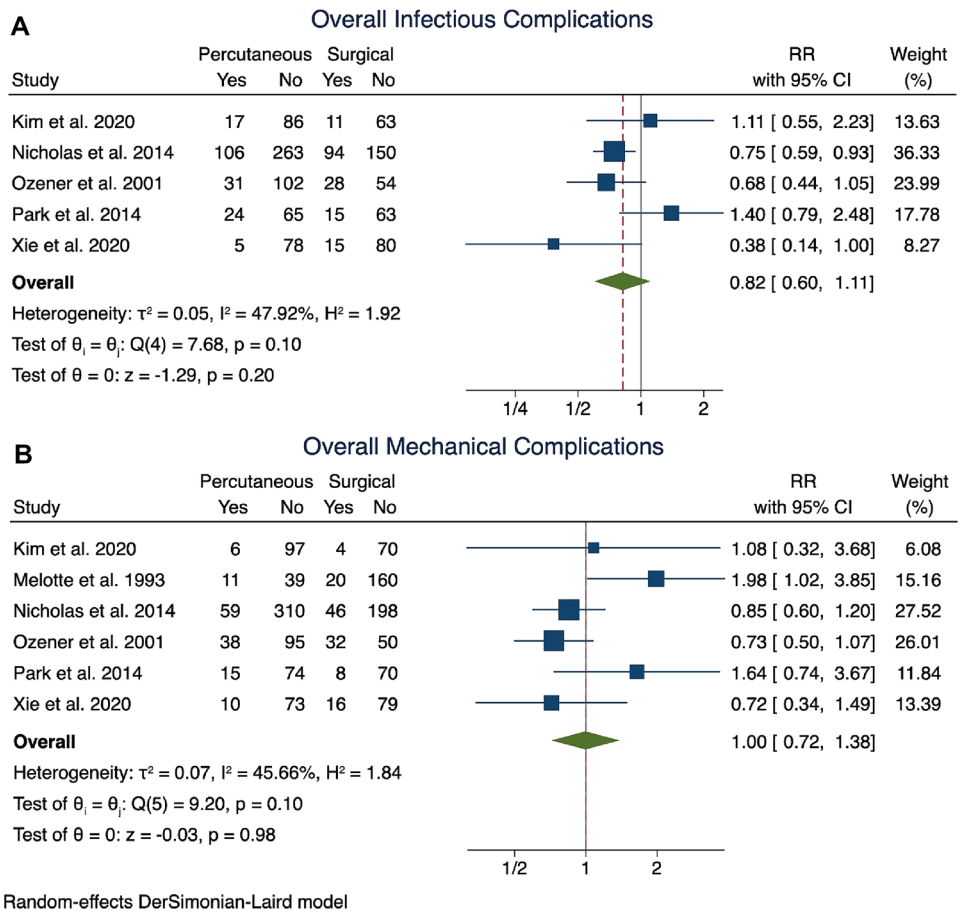


Fig. 3 Forest plots of overall infectious complication rate (**a**) and overall mechanical complication rate (**b**)

Post-procedural mortality rate

The post-procedural mortality rate was reported in 6 studies [30, 32, 47, 48, 51, 57]. No statistically significant difference was found between the percutaneous group (0.0%; n = 0/597) and the surgical group (1.4%; n = 6/440) (RR 0.42, 95% CI 0.10–1.87; p = 0.26). Statistical heterogeneity was low ($I^2 = 0.0\%$) (Online Resource 3K). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 0.94, 95% CI 0.06–14.51 or the open surgical group (RR 0.98, 95% CI 0.01–2.00).

Overall mortality rate

The overall mortality rate was reported in 12 studies [29, 30, 33, 40, 42, 43, 46, 48, 51, 52, 56]. No statistically significant difference was found between the percutaneous group (12.7%; n = 140/1105) and the surgical group (13.3%; n = 171/1287) (RR 1.03, 95% CI 0.73–1.45; p = 0.86). Statistical heterogeneity was high ($I^2 = 51.2\%$) (Online Resource 3L). No statistically significant difference was observed in the subgroup analysis between the percutaneous and the laparoscopic group (RR 2.17, 95% CI 0.20–23.71), or the open surgical group (RR 0.92, 95% CI 0.66–1.29).

Early outcomes

An additional analysis was performed on the rates of peritonitis, tunnel and exit-site infections, and leakage, specifically occurring at 2 weeks and 4 weeks following catheter placement. The forest plots of these meta-analyses are presented in Online Resource 3M-R and their results are summarized in Table 3.

Subgroup analysis

An additional subgroup analysis was performed for patients with no previous abdominal operation history. No statistically significant difference was detected regarding the rates of peritonitis, tunnel and exit-site infection, leakage, inflow/outflow obstruction, migration,

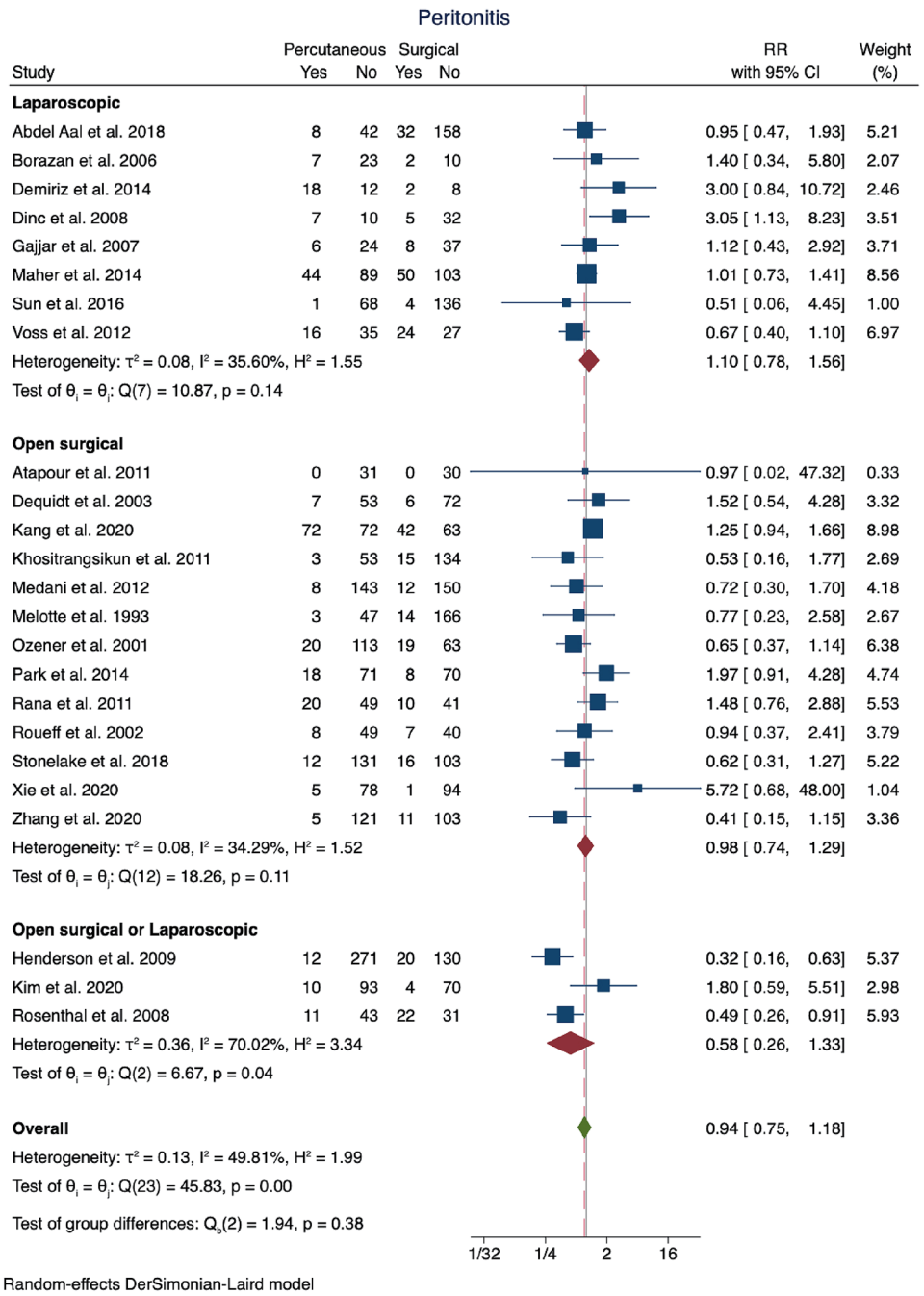


Fig. 4 Forest plot of peritonitis rate

post-procedural hemorrhage, hernia, bowel perforation, and catheter removal (Online Resource 4).

Discussion

The results of this systematic review and meta-analysis show that percutaneous PDC placement is an overall safe technique and, compared to surgical placement, may lead to lower rates of tunnel/exit-site infection, catheter migration, and catheter removal. With the exception of peritonitis rate in Boujelbane et al., previous meta-analyses have failed to detect any significant difference in the outcomes of the two methods [9–11]. In Tullavardhana et al. and Boujelbane et al., the lack of statistically significant results can be attributed to several methodological flaws; these include limiting their search strategy to one database, omitting important outcomes such as catheter migration, mixing count data

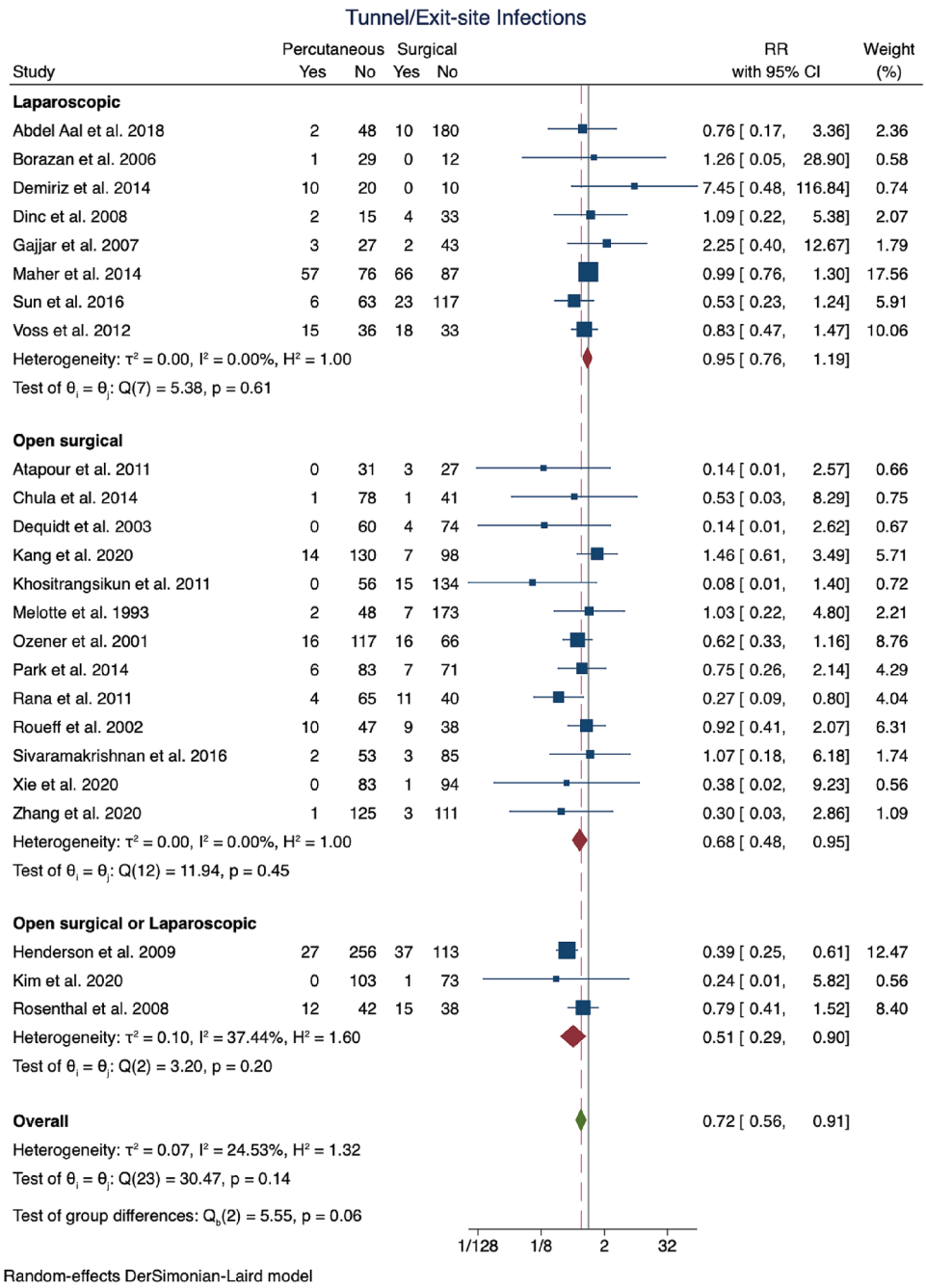


Fig. 5 Forest plot of tunnel/exit-site infection rate

and dichotomous data in the meta-analyses of binary outcomes, adding the rates of individual non-mutually exclusive events to obtain cumulative rates, and extracting survival data from Kaplan–Meier curves, without taking into account censored data for death or other causes [18]. Our systematic search yielded 24 additional studies and 18 additional studies compared to Tullavardhana et al. and Boujelbane et al., respectively. The inclusion criteria of our study were almost identical with those of Tullavardhana et al. and narrower compared to those of Boujelbane et al., as the latter also included pediatric patients in their sample. The anatomic differences of children may predispose them to certain complications, such as catheter migration, and thus we decided to exclude them from our analysis [58]. The large difference in the number of included studies cannot be solely explained by our more recent search date and is rather the result of a more rigorous search strategy. Indeed, just 11 of the 34 included studies were published after the last search date of Tullavardhana et al. and Boujelbane et al. [24, 25, 35, 37, 40, 43, 46, 49–51, 56]. On the other hand, Htay et al. only included RCTs [10]. Despite the higher quality of evidence provided, this strategy may compromise the statistical power

of the meta-analysis, when available RCTs on the subject are limited.

Infectious complications are common in the setting of peritoneal dialysis. According to our pooled data, the overall rate of infectious complications was 23.6% in the percutaneous group and 28.5% in surgical group. However, only a limited number of studies reported data on this specific outcome. Most included studies reported data on the incidence of peritonitis and tunnel and exit-site infections individually. Infectious complications were also a major [27, 33, 40] or even the most common [28, 29, 31, 38, 39, 41] cause of catheter removal in many of the included studies. Percutaneous PDC placement resulted in significantly lower tunnel/exit-site infection rates. The lower incidence of this complication may account for the lower complication-related catheter removal rate seen in the percutaneous group. Surgical placement may predispose patients to infectious complications due to its highly invasive nature, providing a larger port of entry for microorganisms [32]. Specifically, early tunnel and exit-site infections, occurring at 2 weeks and 4 weeks following catheter placement, were also lower in the percutaneous group. The close temporal association of these early infections to the PDC placement implicates that the advantage of the percutaneous group may stem from the technique itself rather than other risk factors unrelated to catheter placement. On the other hand, both early and overall peritonitis rates were similar between the two groups. Early utilization of the PDC early after placement is a known advantage of the percutaneous technique over its surgical counterpart, but it also is a risk factor for early peritonitis and thus may initially offset any potential advantage of percutaneous placement [24, 59].

Mechanical complications also affect a significant proportion of patients undergoing PDC placement. Overall, 16.8% of patients in the surgical group and 16.7% in the percutaneous group developed a mechanical complication. Just as with infectious complications, mechanical complications were also a major cause of catheter removal in many of the included studies [27–29, 31, 39]. Multiple concerns have been raised over the years regarding the occurrence of mechanical complications with percutaneous PDC placement. Leakage, particularly occurring during the first weeks following the placement, may occur more frequently because of earlier catheter utilization compared to surgically inserted catheters [28]. The lack of direct visualization may predispose patients to bowel perforation, which can be a life-threatening complication. However, the risk varies substantially with operator experience and history of previous abdominal operations [24, 60]. Higher post-procedural hemorrhage rate may be more common with percutaneous placement, as bleeding control can be achieved intraoperatively with surgical placement [47]. On the other hand, hernias may occur more frequently with surgical placements due to the larger incision sites [28]. Surgical placement is also thought to promote mechanical complications through increased fibrous tissue formation [32]. Despite their theoretical basis, none of these associations were corroborated by our meta-analyses. Instead, percutaneous and surgical PDC placement were shown to be overall equally safe in terms of mechanical complications.

Migration is a complication that often leads to malfunction, eventually requiring revision or removal of the catheter [29, 56]. Depending on the severity, restoring function can be achieved via non-surgical or surgical manipulation [61]. In our study, migration was less common with percutaneous placement. However, the rates of catheter malfunction and catheter-related surgery were not significantly different between the two groups, as would be expected. Many of the studies reporting on catheter migration did not report on either of these two additional outcomes, which may explain this inconsistency. Catheter migration may also be influenced by the catheter type [61] or certain interventions during placement, such as the addition of a subcutaneous sling to prevent catheter movement [40]. Sivaramakrishnan et al. hypothesized that the latter may have significantly contributed to the lower incidence of catheter migration in the percutaneous group, rather than the technique itself [40].

Both techniques proved to be very safe, as post-procedural mortality was minimal and none of the deaths was directly related to the procedure [30]. Overall mortality varied significantly across studies, presumably due to the differences in the follow-up duration. Most studies did not provide a detailed breakdown of the causes leading to death. Perakis et al. reported that more than 60% of all patient deaths were caused by underlying cardiovascular disease, but also more than 20% were attributed to infectious complications [31]. Medani et al. concluded that all deaths were unrelated to peritoneal dialysis itself, with the exception of a fungal peritonitis case [42]. Due to the heterogeneity in patient characteristics across studies, including underlying comorbidities, it is hard to extrapolate a definitive conclusion about the long-term patient outcomes. As previously said, percutaneous catheter placement was associated with lower risk for infectious complications, such as tunnel and exit-site infections. Taking into consideration that a small but significant minority of patient deaths are attributed to infectious complications, percutaneous catheter placement might therefore indirectly decrease overall mortality, when all other risk factors for death (e.g., underlying comorbidities) are accounted for. However, further studies are needed, ideally in the form of randomized controlled trials, to confirm this statement.

In terms of catheter-specific long-term outcomes, both techniques displayed similar results. Catheter survival did not significantly differ between the methods for both 3 months and 1 year following placement. Most

studies reported data on catheter survival in the form of Kaplan–Meier curves, censoring patients for catheter removal due to death, transplantation, or transfer to hemodialysis, thus preventing us from extracting accurate dichotomous data. The results from individual studies in this case were inconclusive; some studies favored percutaneous placement [29, 37, 40], others favored surgical placement [28, 35], while many reported comparable catheter survival rates between the two methods [24, 26, 30, 31, 33, 42, 50]. These findings suggest that neither of the two methods seems to have a clear advantage over the other in terms of catheter survival. Nonetheless, more data are needed before definitive conclusions can be made.

When examining the laparoscopic and open surgical procedures separately, percutaneous placement resulted in lower rates of tunnel/exit-site infection and catheter migration compared to the open surgical but not the laparoscopic group. Two systematic reviews in the past have shown an advantage of laparoscopy, especially in regard to mechanical complications [19, 20], while another study showed a long-term cost benefit over the open approach [62]. Therefore, laparoscopy might be the preferred option as the standard surgical approach, provided an operator experienced with this technique is available. In the second subgroup analysis, patients with a history of previous abdominal operations were excluded from both groups. Despite the lower absolute complication rates of the percutaneous group for most outcomes, none of these differences were statistically significant. However, no certain conclusions can be made, as the statistical power of the subgroup analyses was compromised by the smaller samples, compared to the cumulative analyses.

The results of this systematic review and meta-analysis should be interpreted with caution due to its inherent limitations. We only included articles in the English language which may have introduced some language bias in our search results. Most of the included articles (94.1%; n = 32/34) were observational non-randomized studies, which are characterized by a lower quality of evidence compared to RCTs. Selection bias is common among studies reporting on percutaneous PDC placement [21]. Some studies entirely excluded patients with a history of an abdominal operation [29, 32, 34, 36, 38, 46], while others allocated patients to the surgical group if technical difficulties were expected or contraindications to percutaneous placement were present [27, 30, 31, 35, 41, 49, 54]. The latter scenario included severe obesity and previous abdominal operations. To address this issue, we decided to perform subgroup analyses that were not included in the original protocol, which could also introduce a certain degree of bias. The definition of many complications varied widely across studies, which can directly affect the reported incidence of certain complications, as in the case of leakage in Voss et al. [38]. There was also significant heterogeneity in the prophylactic antibiotic protocols used. Many studies did not report on the operator's experience with either placement method or were less experienced with the percutaneous method [24, 54]. This is important, as the operator's experience can directly affect the outcomes of the procedure [64]. A considerable amount of studies did not have adequate follow-up length and rates, which might have resulted in under-reporting of complication rates. The statistical power of funnel plots and Egger's test to detect publication bias is limited when less than 10 studies report data on an outcome of interest, as was the case in four primary (3-month catheter survival, 1-year catheter survival, overall infectious complications, and overall mechanical complications) and three secondary outcomes (catheter-related surgery required, catheter replacement, and post-procedural mortality) in our main analysis. Therefore, they should be interpreted with caution [18]. Finally, the amount of data for many outcomes was limited. This was caused either due to selective reporting or lack of data extractability, such as death/transplant-censored Kaplan Meier curves for survival data. As a result, the statistical power for some outcomes was low.

In conclusion, percutaneous PDC placement is an overall safe procedure with comparable outcomes to surgical placement, and may potentially lead to fewer infectious complications, such as peritonitis and tunnel/exit-site infections, catheter migrations, and removals. Therefore, it might be safe to say that the percutaneous method can be initially attempted for all low-risk patients, such as those with normal BMI and no history of previous abdominal operation. Taking into account other advantages of the percutaneous technique, such as the lower cost and faster PD initiation, it may become the preferred approach for low-risk patients [24, 63]. In contrast, the surgical method can be reserved for cases of failed percutaneous placement or high-risk patients, as it is more invasive and delays PDC utilization without leading to better outcomes. Choosing between the open surgical and the laparoscopic approach in this scenario will mainly depend on the surgeon's experience and availability. Nonetheless, the quality of the published literature on the topic remains poor. Well-designed RCTs comparing the outcomes between the percutaneous and surgical technique are still needed to inform decisions on optimal PDC placement.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval Since this study only used published data, no Institutional Review Board approval was necessary.

Consent to participate Since this study only used published data, no patient written consent was necessary.

Consent for publication Since this study only used published data, no consent for publication was necessary.

Code availability Not applicable.

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