Original Clinical Research Quantitative

Percutaneous Versus Surgical Insertion of Peritoneal Dialysis Catheters: A Systematic Review and Meta-Analysis

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Abstract

Background: Home-based peritoneal dialysis (PD) is an alternative to facility-based hemodialysis and has lower costs and greater freedom for patients with kidney failure. For a patient to undergo PD, a safe and reliable method of accessing the peritoneum is needed. However, different catheter insertion techniques may affect patient health outcomes.

Objective: To compare the risk of infectious and mechanical complications between surgical (open and laparoscopic) PD catheter insertion and percutaneous catheter insertion.

Design: Systematic review and meta-analysis.

Setting: We searched for observational studies and randomized controlled trials (RCTs) in CENTRAL, EMBASE, MEDLINE, PubMed, and SCOPUS from inception until June 2018. Data were extracted by 2 independent reviewers based on a preformed template.

Patients: Adult (aged 18+) patients with kidney failure who underwent a PD catheter insertion procedure.

Measurements: We analyzed leak, malfunction, and bleed as early complications (occurring within 1 month of catheter insertion). Infectious complications (exit-site infections, tunnel infections, and peritonitis) were presented as both early complications and with the longest duration of follow-up.

Methods: Random effects meta-analyses with the generic inverse variance method to estimate pooled rate ratios and 95% confidence intervals. We quantified heterogeneity by using the I2 statistic for inconsistency and assessed heterogeneity using the χ^2 test. Sensitivity analysis was performed by removing studies at high risk of bias as measured with the Newcastle-Ottawa Scale and the Cochrane Risk of Bias tool.

Results: Twenty-four studies (22 observational, 2 RCTs) with 3108 patients and 3777 catheter insertions were selected. Data from 2 studies were unable to be extracted and were qualitatively assessed. In the remaining 22 studies, percutaneous insertion was associated with a lower risk of both exit-site infections (risk ratio [RR] = 0.36, 95% confidence interval [CI] = 0.24-0.53, I2 = 0%) and peritonitis (RR = 0.52, 95% CI = 0.36-0.77, I2 = 3%) within 1 month of the procedure. There was no difference in mechanical complication rates between the 2 techniques.

Limitations: Lack of consistency in the time periods for the various outcomes reported, risk of bias concerns with respect to population comparability, and the inability to analyze individual component causes of primary nonfunction (catheter obstruction, catheter migration, and leak).

Conclusions: Our meta-analysis suggests differences in early infectious complications in favor of percutaneous insertion and no significant differences in mechanical complications compared with surgical insertion. These findings have implications on the direction of PD programs in terms of maximizing operating room resources.

Abrégé

Contexte: La dialyse péritonéale à domicile (DPD) est une alternative plus économique à l'hémodialyse en centre et offre une plus grande liberté aux patients atteints d'insuffisance rénale. Or, pour qu'un patient soit traité par DPD, il est essentiel de recourir à une méthode d'accès au péritoine qui soit fiable et sûre. Les techniques existantes pour l'insertion du cathéter sont toutefois susceptibles d'affecter les résultats de santé du patient.

Objectifs: Comparer le risque de complications mécaniques et infectieuses entre l'insertion chirurgicale (incision et laparoscopie) et percutanée d'un cathéter de DP.

Type d'étude: Revue systématique et méta-analyse.

Cadre: Nous avons consulté les bases de données CENTRAL, EMBASE, MEDLINE, PubMed et SCOPUS à la recherche d'études observationnelles et d'essais contrôlés à répartition aléatoire (ECRA) de la création à juin 2018. Deux réviseurs indépendants ont procédé à l'extraction des données en suivant un modèle préformé.

Sujets: Des adultes atteints d'insuffisance rénale ayant subi une procédure d'insertion d'un cathéter de DP.

Mesures: Nous avons analysé les fuites, le dysfonctionnement et les saignements comme des complications précoces (survenant dans le mois suivant l'insertion du cathéter). Les complications infectieuses (infections au point de sortie, infections des tunnels, péritonite) ont été présentées comme complications précoces et avec la plus longue durée de suivi.

Méthodologie: Nous avons procédé à des méta-analyses selon la méthode générique de l'inverse de la variance avec effets aléatoires pour estimer les rapports des taux combinés et les intervalles de confiance à 95 %. L'hétérogénéité a été quantifiée en utilisant la statistique I2 pour l'incohérence et a été évaluée par le test du Chi-Deux. L'analyse de sensibilité a été réalisée en retirant les études présentant un risque élevé de biais, lesquelles ont été définies à l'aide de l'échelle Newcastle-Ottawa et de l'outil Cochrane sur le risque de biais.

Résultats: En tout, 24 études (22 études observationnelles, 2 ECRA) ont été sélectionnées, ce qui représente 3 108 patients et 3 777 insertions de cathéters. Les données de deux études n'ont pu être extraites et ont été évaluées qualitativement. Dans les 22 autres études, l'insertion percutanée a été associée, dans le mois suivant la procédure, à un risque plus faible d'infections au site de sortie (RR = 0,36; IC à 95 %: 0,24-0,53; I^2 = 0 %) et de péritonite (RR = 0,52; IC à 95 %: 0,36-0,77; I^2 = 3 %). Aucune différence dans les taux de complications mécaniques n'a été observée entre les deux techniques.

Limites: Les résultats sont limités par le manque de cohérence dans les périodes associées aux divers résultats signalés, le risque de biais quant à la comparabilité des populations et l'incapacité d'analyser les causes individuelles du non-fonctionnement primaire (obstruction du cathéter, migration du cathéter, fuite).

Conclusion: Notre méta-analyse suggère des différences en faveur de l'insertion percutanée par rapport à l'insertion chirurgicale pour les complications infectieuses précoces, mais aucune différence significative en ce qui concerne les complications mécaniques. Ces résultats ont des implications sur l'orientation des programmes de DP relativement à l'optimisation des ressources du bloc opératoire.

Introduction

Studies have shown that a large[1] (and growing[2]) portion of the population have chronic kidney disease which can lead to kidney failure.[3] Kidney failure is often treated with dialysis when a patient is unable to receive or not suitable for a kidney transplant. Dialysis is associated with poor health outcomes and puts a large financial burden on health care systems.[4] Home-based dialysis modalities, such as peritoneal dialysis (PD), have been shown to cost less than in-hospital treatments and require less provider hours.[4,5] In addition, studies report patients being more satisfied with home-based dialysis than facility-based hemodialysis,[6] likely due to the freedom that it offers.[7]

An important factor which affects the success of PD is the access to the peritoneum, which is typically accomplished through the insertion of a catheter. Having a safe and reliable method of accessing the peritoneum may affect patient outcomes with respect to infectious and mechanical complications, and downstream technique failure.

Several techniques are currently available for catheter insertion, ranging from less invasive procedures such as percutaneous insertion to more resource-intensive procedures such as open surgical techniques. Although surgical and laparoscopic techniques have the advantage of being able to address other abdominal concerns at the time of surgery, they typically require a larger number of personnel, a

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surgical suite, and general anesthesia. In comparison, percutaneous techniques allow for quicker insertion without the use of general anesthetic or a surgical suite which allows the procedure to be performed quicker and with fewer side effects of anesthesia. However, it can potentially be problematic in patients with previous abdominal surgery or patients with high body mass index, limiting the pool of potential candidates.

While most programs in North America rely heavily on surgical insertion techniques, there may be advantages to bedside insertion of PD catheters. The intention of this systematic review is to compare the risk of infectious and mechanical complications between surgical (open and laparoscopic) PD catheter insertion and percutaneous catheter insertion.

Methods

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement.[8]

Data Sources/Search Strategies

An electronic search was performed using CENTRAL, EMBASE, MEDLINE, PubMed, and SCOPUS databases from inception until June 2018. Search strategies were developed in consultation with a medical librarian. Searches were conducted with terms of interest ("peritoneal dialysis," "catheter," "laparoscopy," "percutaneous," "surgical") and, wherever possible, the appropriate MeSH terms or equivalent (see Supplemental Item S1). The reference lists of included studies were assessed for any additional relevant studies.

Study Selection/Eligibility

Percutaneous insertion was defined as a PD catheter insertion using the Seldinger technique,[9] with or without the use of fluoroscopic guidance. Surgical insertion was defined as a PD catheter insertion with direct visualization through open surgery or laparoscopic technique.

In order to be included in the systematic review, studies were required to meet the following criteria: (1) insertion of a PD catheter in adult (aged 18+) patients with kidney failure; (2) comparison between percutaneous and surgical insertions methods; (3) randomized controlled trials (RCTs) or observational studies (prospective or retrospective); and (4) reported at least 1 of the following outcomes: peritonitis, exit-site infection, tunnel infection (infectious complications), malfunction (defined as an inability to use the catheter properly due to either[1] migration of the catheter tip[2] or obstruction of the catheter), bleed, or leak (mechanical complications).

Titles and abstracts of all studies were reviewed by 2 reviewers for relevance. If they were found to be potentially relevant, full texts were retrieved and assessed for eligibility by each reviewer. Studies that were deemed relevant by both reviewers were included in the final analysis. Disagreements between reviewers were resolved by consensus with the inclusion of a third reviewer when necessary. Studies that were deemed not relevant by both reviewers at the full text stage were excluded and the reason for exclusion documented.

Quality Assessment

A risk of bias assessment was performed on the included studies using a modified Newcastle-Ottawa Scale for observational studies[10] and the revised Cochrane Risk of Bias tool for RCTs.[11] The assessment was performed by 2 independent reviewers, and disagreements were resolved by consensus. The modified Newcastle-Ottawa Scale we used (see Supplemental Item S2) resulted in a score from 0 to 9 being applied to each observational study. Scores from 0 to 3 were regarded as a high risk of bias, 4 to 6 as medium risk, and 7 to 9 as low risk. In the revised Cochrane Risk of Bias tool for RCTs, 5 domains that address all types of bias relevant to RCTs[11] were assessed for low, high, or some concerns regarding the risk of bias.

Data Extraction/Statistical Analysis

Data were extracted from each study by 2 independent reviewers and then reviewed for agreement. We extracted the following data: number of patients, mean age, percentage female, number of catheters inserted, total follow-up time (in patient-months), study duration, incidence rates and number of events for our outcomes of interest and 1-year catheter survival. Each data field was extracted for all patients and for each intervention group.

As the risks of both infectious and mechanical complications are not constant over time, we presented complications that occurred within a timeframe that could be plausibly connected to the method of insertion. We analyzed leak, malfunction, and bleed as early complications (occurring within 1 month of catheter insertion). Infectious complications (exit-site infections, tunnel infections, and peritonitis) were presented as both early complications and with the longest duration of follow-up. A correction of .5 was added to each count in the case of zero events.[12] Studies where duration was not reported were excluded from meta-analysis.

For each outcome, we used random effects meta-analyses with the generic inverse variance method[13] to estimate pooled rate ratios and 95% confidence intervals (CIs). We quantified heterogeneity by using the I^2 statistic for inconsistency and used the χ^2 test to assesses whether heterogeneity was significant.[14] Sensitivity analysis was performed by removing studies with a Newcastle-Ottawa Scale score less than 4 (very high risk of bias) or a Cochrane Risk of Bias score of high risk. Statistical analyses were performed using Review Manager (RevMan) (Version 5.3).[15]
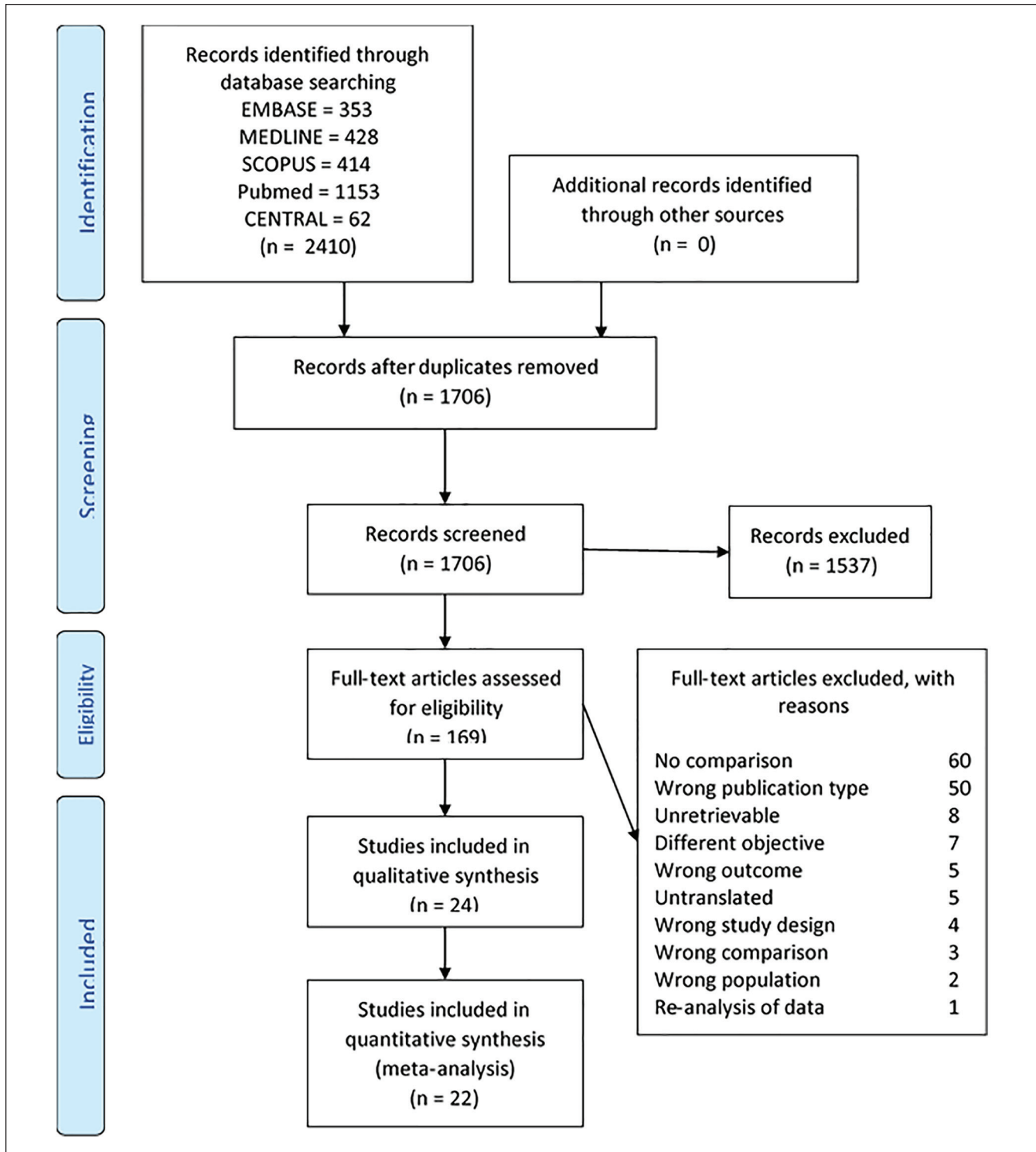
Figure 1. PRISMA flow diagram outlining study selection process.

Results

Study Selection

A flow diagram of the study selection process is shown in Figure 1. The initial search strategy yielded 1770 nonduplicate studies, of which 169 were selected for full-text review. Of the 169 studies, 24[16-39] met the inclusion criteria for our systematic review. Screening the reference lists of the included studies did not yield any additional studies. Of the 24 studies selected, 22 were meta-analyzed and 2 studies[16,17] were

excluded from meta-analysis due to specific follow-up times not being reported for each outcome. The characteristics of the included studies can be seen in Table 1. The selected studies had a total of 3777 catheter placements (1783 percutaneous, 1994 surgical). A breakdown by study of the number of events for each outcome can be found in Supplemental Item S3. Study-specific population characteristics are in Supplemental Item S4.

Risk of Bias of the Selected Studies

A breakdown of the risk of bias assessment for the included observational and RCT studies can be found in Tables 2 and 3, respectively. In total, there were 20 observational studies[18-25,27-36,38,39] and 2 RCTs.[26,37] Of the 20 total observational studies included, 3 were considered at high risk of bias.[28,35,39] As per the Newcastle-Ottawa Scale, these studies primarily exhibit concerns in the selection and comparability of study cases and controls. Of the remaining 17 observational studies, 15 were assessed as a medium risk of bias,[18-22,24,25,27,29-34,36] expressing concerns primarily in the comparability of study cases and controls, and 2 were a low risk of bias.[23,38] The 2 RCTs had a low risk of bias in 4 of 5 categories; however, some concern for bias was observed in both studies with respect to their selection of reported results.

Qualitative Review

Two studies were excluded from the meta-analysis due to their inability to determine the timeframe in which the complications were noted.[16,17] Gajjar et al[16] examined differences in catheter insertion outcomes (exit-site leaks, cuff infections, peritonitis, and previous abdominal surgery) between 2 groups performing surgical and percutaneous insertion methods and found no statistically significant differences.[16] Picó-Vicent et al studied differences in noninfectious complications (extraperitoneal placement, pericatheter leaks, cases of omental wrapping [malfunction], and blood-tinged dialysate) between percutaneous and surgical methods in patients who were obese or had previous abdominal surgery.[17] No statistically significant differences were found for any of the complication outcomes between the 2 methods.[17] There were 8 studies which employed a basic laparoscopic approach to catheter insertion, with 2 of those combining open surgical and laparoscopic insertion to create a "surgical insertion" comparison group (Table 1).[16,19,23-25,28,38]

Quantitative Meta-Analyses

Infectious complications. Early infectious complication information was able to be extracted for exit-site infections and peritonitis. For exit-site infections, 7 studies[18-24] reported this outcome (Figure 2). The pooled analysis of the risk ratio (RR) indicated a significant difference in the exit-site infection rate (RR = 0.36, 95% CI = 0.24-0.53) between both

techniques favoring percutaneous insertion. There was no significant heterogeneity ($I^2 = 0\%$, $P = .45$). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5a.

For early peritonitis, 13 studies[18-30] reported results (Figure 2). The analysis of the pooled RR indicated a significant difference (RR = 0.52, 95% CI = 0.36-0.77) between the 2 techniques favoring percutaneous insertion, with no significant heterogeneity ($I^2 = 3\%$, $P = .41$). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5b.

Overall complication rates were reported for exit-site infection, tunnel infection, and peritonitis. For overall exit-site infections, 16 studies[18-24,26,28,31-37] reported it as an outcome (Figure 2), and upon analysis of the pooled RR, there was a significant difference favoring percutaneous insertion (RR = 0.61, 95% CI = 0.46-0.82). There was no significant heterogeneity ($I^2 = 25\%$, $P = .17$). With further sensitivity analysis removing 1 study[35] due to high risk of bias, the result remained significant (RR = 0.60, 95% CI = 0.44-0.81). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5c.

For overall tunnel infections, 7 studies[23,25,32,33,35-37] reported it as an outcome (Figure 2), and upon analysis of the pooled RR, there was no significant difference (RR = 0.76, 95% CI = 0.38-1.51). There was no significant heterogeneity ($I^2 = 0\%$, $P = .96$). With further sensitivity analysis removing 1 study[35] due to high risk of bias, the result remained nonsignificant (RR = 0.75, 95% CI = 0.37-1.54). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5d.

For overall peritonitis, 21 studies[18-35,37-39] reported it as an outcome (Figure 2), and upon analysis of the pooled RR, there was no significant difference (RR = 0.86, 95% CI = 0.68-1.09) between the 2 techniques. There was substantial heterogeneity ($I^2 = 58\%$, $P < .001$). With further sensitivity analysis removing 2 studies[35,39] due to high risk of bias, the result remains nonsignificant (RR = 0.83, 95% CI = 0.64-1.08). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5e.

Mechanical complications. Early mechanical complication information was able to be extracted for bleed, leak, and malfunction. For bleed, 6 studies[15,17,19,25,27,30] reported it as an outcome (Figure 3), and upon analysis of the pooled RR, there was no significant difference (RR = 1.24, 95% CI = 0.39-3.93) between the 2 techniques. There was no significant heterogeneity ($I^2 = 27\%$, $P = .24$). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5f.

Table 1. Study Summary Table.

First author	Year	Country	Design	Comparison		Study (n)	Age (mean)	Female (%)	Catheters (n)			ROB
				Perc	Surg				Total	Perc	Surg	
Swartz	1990	USA	R	Seldinger	Open	180			213	134	79	3*
Melotte	1993	UK	R	Seldinger	Open	220			230	50	180	4*
Picó-Vicent	2000	Spain	R	Seldinger	Open	100		51.00	144	70	74	1*
Ozener	2001	Turkey	R	Seldinger	Open	191	53.1	46.00	215	133	82	5*
Roueff	2002	France	R	Seldinger	Open	104			104	57	47	2*
Dequidt	2003	Belgium	R	Seldinger	Open	118	58.0	58.00	138	60	78	4*
Liberek	2003	Poland	R	Seldinger	Open	42			43	18	25	4*
Gajjar	2007	USA	R	Seldinger	Basic Laparoscopic	75	59.6		75	30	45	3*
Rosenthal	2008	USA	R	Seldinger + Fluoroscopy	Basic Laparoscopic + Open	101	56.4	53.57	107	54	53	8*
Perakis	2009	Greece	R	Seldinger	Open	152	62.8	42.10	170	86	84	5*
Henderson	2009	UK	P	Seldinger	Basic Laparoscopic + Open				433	283	150	5*
Brum	2010	Portugal	R	Seldinger	Mini-Laparotomy	287	47.7	46.40	287	76	211	4*
Rana	2011	UK	R	Seldinger	Open	97			120	69	51	6*
Khositrangsikun	2011	Thailand	R	Seldinger	Mini-Laparotomy	205	49.8		205	56	149	5*
Sivaramakrishnan	2015	India	R	Seldinger	Mini-Laparotomy	132	53.0	39.22	143	55	88	4*
Chula	2014	Brazil	P	Seldinger	Open	95	57.2	49.40	95	53	42	4*
Maher	2014	New Zealand	R	Seldinger + Fluoroscopy	Basic Laparoscopic	249	57.6		286	133	153	7*
Demiriz	2014	Turkey	R	Seldinger	Basic Laparoscopic	40	41.9	47.75	40	30	10	2*
Park	2014	South Korea	R	Seldinger	Open	167	49.1	40.11	167	89	78	5*
Al-Hwiesh	2014	Saudi Arabia	R	Seldinger	Basic Laparoscopic	43	50.0	34.90	52	27	25	5*
Medani	2015	Ireland	R	Seldinger	Mini-Laparotomy	127	50.2	32.30	127	63	64	6*
Sun	2016	New Zealand	R	Seldinger + Fluoroscopy	Basic Laparoscopic	209	55.6	47.85	209	69	140	5*
Atapour	2011	Iran	RCT	Seldinger	Open	61	55.1	45.90	61	31	30	SC**
Voss	2012	New Zealand	RCT	Seldinger + Fluoroscopy	Laparoscopic	113	61.0	48.67	113	57	56	SC**

Note. Per = percutaneous; Surg = surgical; R = retrospective; P = prospective; RCT = randomized control trial; ROB = Risk of bias.
* = Observational study, ** = Randomized control trial study.

Table 2. Observational Study Risk of Bias Assessment.

Study	Selection (Max 4 stars)	Comparability (Max 2 stars)	Outcome (Max 3 stars)	Sum (Max 9 stars)	Risk of bias
Swartz et al[39]	*		**	3	High
Mellotte et al[21]	**		**	4	Medium
Pico-Vicent et al[17]	*			1	High
Ozener et al[33]	**	*	**	5	Medium
Roueff et al[35]	*		*	2	High
Dequidt et al[18]	**		**	4	Medium
Liberek et al[32]	**		**	4	Medium
Gajjar et al[16]	**		*	3	High
Rosenthal et al[23]	***	**	***	8	Low
Perakis et al[22]	**	*	**	5	Medium
Henderson et al[19]	***		**	5	Medium
Brum et al[31]	**	*	*	4	Medium
Khositrangsikun et al[20]	***	*	*	5	Medium
Rana et al[34]	***		***	6	Medium
Al-Hwiesh[25]	***	*	*	5	Medium
Chula et al[27]	***		*	4	Medium
Demiriz et al[28]	*		*	2	High
Maher et al[38]	***	*	***	7	Low
Park et al[30]	***		**	5	Medium
Medani et al[29]	**	*	***	6	Medium
Sivaramakrishnan et al[36]	**	*	*	4	Medium
Sun et al[24]	**	*	**	5	Medium

Note. Sum 0-3 stars = high risk of bias. Sum 4-6 stars = medium risk of bias. Sum 7-10 stars = low risk of bias.

* = 1 criteria met per domain of bias assessed, ** = 2 criteria met per domain of bias assessed, *** = 3 criteria met per domain of bias assessed.

Table 3. Randomized Control Trial Study Risk of Bias Assessment.

Study	Randomization Process	Deviations from intended interventions	Missing outcome data	Measurement of outcome	Selection of the reported results
Atapour 2011	+	+	+	+	SC
Voss 2012	+	+	+	+	SC

Note. + = low risk of bias; − = high risk of bias; SC = some concerns.

For leak, 9 studies[18-22,25,28,33,39] reported it as an outcome (Figure 3), and upon analysis of the pooled RR, there was no significant difference (RR = 1.59, 95% CI = 0.92-2.75) between the 2 techniques. There was substantial heterogeneity (I^2 = 50%, P = .04). With further sensitivity analysis removing 1 study[39] due to high risk of bias, the result remains nonsignificant (RR = 1.48, 95% CI = 0.77-2.85). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5g.

For malfunction, 8 studies[18,19,21,22,25,27,28,39] reported it as an outcome (Figure 3), and upon analysis of the pooled RR, there was no significant difference (RR = 1.04, 95% CI = 0.76-1.41) between the 2 techniques. There was no significant heterogeneity (I^2 = 0%, P = .65). With further sensitivity analysis removing 1 study[39] due to high risk of bias, the result remains nonsignificant (RR = 1.00, 95%

CI = 0.72-1.38). The number of events, patients, and duration of follow-up for all studies meta-analyzed under this outcome are in Supplemental Item S5h.

Discussion

In this systematic review and meta-analysis comparing complication rates between surgical and percutaneous insertion of PD catheters in adult patients with kidney failure, percutaneous catheter insertions were associated with a 64% (95% CI = 47%-76%) relative risk reduction of early exit-site infection and a 48% (95% CI = 23%-64%) relative risk reduction of early peritonitis compared with surgically inserted catheters. This effect continued to be significant for exit-site infections when pooling all durations of follow-up, but with a reduced magnitude. We also found no difference in the rate of mechanical complications between the 2
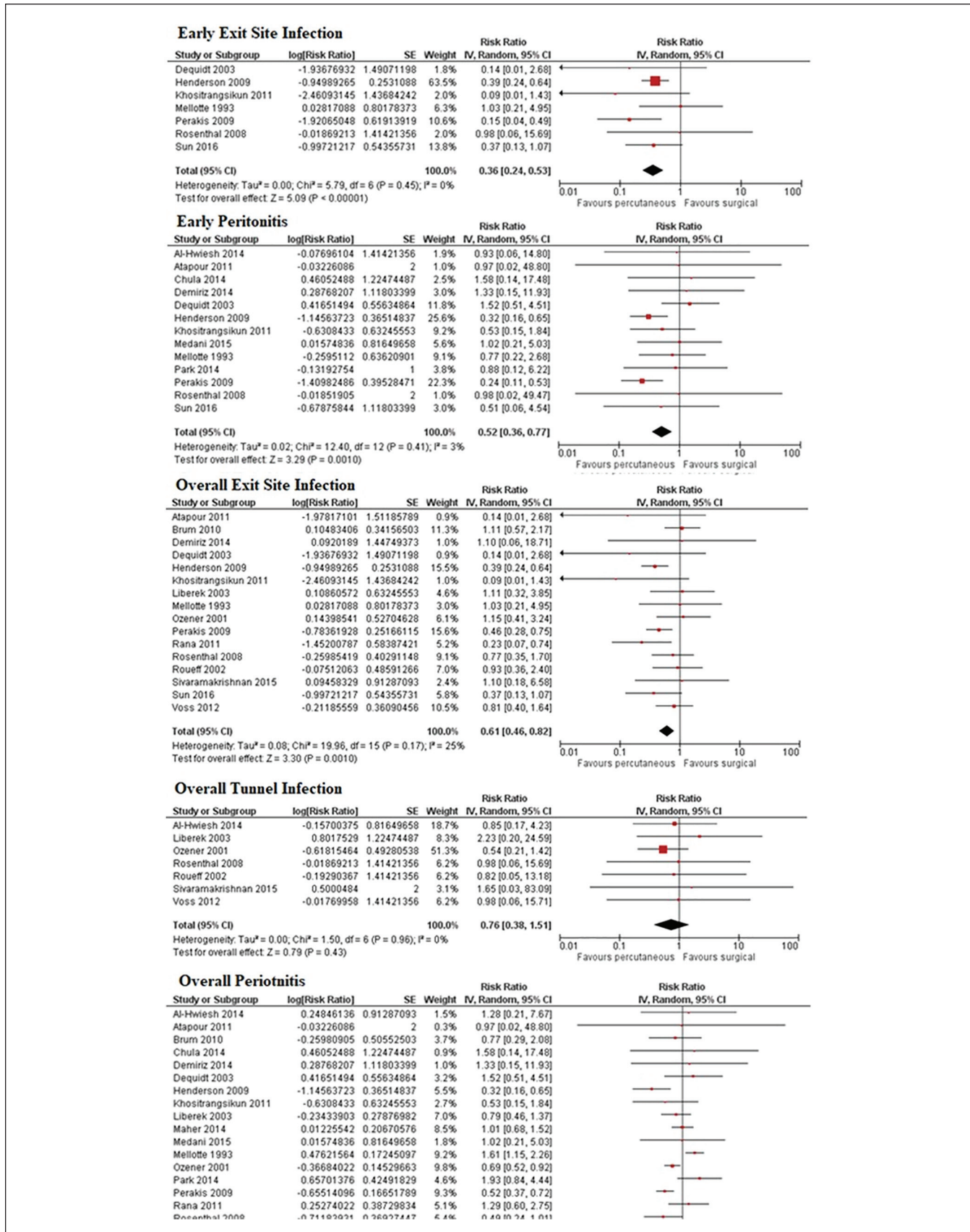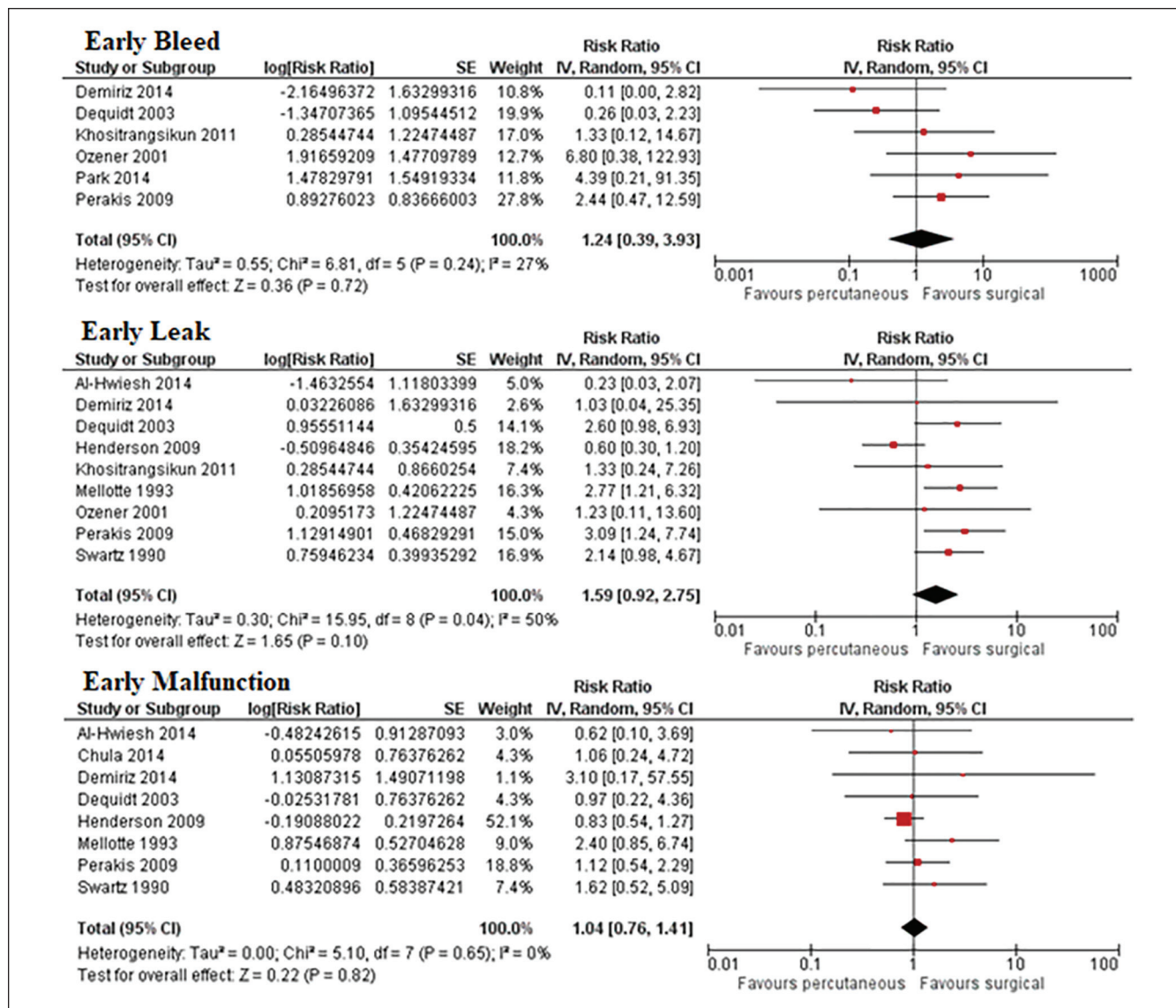
Figure 2. Results of random effects meta-analysis for infectious complications.
Note. CI = confidence interval.

Figure 3. Results of random effects meta-analysis for mechanical complications.
Note. CI = confidence interval.

insertion methods. Taken together, these findings suggest that percutaneous insertion is associated with similar safety outcomes as surgical insertion of PD catheters.

To our knowledge, this systematic review represents the largest assessment of PD catheter complications between surgical and percutaneous insertion. Two previous systematic reviews have been conducted to identify differences in complication rates between percutaneous and surgical catheter insertion. These reviews included studies until 2014 and as such had less than half of the patients than our review. The first of these reviews[40] found no significant difference between percutaneous and surgical insertion for any of the outcomes they analyzed (1-year catheter survival, dysfunction, leak) from the 13 studies they identified, apart from peritonitis, which favored percutaneous insertion. Their results are consistent with ours, as we also

found percutaneous insertion favorable for early infectious complications and nonsignificant results for mechanical complications.

As the primary goal of PD catheter insertions is ultimately to provide a functioning catheter, nonfunction as a failed outcome should be given additional importance. We found no significant difference between the 2 techniques when analyzing the pooled RR for early malfunction. Primary nonfunction may be caused by factors such as catheter obstruction, catheter migration and leak.[41] Although our analysis was unable to separately address each component due to a lack of data, we were able to address malfunction specifically as an early outcome (within 1 month).

An important topic to address is the variability of definition and reporting for both infectious and mechanical complications of PD catheter insertion. The *International Society*

for Peritoneal Dialysis (*ISPD*) *Catheter-Related Infection Recommendations: 2017 Update* recommends a definition of exit-site infection as the presence of purulent discharge with or without the presence of erythema of the skin at the catheter-epidermal interface.[42] In a large portion of the studies that were included in the review (n = 8), the definition of exit-site infection was not clearly stated. In those that were, some simply defined exit-site infection as a clinical diagnosis or used criteria which was not consistent with the ISPD guideline (n = 3). Finally, there were 5 articles which employed an ISPD guideline–consistent definition of exit-site infection, either explicitly defined or through mention of guideline.

An important consideration in the frequency of leak as a complication is the amount of time the catheters were allowed to rest before being used for dialysis, and whether there was any difference between the break-in time allowed between surgical and percutaneous insertion. In 9 studies, there was no mention of time between insertion of the catheter to use. However, in every other study, either most or all catheters were allowed a minimum of 1 week (more often 2 weeks) to settle before the initiation of dialysis. In the 10 studies meta-analyzed by the second review,[43] they found no significant difference between the 2 insertion methods in any of the outcomes they analyzed (peritonitis, tunnel and exit site infection, leak, obstruction, or bleed). We may have found different results because our study differed in our approach of identifying and analyzing complications which occur within a defined timeframe (1 month for early complications). This was done with the intent of potentially isolating complications which are more directly due to catheter insertion rather than patient or other catheter care factors which occur later.

The definition of mechanical complication (particularly malfunction) was quite variable from study to study, not only in how broad the definition used was, but also with what specifically constituted a particular type of complication. Unfortunately, there were very few papers which explicitly defined their criteria for a type of complication (notably Perakis et al) who explicitly stated that they were using the ISPD definitions.[22,42] The most common type of mechanical outcome that was grouped under malfunction outflow obstruction (n = 8), with tip migration/displacement as the next most common (n = 5). Both outcomes have several different factors contributing to how they are defined and can be reported, which makes this a rather heterogenous set of data. However, as the main comparison is being made the different methods of insertion, rather than between studies themselves, part of that is dealt with by the fact that the studies use consistent internal definitions for the sake of recording outcomes.

Although laparoscopic insertions, laparotomies, and open catheter placements are all surgical techniques, they vary in their level of invasiveness, postoperative pain, and recovery time.[44] As a result, the interventions used in the surgical group may have been more heterogeneous than those in the percutaneous group. Current guidelines from the ISPD have recognized the difference and their order of recommended insertion approaches in patients without peritonitis and previous major surgery are advanced laparoscopic, image-guided percutaneous, and open surgical dissection.[45] Advanced laparoscopic techniques differ from basic laparoscopy as they use additional preemptive procedures to minimize risks of complications such as catheter migration and omental wrapping.[45,46] However, laparoscopic and open techniques have been grouped together in previous systematic reviews and meta-analyses as previous research has found no difference in mechanical or infectious complications.[40,43,47,48] Furthermore, a recent systematic review and meta-analysis comparing advanced laparoscopy to basic laparoscopy and open surgical placement did not find any difference between the surgical techniques in infectious complications (peritonitis and exit-site infections), whereas we found a clear trend favoring percutaneous insertion for those outcomes.[49] In addition, where differences favoring advanced laparoscopy were found (mechanical complications of leaks), the number of studies included and events experienced were low, and the difference was almost entirely driven by 1 study.

We believe that along with complications, it is also important to consider the difference in cost and resource use associated with percutaneous and surgical insertion. In a previous study conducted in Ireland,[29] the cost per procedure of percutaneous insertion and surgical insertion was estimated as €650 and €1200, respectively, due to the higher operating theater costs. In another study conducted in the United States,[37] the direct hospital costs were $2076 and $4125 for percutaneous and surgical insertion, respectively. As these values reported are directly related to the insertion of the catheter, cost differences may be more apparent when considering future hospital visits for complications which are attributable to the insertion method. Given that percutaneous insertion appears less expensive and less likely to result in early infectious complications without an increased risk in mechanical complications, it would provide a greater benefit to patients at less cost to the health care system compared with surgical insertion. Classification of this potential benefit from a formal cost-utility analysis is warranted.

Pain is a consideration for the insertion of the PD catheters, as it can change the patient experience with the catheter and affect later follow-up. As most papers were retrospective, they did not report pain as an outcome, with the only paper to report it being Voss et al.[37] They employed a 10-point pain scale pre- and postinsertion to determine the change in pain that was attributable to the catheter insertion. They noted that the postoperative pain scores were higher in the laparoscopic group in comparison with the radiological insertion (3 vs 1). This suggests that percutaneous insertion might be more advantageous from a pain perspective, but would require a larger body of evidence to make it a strong recommendation.

It is difficult to determine whether differences in rates of complications can be attributed to the technique employed by interventionalists or other factors such as the complexity of patients. In one study, there were an additional 150 catheters in the percutaneous group placed by the same physicians (433 percutaneously vs 283 surgically).[19] It is therefore possible that the additional 150 catheters placed percutaneously allowed a greater degree of familiarity with the insertion technique. One study showed an increase in the catheter survival after the last set of 30 catheters placed percutaneously in comparison with the first 30 catheters placed.[18] As with other procedures, a local operator/center effect that may influence catheter outcomes cannot be ruled out and should be considered when applying these results to an individual center.

Furthermore, postcatheter placement outcomes may be influenced by the unique patient pathways associated with each technique. Percutaneous catheter insertions are primarily performed by nephrologists with after-care likely done within the renal unit.[50] Those undergoing surgical catheter placement are likely to receive postsurgical care separate from the renal unit. These differences in patient pathways may contribute to differences found in outcomes such as exit-site infection rates and early peritonitis which favored the percutaneous insertion technique.

Our review's main strength is the initial search strategy that was designed to be widely inclusive at each stage of screening as to select as many potential articles for full-text review as possible before applying our objective criteria for inclusion in the review and meta-analysis. In turn, this resulted in many studies from which outcome information was extracted and analyzed. In addition, our review provided a meta-analysis of complications in a more granular manner, providing more specific details on the differences in outcomes between both insertion techniques.

One of the limitations to this review is the lack of consistency in the time periods for the various outcomes reported. Although event rates for most postimplantation outcomes are typically highest immediately after catheter implantation, many studies reported only cumulative events over extended periods of time. This variability in follow-up times between studies and between groups within studies may have affected the appropriateness of long-term comparisons. As such, we would suggest a convention of reporting early outcomes (within 30 days of the procedure) to be able to more adequately associate complications with the insertion method. In addition, most studies included had a moderate risk of bias. The domain where most observational studies scored lowest was the comparability of the 2 populations. Although there were a few studies which made efforts to ensure that both groups were drawn from the same population, most studies relied on retrospective data and as such are subject to selection bias based on patients who were deemed able to tolerate either a percutaneous or surgical insertion based on physician judgment. Of the studies selected, obesity and prior abdominal surgery were both specific contraindications to percutaneous catheter insertion in many. However, there were a few studies[23,25,26,29,33,36,37] which addressed this factor by specifically excluding these patients from both populations, helping to create a more comparable population of patients in both intervention arms. In addition, primary nonfunction may be caused by factors such as catheter obstruction, catheter migration, and leak. This analysis was unable to separately address each component due to a lack of data.

One other potential source of bias is the effect of experience and familiarity with the physicians performing the catheter insertion. Most studies included were single-center reports, and of those, many specifically highlighted the fact that the nephrology team at their institution had been inserting these catheters percutaneously for a certain number of years, whereas when it came to the surgical comparison, only brief mention was made of the surgical team in the abstract, implying those who had not been specifically chosen or trained for this procedure. The only study which specifically highlighted the experience of the surgical team was Gajjar et al.[16] Along with the fact that most studies were published by nephrologists or radiologists, there is a large likelihood of publication bias with an understandable desire to publish results which are beneficial for a procedure that they themselves perform.

Conclusions

In conclusion, our meta-analysis suggests significant differences in early infectious complications in favor of percutaneous insertion. In addition, no significant difference was found for mechanical complications, suggesting that percutaneous insertion may be noninferior to surgical insertion in select patients who are candidates for this procedure. These results may have significant implications on the direction of PD programs in terms of maximizing operating room resources. Large RCTs should be conducted to help improve the quality of these findings.

Ethics Approval and Consent to Participate

Consent for Publication

All authors consented to publication.

Availability of Data and Materials

Will be made available on request.

Declaration of Conflicting Interests

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Supplemental Material

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References

1. Arora P, Vasa P, Brenner D, et al. Prevalence estimates of chronic kidney disease in Canada: results of a nationally representative survey. *CMAJ*. 2013;185(9):E417-E423. doi:10.1503/cmaj.120833.

2. James MT, Hemmelgarn BR, Tonelli M. Early recognition and prevention of chronic kidney disease. *Lancet*. 2010;375(9722):1296-1309. doi:10.1016/s0140-6736(09)62004-3.

3. Coresh J, Selvin E, Stevens LA, et al. Prevalence of chronic kidney disease in the United States. *JAMA*. 2007;298(17):2038-2047. doi:10.1001/jama.298.17.2038.

4. Goeree R, Manalich J, Grootendorst P, Beecroft ML, Churchill DN. Cost analysis of dialysis treatments for end-stage renal disease (ESRD). *Clin Invest Med*. 1995;18(6):455-464.

5. Coyte PC, Young LG, Tipper BL, et al. An economic evaluation of hospital-based hemodialysis and home-based peritoneal dialysis for pediatric patients. *Am J Kidney Dis*. 1996;27(4):557-565. doi:10.1016/s0272-6386(96)90167-5.

6. Rubin HR, Fink NE, Plantinga LC, Sadler JH, Kliger AS, Powe NR. Patient ratings of dialysis care with peritoneal dialysis vs hemodialysis. *JAMA*. 2004;291(6):697-703. doi:10.1001/jama.291.6.697.

7. Morton RL, Snelling P, Webster AC, et al. Dialysis modality preference of patients with CKD and family caregivers: a discrete-choice study. *Am J Kidney Dis*. 2012;60(1):102-111. doi:10.1053/j.ajkd.2011.12.030.

8. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009;151(4):264-269, W64. doi:10.7326/0003-4819-151-4-200908180-00135.

9. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography; a new technique. *Acta Radiol*. 1953;39(5):368-376. doi:10.3109/00016925309136722.

10. Wells G, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses 2001. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed October 5, 2021.

11. Sterne JAC, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:l4898. doi:10.1136/bmj.l4898.

12. Higgins JP, Green S. *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester, England: Wiley-Blackwell; 2008.

13. Hartung J, Knapp G, Sinha B. *Statistical Meta-Analysis With Applications*. NJ: John Wiley; 2008. Hoboken, United States.

14. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002;21(11):1539-1558. doi:10.1002/sim.1186.

15. *Review Manager (RevMan)*. Version 5.3. Copenhagen, Denmark: The Nordic Cochrane Centre, The Cochrane Collaboration; 2014.

16. Gajjar AH, Rhoden DH, Kathuria P, Kaul R, Udupa AD, Jennings WC. Peritoneal dialysis catheters: laparoscopic versus traditional placement techniques and outcomes. *Am J Surg*. 2007;194(6):872-875; discussion 5-6. doi:10.1016/j.amjsurg.2007.08.038.

17. Picó-Vicent L, Cases JM, Picó-Mira L, Contreras JP. Post-implantation events of swan-neck catheters for PD. *EDTNA-ERCA J*. 2000;26(4):17-18. doi:10.1111/j.1755-6686.2000.tb00112.x.

18. Dequidt C, Vijt D, Veys N, Van Biesen W. Bed-side blind insertion of peritoneal dialysis catheters. *EDTNA ERCA J*. 2003;29(3):137-139. doi:10.1111/j.1755-6686.2003.tb00294.x.

19. Henderson S, Brown E, Levy J. Safety and efficacy of percutaneous insertion of peritoneal dialysis catheters under sedation and local anaesthetic. *Nephrol Dial Transplant*. 2009;24(11):3499-3504. doi:10.1093/ndt/gfp312.

20. Khositrangsikun K, Chujohn W, Kanokkantapong C, Kanjanabuch T. Comparison of the Seldinger technique and surgical technique in Tenckhoff catheter insertion in CAPD patients: a single center experience. *J Med Assoc Thai*. 2011;94(suppl 4):S77-S80.

21. Mellotte G, Ho C, Morgan S, Bending M, Eisinger A. Peritoneal dialysis catheters: a comparison between percutaneous and conventional surgical placement techniques. *Nephrol Dial Transplant*. 1993;8(7):626-630.

22. Perakis KE, Stylianou KG, Kyriazis JP, et al. Long-term complication rates and survival of peritoneal dialysis catheters: the role of percutaneous versus surgical placement. *Semin Dial*. 2009;22(5):569-575. doi:10.1111/j.1525-139X.2009.00621.x.

23. Rosenthal MA, Yang PS, Liu IL, et al. Comparison of outcomes of peritoneal dialysis catheters placed by the fluoroscopically guided percutaneous method versus directly visualized surgical method. *J Vasc Interv Radiol*. 2008;19(8):1202-1207. doi:10.1016/j.jvir.2008.05.006.

24. Sun TY, Voss D, Beechey D, Lam-Po-Tang M. Comparison of peritoneal dialysis catheter insertion techniques: peritoneoscopic, radiological and laparoscopic: a single-centre study. *Nephrology (Carlton)*. 2016;21(5):416-422. doi:10.1111/nep.12621.

25. Al-Hwiesh AK. Percutaneous versus laparoscopic placement of peritoneal dialysis catheters: simplicity and favorable outcome. *Saudi J Kidney Dis Transpl*. 2014;25(6):1194-1201. doi:10.4103/1319-2442.144252.

26. Atapour A, Asadabadi H, Karimi S, Eslami A, Beigi AA. Comparing the outcomes of open surgical procedure and percutaneously peritoneal dialysis catheter (PDC) insertion using laparoscopic needle: a two month follow-up study. *J Res Med Sci*. 2011;16(4):463-468.

27. Chula DC, Campos RP, de Alcantara MT, Riella MC, do Nascimento MM. Percutaneous and surgical insertion of peritoneal catheter in patients starting in chronic dialysis therapy: a comparative study. *Semin Dial*. 2014;27(3):E32-E37. doi:10.1111/sdi.12147.

28. Demiriz B, Bulut M, Gok Oguz E, et al. A comparison of laparoscopic and conventional methods in peritoneal

dialysis catheter placement in patients with end-stage renal disease: single center experience. *Turk Nephrol Dial Transplant*. 2014;23(3):181-184. doi:10.5262/tndt.2014.1003.02.

29. Medani S, Hussein W, Shantier M, Flynn R, Wall C, Mellotte G. Comparison of percutaneous and open surgical techniques for first-time peritoneal dialysis catheter placement in the unbreached peritoneum. *Perit Dial Int*. 2015;35(5):576-585. doi:10.3747/pdi.2013.00003.

30. Park YS, Min SI, Kim DK, et al. The outcomes of percutaneous versus open placement of peritoneal dialysis catheters. *World J Surg*. 2014;38(5):1058-1064. doi:10.1007/s00268-013-2346-5.

31. Brum S, Rodrigues A, Rocha S, et al. Moncrief-Popovich technique is an advantageous method of peritoneal dialysis catheter implantation. *Nephrol Dial Transplant*. 2010;25(9):3070-3075. doi:10.1093/ndt/gfq142.

32. Liberek T, Chmielewski M, Lichodziejewska-Niemierko M, Renke M, Zadrozny D, Rutkowski B. Survival and function of Tenckhoff peritoneal dialysis catheter after surgical or percutaneous placement: one centre experience. *Int J Artif Organs*. 2003;26(2):174-175. doi:10.1177/039139880302600213.

33. Ozener C, Bihorac A, Akoglu E. Technical survival of CAPD catheters: comparison between percutaneous and conventional surgical placement techniques. *Nephrol Dial Transplant*. 2001;16(9):1893-1899. doi:10.1093/ndt/16.9.1893.

34. Rana T, Cramp H, Akoh J. Evaluation of medical insertion of peritoneal dialysis catheters. *Nephro-Urology Monthly*. 2011;3(1):46-53.

35. Roueff S, Pagniez D, Moranne O, et al. Simplified percutaneous placement of peritoneal dialysis catheters: comparison with surgical placement. *Perit Dial Int*. 2002;22(2):267-269.

36. Sivaramakrishnan R, Gupta S, Agarwal SK, Bhowmik D, Mahajan S. Comparison of outcomes between surgically placed and percutaneously placed peritoneal dialysis catheters: a retrospective study. *Indian J Nephrol*. 2016;26(4):268-274. doi:10.4103/0971-4065.163425.

37. Voss D, Hawkins S, Poole G, Marshall M. Radiological versus surgical implantation of first catheter for peritoneal dialysis: a randomized non-inferiority trial. *Nephrol Dial Transplant*. 2012;27(11):4196-4204. doi:10.1093/ndt/gfs305.

38. Maher E, Wolley MJ, Abbas SA, Hawkins SP, Marshall MR. Fluoroscopic versus laparoscopic implantation of peritoneal dialysis catheters: a retrospective cohort study. *J Vasc Interv Radiol*. 2014;25(6):895-903. doi:10.1016/j.jvir.2014.01.023.

39. Swartz R, Messana J, Rocher L, Reynolds J, Starmann B, Lees P. The curled catheter: dependable device for percutaneous peritoneal access. *Perit Dial Int*. 1990;10(3):231-235.

40. Boujelbane L, Fu N, Chapla K, et al. Percutaneous versus surgical insertion of PD catheters in dialysis patients: a meta-analysis. *J Vasc Access*. 2015;16(6):498-505. doi:10.5301/jva.5000439.

41. Singh N, Davidson I, Minhajuddin A, Gieser S, Nurenberg M, Saxena R. Risk factors associated with peritoneal dialysis catheter survival: a 9-year single-center study in 315 patients. *J Vasc Access*. 2010;11(4):316-322. doi:10.5301/jva.2010.5774.

42. Szeto CC, Li PK, Johnson DW, et al. ISPD catheter-related infection recommendations: 2017 update. *Perit Dial Int*. 2017;37(2):141-154. doi:10.3747/pdi.2016.00120.

43. Tullavardhana T, Akranurakkul P, Ungkitphaiboon W, Songtish D. Surgical versus percutaneous techniques for peritoneal dialysis catheter placement: a meta-analysis of the outcomes. *Ann Med Surg (Lond)*. 2016;10:11-18. doi:10.1016/j.amsu.2016.07.007.

44. Amerling R, Cruz C. A new laparoscopic method for implantation of peritoneal catheters. *ASAIO J*. 1993;39(3):M787-M789.

45. Crabtree JH, Shrestha BM, Chow KM, et al. Creating and maintaining optimal peritoneal dialysis access in the adult patient: 2019 update. *Perit Dial Int*. 2019;39(5):414-436. doi:10.3747/pdi.2018.00232.

46. Crabtree JH, Fishman A. A laparoscopic method for optimal peritoneal dialysis access. *Am Surg*. 2005;71(2):135-143.

47. Xie H, Zhang W, Cheng J, He Q. Laparoscopic versus open catheter placement in peritoneal dialysis patients: a systematic review and meta-analysis. *BMC Nephrol*. 2012;13:69. doi:10.1186/1471-2369-13-69.

48. Hagen SM, Lafranca JA, Steyerberg EW, IJzermans JNM, Dor FJ. Laparoscopic versus open peritoneal dialysis catheter insertion: a meta-analysis. *PLoS One*. 2013;8(2):e56351. doi:10.1371/journal.pone.0056351.

49. Shrestha BM, Shrestha D, Kumar A, Shrestha A, Boyes SA, Wilkie ME. Advanced laparoscopic peritoneal dialysis catheter insertion: systematic review and meta-analysis. *Perit Dial Int*. 2018;38(3):163-171. doi:10.3747/pdi.2017.00230.

50. Al-Hwiesh AK. Percutaneous peritoneal dialysis catheter insertion by a nephrologist: a new, simple, and safe technique. *Perit Dial Int*. 2014;34(2):204-211. doi:10.3747/pdi.2012.00160.