Advanced Image-Guided Percutaneous Technique Versus Advanced Laparoscopic Surgical Technique for Peritoneal Dialysis Catheter Placement

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Rationale & Objective: Timely placement of a functional peritoneal dialysis (PD) catheter is crucial to long-term PD success. Advanced image-guided percutaneous and advanced laparoscopic techniques both represent best practice catheter placement options. Advanced image-guided percutaneous is a minimally invasive procedure that does not require general anesthesia.

Study Design: Retrospective cohort study comparing time from referral to procedure, complication rate, and 1-year catheter survival between placement techniques.

Setting & Participants: Patients who had advanced laparoscopic or advanced image-guided percutaneous PD catheter placement from January 1, 2011 to December 31, 2013 in an integrated Northern California health care delivery system.

Exposure: PD catheter placement using advanced laparoscopic or advanced image-guided percutaneous techniques.

Outcomes: One-year PD catheter survival; major, minor, and infectious complications; time from referral to PD catheter placement; and procedure time.

Analytical Approach: Wilcoxon rank sum tests to compare referral and procedure times; χ^2/Fisher exact tests to compare complications; and modified least-squares regression to compare adjusted 1-year catheter survival between PD placement techniques.

Results: We identified 191 and 238 PD catheters placed through advanced image-guided percutaneous and advanced laparoscopic techniques, respectively. Adjusted 1-year PD catheter survival was 80% (95% CI, 74%-87%) using advanced image-guided percutaneous technique vs 91% (87%-96%) using advanced laparoscopic technique ($P = 0.01$). Major complications were <1% in both groups. Minor and infectious complications were 45.6% and 38.7% in advanced image-guided percutaneous and advanced laparoscopic techniques, respectively ($P = 0.01$). Median days from referral to procedure were 12 and 33 for patients undergoing advanced image-guided percutaneous and advanced laparoscopic techniques, respectively ($P < 0.001$). Median procedure time was 30 and 44.5 minutes for patients undergoing advanced image-guided percutaneous and advanced laparoscopic techniques, respectively ($P < 0.001$).

Limitations: Retrospective study with practice preference influenced by timing, local expertise, and resources.

Conclusions: Both advanced image-guided percutaneous and advanced laparoscopic techniques reported rare major complications and demonstrated excellent (advanced laparoscopic) and acceptable (advanced image-guided percutaneous) 1-year PD catheter survival. For patients referred for PD catheter placement at centers where advanced laparoscopic resources or expertise remain limited, the advanced image-guided percutaneous technique can provide a complementary and timely option to support the utilization of PD.

Visual Abstract included

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Peritoneal dialysis (PD) is an underutilized therapy for kidney replacement despite many advantages over in-center hemodialysis (HD).[1] Compared with in-center HD, PD provides better preservation of residual kidney function, improvement of cognitive functioning, greater quality of life, and higher likelihood of employment.[2-4] Furthermore, PD is associated with lower medical costs.[4] Despite its many advantages, PD remains widely underutilized in the United States. As of 2019, only 12.6% of patients receiving incident dialysis and 11.2% of patients receiving prevalent dialysis were using PD as their modality for kidney replacement therapy.[5] The Advance America Kidney Health initiative has provided an impetus to increase home dialysis and preemptive transplant, with a goal of reaching an 80% incidence of either or both by 2025.

There are many reasons for this low utilization, such as the traditional hemodialysis centric approach to kidney replacement therapy. Another factor leading to low PD utilization is the lack of experienced operators available to place PD catheters. A survey performed by Wong et al[6] showed that despite many US surgery residency programs providing PD catheter training, most surgeons placed only 2-5 catheters during residency. Low PD utilization and lack of referrals limit surgical training at most centers.[6] This perpetuates a vicious cycle: fewer patients referred for PD catheter placement leading to fewer operators that are proficient in placing a PD catheter. Thus,

PLAIN-LANGUAGE SUMMARY

Peritoneal dialysis is a preferred dialysis modality for many patients. However, the lack of available skilled surgeons can limit the placement of the peritoneal dialysis catheter in a timely manner. In the past decade, interventional radiology has developed expertise in placing peritoneal dialysis catheters. Using data from an integrated health care system, we compared the outcome of peritoneal dialysis catheters placed using laparoscopic surgery and interventional radiology techniques. Our results showed excellent 1-year patency of peritoneal dialysis catheters placed using laparoscopic surgery, whereas interventional radiology placement of catheters had lower but acceptable 1-year patency survival, based on best practice guideline criteria. Hence, interventional radiology placement of peritoneal dialysis catheters may be a viable alternative when laparoscopic surgery is not available or feasible.

fewer timely and quality PD catheters are placed, resulting in delayed and problematic PD catheters. In this environment, nephrologists have little confidence in starting their patients on PD.

Other factors leading to low utilization of PD include infrastructure issues related to PD catheter placement, such as limited operating room access and the need for general anesthesia. These factors lead to delays in PD catheter placement, resulting in patients starting on HD using a central venous catheter (CVC), regardless of their initial modality choice. The use of CVC has been shown to be associated with increased infectious complications, hospitalizations, and mortality.[7-9] Traditionally, most PD catheters are placed surgically in the operating room under general anesthesia.[10] Recently, interventional radiologists and interventional nephrologists have been placing PD catheters using conscious sedation.[11,12]

Different techniques have been used to place PD catheters, such as open surgical, basic laparoscopic, advanced laparoscopic, and image-guided percutaneous methods. Advanced laparoscopic technique has been shown to have excellent catheter survival and low malfunction or complication rates. Moreover, it provides the opportunity to perform adhesiolysis, omentopexy, and hernia repair during a single session.[13,14] Alternatively, advanced image-guided percutaneous technique performed by interventional radiologists is a minimally invasive procedure performed under conscious sedation in a fluoroscopy suite. Image-guided catheter placement by radiologists is a relatively new technique and a limited number of studies reported good catheter survival and low rates of catheter malfunction and complications.[15,16] Advantages of advanced image-guided percutaneous over laparoscopic surgery include greater expediency, less invasive approach, avoidance of general anesthesia, and lower cost. Easier access to PD catheter placement may increase utilization of PD.[11,17]

Kaiser Permanente Northern California (KPNC) is an integrated health care system with 21 medical centers serving 4.6 million members in Northern California. KPNC and The Permanente Medical Group have increased PD incidence from 15%–34% over an 11-year period (2008-2018) through a multidisciplinary, system-wide approach.[18] An important factor that contributed to the high percentage of PD utilization was the availability of skilled surgeons or interventional radiologists across multiple medical centers who facilitated placement of PD catheters in a timely manner. Here, we report findings of a retrospective study comparing PD catheters placed by interventional radiologists utilizing the advanced image-guided percutaneous technique versus PD catheters placed by surgeons through the advanced laparoscopic technique from January 2011 to December 2013. Our primary objective was to compare overall catheter survival and category specific complications between the 2 groups. We also compared time to procedure and catheter patency between the groups.

METHODS

Study Population

The source population was adult (age ≥18 years) KPNC members who had a PD catheter placed between January 1, 2011 and December 31, 2013 by either advanced image-guided percutaneous or advanced laparoscopic techniques. The PD catheter insertion procedures performed using the advanced image-guided percutaneous technique were identified from KPNC hospitalization and financial transaction databases linked to Current Procedural Terminology 4 procedural codes 49418 and 49421, and to the appropriate locations (medical center and interventional radiology suite) and performing providers. Procedure notes were reviewed to confirm that there was no evidence of embedded catheters. KPNC electronic operating room and hospitalization databases were the source of PD catheter insertion procedures performed using the advanced laparoscopic technique. Cases were identified by key words in the operating room record log consistent with PD catheter insertion, laparoscopically, for dialysis access or from Current Procedural Terminology 4 code 49324 linked to hospital discharge records.

Data Sources

All study data were obtained from KPNC clinical and administrative databases or from review of electronic health records. Demographic data for birth date, sex, race or ethnicity, height, and weight were obtained from electronic data sources. Age was computed at the time of the index PD catheter insertion procedure. Body mass index (BMI) was calculated from measured height and weight captured as close as possible to catheter insertion and within 1 year previous or 3 months thereafter. Time to procedure was defined as the number of days between date of initial PD consultation request from the nephrologist (to interventional radiology or surgery) and date of catheter insertion procedure. The electronic consult database was the source of this information. Procedure time was captured from electronic data sources, including flowchart records for advanced image-guided percutaneous cases and operating room event records for the advanced laparoscopic group. The Deyo version of the Charlson Comorbidity Index (CCI) was calculated using a 1-year look-back period from the PD catheter insertion procedure for capture of relevant diagnosis and procedure codes. Deaths were ascertained from KPNC electronic data sources, including those linked through probabilistic matching to California State death certificate records and social security administration data bases, and chart review. Kidney transplant events that occurred during the study period were captured from chart review and supplemented from the KPNC end-stage renal disease registry.

Chart review data included history of abdominal surgery, catheter survival, mechanical (catheter-related) complications, and major/minor medical complications. Additional data were collected regarding PD modality failure status, whether kidney function was regained, and whether the patient underwent kidney transplant or died during the follow-up period. The electronic health record review also ranged from date of catheter insertion through date of catheter failure, death, regain of kidney function, discontinuation of PD modality, disenrollment from the health plan, or December 31, 2014, whichever occurred first.

History of abdominal surgery was categorized as minor (tubal ligation or uncomplicated appendectomy, hysterectomy, salpingo-oophorectomy, and C-section) and major (laparotomy or any lower midline incision, bowel resection, cystectomy, and kidney transplant). Major complications that occurred at the time of or after catheter insertion were recorded and included bowel perforation, arterial laceration, and bleeding not conservatively managed. Also captured were infectious complications and noninfectious minor complications, such as bleeding conservatively managed, pain, hernia exacerbation, skin breakdown, or conservatively managed organ injury. Catheter malfunction events included catheter flow obstruction, pericatheter leak, superficial cuff extrusion events, and pericatheter hernia. Data related to catheter survival were collected, including primary and secondary patency. For all complications, the earliest date of each event was captured, and complications were later categorized as early (occurring within 30 days of catheter placement) or late (occurring more than 30 days after insertion).

Statistical Analyses

Demographic and clinical characteristics by catheter insertion technique were compared using χ^2 or Fisher exact tests for categorical variables (summarized as counts and percentages) and *t* tests and nonparametric (Wilcoxon rank sum test) tests for continuous variables (described by means ± standard deviations [SDs] and medians (with interquartile ranges [IQRs]), respectively.

For 1-year catheter survival analyses, the cohort was limited to the subset of advanced image-guided percutaneous and advanced laparoscopic cases that either experienced catheter failure within the 1st year of follow-up or were still under observation at 1 year without evidence of catheter failure.

Unadjusted and adjusted risk differences in 1-year catheter survival were estimated using a modified least-squares regression method based on an unweighted least-squares regression with a Huber-White robust standard error.[19] Multivariable models were adjusted for sex (male vs female reference); age category (20-49, reference; 50-59; 60-69; and ≥70 years); race or ethnicity (White, reference; Black and Asian or Pacific Islander; Hispanic; and other, including Native American and mixed race); BMI category (<25.0 kg/m^2, reference; 25.0-29.9 kg/m^2 and ≥30.0 kg/m^2); CCI category (2, reference; 3-4 and 5+); and history of abdominal surgery (any vs none, reference; and major vs minor or none, reference).

All analyses were conducted using SAS 9.3 (SAS Institute, Inc). The KPNC institutional review board approved this study with waiver of informed consent.

RESULTS

A total of 203 unique advanced image-guided percutaneous and 316 advanced laparoscopic procedure cases were identified. Within each group, if a patient had more than 1 procedure, only the first was selected, leaving 197 and 288 advanced image-guided percutaneous and advanced laparoscopic cases, respectively. Among these 485 patients, 3 had both procedures with advanced image-guided percutaneous first, resulting in a final source cohort of 197 advanced image-guided percutaneous and 285 advanced laparoscopic cases (Fig 1). Of these 482 cases, 6 (3.0%) advanced image-guided percutaneous cases were excluded because age was <18 years or a previous PD catheter insertion or removal occurred within 1 year before the index procedure. An additional 47 (16.5%) advanced laparoscopic cases were also excluded because of previous PD catheter insertion or removal in the previous year, the index catheter was found to have been embedded, or chart review indicated that the catheter was never used. Thus, the final study cohort consisted of 429 cases: 191 receiving advanced image-guided percutaneous and 238 receiving advanced laparoscopic for PD catheter placement.

Demographic and clinical characteristics for the 429 cases, by PD catheter insertion technique, are shown in Table 1. The sex distribution between the 2 groups was similar (39% and 45% female in the advanced image-guided percutaneous and advanced laparoscopic group, respectively). Statistically significant differences ($P < 0.001$) were observed in racial and ethnic distributions. The advanced image-guided percutaneous group had a higher proportion of Asian or Pacific Islander (37.2% vs 29.4%) patients and Hispanic (19.4% vs 10.9%) patients, but a lower proportion of Black patients compared with the advanced laparoscopic group (9.9% vs 26.1%). Age distribution and mean age at advanced image-guided percutaneous or advanced laparoscopic PD placement were similar at 60 and 61 years, respectively. Although distribution of BMI in the advanced image-guided percutaneous and advanced laparoscopic cohorts was similar (mean 27.8 and 28.5 kg/m^2, respectively), distribution of BMI-based weight categories differed. The advanced laparoscopic cohort reported a higher proportion of patients with obesity (BMI ≥30 kg/m^2) compared with the advanced image-guided percutaneous group, 38% versus 30% ($P < 0.01$). The proportion with diabetes mellitus was similar between the 2 groups (60% for advanced image-guided percutaneous and 57% for advanced laparoscopic) and underlying distributions of CCI scores were also similar (Table 1).

As shown in Table 2, the adjusted 1-year catheter survival (95% confidence interval [CI]) was 80% (74%-87%) and 91% (87%-96%) in the advanced image-guided percutaneous and advanced laparoscopic groups, respectively. The corresponding risk difference was −10.9%; (−19.1% to −2.7%; $P < 0.001$), demonstrating a significantly lower 1-year catheter survival in the advanced image-guided percutaneous group compared with advanced laparoscopic group.

The median interquartile range (IQR) procedure time for PD catheter placement was shorter for the advanced image-guided percutaneous technique compared with the advanced laparoscopic technique: 30.0 (23.0-43.0) vs. 44.5 (34.0-70.0) minutes ($P < 0.001$). In addition, time to procedure was shorter for the advanced image-guided percutaneous group than the advanced laparoscopic group with a median (IQR) time of 12 (6-19) and 33 (13-57) days, respectively; ($P < 0.001$) (Table 2).

Table 3 provides a summary of mutually exclusive reasons why follow-up ended for the cohort, by PD catheter insertion technique. During catheter placement, 7 (3.7%) technical failures occurred in the advanced image-guided percutaneous group and none in the advanced

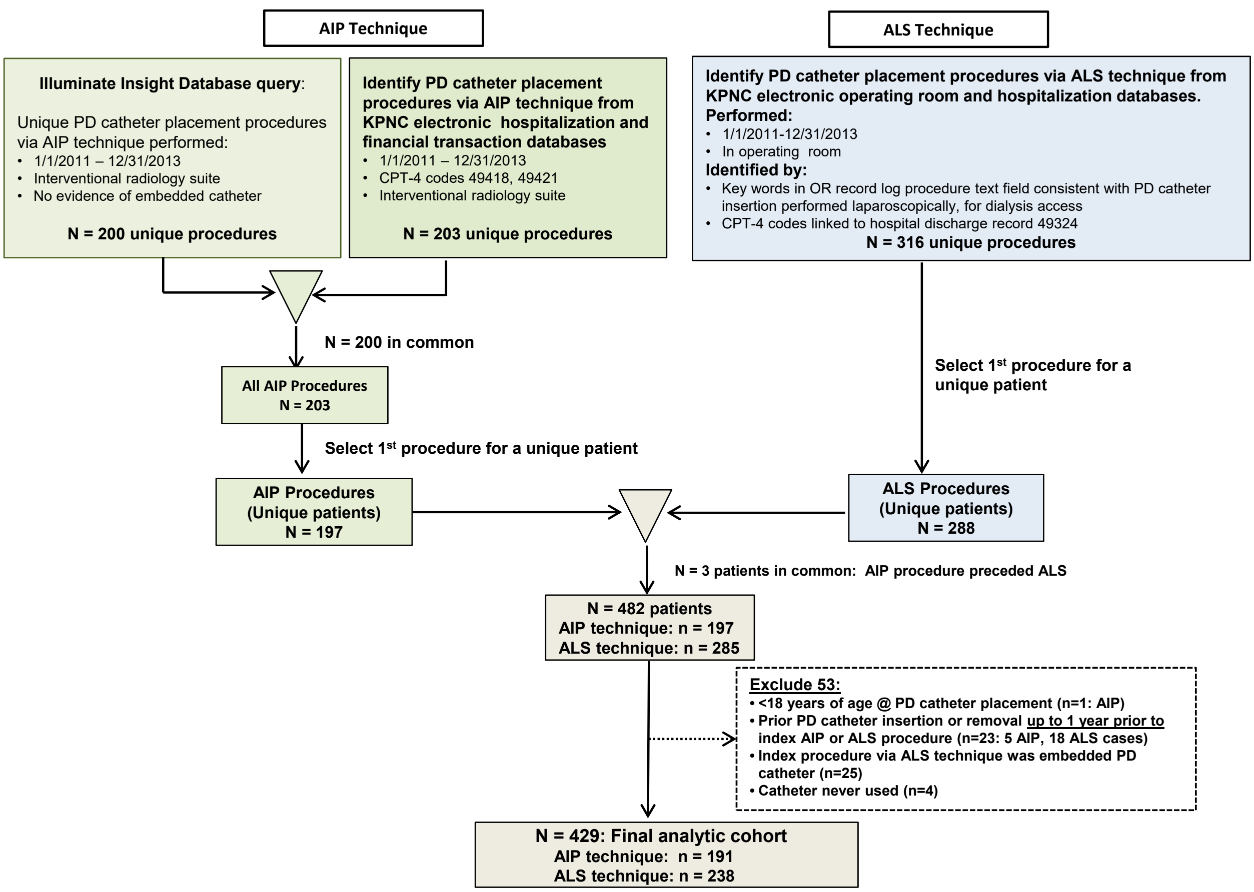

Figure 1. Derivation of the peritoneal catheter placement cohort.

Table 1. Demographic and Clinical Characteristics of the Cohort, by PD Catheter Insertion Technique

Characteristic[a]	Total Cohort (N = 429)	PD Catheter Insertion Technique: Advanced Image-Guided Percutaneous (n = 191)	PD Catheter Insertion Technique: Advanced Laparoscopic (n = 238)	*P*[b]
Sex				0.24
Female	182 (42.4)	75 (39.3)	107 (45.0)	
Male	247 (57.6)	116 (60.7)	131 (55.0)	
Age at procedure (y)[c]	60.3 ± 15.1	60.0 ± 15.7	60.6 ± 14.5	0.65[d]
20-49	92 (21.4)	47 (24.6)	45 (18.9)	0.20
50-59	96 (22.4)	42 (22.0)	54 (22.7)	
60-69	121 (28.2)	45 (23.6)	76 (31.9)	
≥70	120 (28.0)	57 (29.8)	63 (26.5)	
Race and Ethnicity				< 0.001
White	125 (29.1)	55 (28.8)	70 (29.4)	
Black	81 (18.9)	19 (9.9)	62 (26.1)	
Asian/Pacific Islander	141 (32.9)	71 (37.2)	70 (29.4)	
Hispanic	63 (14.7)	37 (19.4)	26 (10.9)	
Other	19 (4.4)	9 (4.7)	10 (4.2)	
Body mass index (kg/m^2)[c]	28.2 ± 6.5	27.8 ± 5.8	28.5 ± 7.1	0.25[d]
<25.0	155 (36.1)	63 (33.0)	92 (38.7)	0.01
25.0-29.9	126 (29.4)	71 (37.2)	55 (23.1)	
≥30.0	148 (34.5)	57 (29.8)	91 (38.2)	
Diabetes Mellitus	250 (58.3)	115 (60.2)	135 (56.7)	0.49
Charlson comorbidity index[e]	4.0 (3.0-5.0)[f]	4.0 (3.0-6.0)[f]	4.0 (3.0-5.0)[f]	0.11[g]
2	91 (21.2)	34 (17.8)	57 (24.0)	0.29
3-4	177 (41.3)	81 (42.4)	96 (40.3)	
≥5	161 (37.5)	76 (39.8)	85 (35.7)	
History of abdominal surgery[h]				0.001
None	305 (71.0)	148 (77.5)	157 (66.0)	
Minor	70 (16.3)	31 (16.2)	39 (16.4)	
Major	54 (12.6)	12 (6.3)	42 (17.6)	

[a]N (%) unless otherwise specified.
[b]Fisher exact test unless otherwise specified.
[c]Mean ± SD.
[d]*t* test.
[e]Weighted score assigned to each of the 17 comorbid conditions: myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, hemiplegia or paraplegia, dementia, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, diabetes w/ and w/o chronic complications, kidney disease, any malignancy (including lymphoma and leukemia), metastatic solid tumor, mild and moderate or severe liver disease, and AIDS or HIV.
[f]Median (interquartile range, IQR).
[g]Wilcoxon rank sum nonparametric test.
[h]Minor: uncomplicated appendectomy, uncomplicated hysterectomy, uncomplicated salpingo/oophorectomy, uncomplicated C-section, and tubal ligation. Major: laparatomy (ie, any lower midline incision), bowel resection, cystectomy, kidney transplant, diverticulitis, endometriosis, and abdominal abscess.

laparoscopic group. Over the full study period (spanning PD catheter insertion date to December 31, 2014), a total of 61 (14.2%) catheter failure events occurred, 33 (17.3%) in the advanced image-guided percutaneous group and 28 (11.8%) in the advanced laparoscopic group. The median (IQR) for days to catheter failure was significantly shorter for the advanced image-guided percutaneous group compared with the advanced laparoscopic group: 78.0 (28.0-263.0) versus 305.5 (67.0-617.5); P = 0.02, and the main reasons for failure in both advanced image-guided percutaneous and advanced laparoscopic cases included catheter infection in 10 (30%) and 13 (46%), respectively, and mechanical malfunction in 20 (61%) and 15 (54%), respectively. An additional 3 (9%) advanced image-guided percutaneous catheters required removal secondary to pericatheter leak, abdominal pain, and catheter location in the mesentery discovered at time of unrelated abdominal surgery. No significant difference was identified with respect to the cause of catheter failure (P = 0.24, data not shown). Modality failure (eg, transition to HD) during follow-up occurred in 41 (21.5%) of advanced image-guided percutaneous cases and 67 (28.1%) of advanced laparoscopic cases (Table 3).

Major complications were very rare in both groups; a bowel perforation occurred in 1 (0.5%) advanced image-guided percutaneous patient and a bladder Trigone perforation in 1 (0.4%) advanced laparoscopic patient (Table 4). Infectious and noninfectious minor complication events are also summarized, with the latter further categorized as shown in Table 4. For each type of complication observed, events were subdivided as occurring within 30 days of PD catheter insertion (early) and

Table 2. Outcomes, by PD Catheter Insertion Technique

Outcome	PD Catheter Insertion Technique: Advanced Image-Guided Percutaneous (n = 191)	Advanced Laparoscopic (n = 238)	*P*
Adjusted 1-year catheter survival (proportion (95% CI))[a]	0.80 (0.74-0.87)	0.91 (0.87-0.96)	0.01[b]
Procedure time, minutes (median [IQR])[c]	30.0 (23.0-43.0)	44.5 (34.0-70.0)	< 0.001[d]
Time to procedure, days (median [IQR])[e]	12.0 (6.0-19.0)	33.0 (13.0-57.0)	< 0.001[d]

[a]Mean 1-year catheter survival using modified least-squares regression (MLS) method, adjusted for age, sex, BMI, history of abdominal surgery (any, major vs none), and Charlson comorbidity index (3-4, 5+ vs 2). Unadjusted mean 1-year survival (95% CI) for advanced image-guided percutaneous: 0.81 (0.75-0.87) and advanced laparoscopic: 0.91 (0.86-0.95), *P* = 0.01. One-year survival was based on a subset of the original analytic cohort and included anyone whose follow-up ended secondary to catheter failure that occurred up to 1 year after catheter placement (n = 43) and cohort members who had a functioning catheter at 1 year and were still under observation at that time (n = 272).
[b]*P* value from least-squares means adjusted risk difference: The adjusted mean risk difference (95% CI) between advanced image-guided percutaneous compared to advanced laparoscopic is −10.9% (−19.1% to −2.7%).
[c]Among the subset of cases without technical failure at the index procedure (advanced image-guided percutaneous: n = 184; advanced laparoscopic: n = 238)
[d]From Wilcoxon rank sum nonparametric test.
[e]Time to procedure defined as the number of days between date of initial request for consultation from the patient's nephrologist to interventional radiology or surgery and date of catheter insertion procedure. Data were unavailable for 1 advanced laparoscopic case.

occurring more than 30 days after insertion (late). The 2 groups had similar proportions with infectious complications, including 57 (29.8%) and 76 (31.9%) in the advanced image-guided percutaneous and advanced laparoscopic subsets, respectively. Bleeding requiring conservative management was rare (<5%) in both groups but occurred more frequently in advanced image-guided percutaneous (9 [4.7%]) compared with advanced laparoscopic patients (2 [0.8%]); P = 0.01. Hernia exacerbation was also identified more frequently >30 days after catheter insertions in both groups (13 [6.8%] and 10 [4.2%], respectively in advanced image-guided percutaneous and advanced laparoscopic subsets). Pericatheter leak was identified in 9 (4.7%) in advanced image-guided percutaneous patients and 8 (3.4%) in advanced laparoscopic patients (P = 0.59). One (0.5%) late superficial cuff extrusion took place in the advanced image-guided percutaneous group.

No significant difference was found between the 2 groups in terms of catheter malfunction (P = 0.14). A total of 28 (14.7%) advanced image-guided percutaneous and 24 (10.1%) advanced laparoscopic catheters malfunctioned during the observation period. Early malfunctions were observed in 11 (5.8%) of advanced image-guided percutaneous and 5 (2.1%) of advanced laparoscopic catheters and late malfunctions in 17 (8.9%) of advanced image-guided percutaneous and 19 (8.0%) advanced laparoscopic catheters (Table 4).

There were 22 (11.5%) and 17 (7.1%), respectively catheter flow obstruction events recorded in the advanced image-guided percutaneous and advanced laparoscopic groups. In both study groups, most occurred more than 30 days after catheter insertion. Among advanced laparoscopic patients, catheter flow obstruction was most frequently attributed to adhesions (12 [70.6%]), omental involvement (2 [11.8%]), subcutaneous kinking (2 [11.8%]), and pain with inflow (1 [5.9%]). In advanced image-guided percutaneous cases, obstruction was secondary to adhesions (5 [22.7%]), benign migration (6 [27.3%]), omental involvement (6 [27.3%]), subcutaneous kinking

Table 3. Reason Follow-Up Ended, by PD Catheter Insertion Technique

Characteristic, n (%)	Total Cohort (N = 429)	PD Catheter Insertion Technique: Advanced Image-Guided Percutaneous (n = 191)	Advanced Laparoscopic (n = 238)
Reason follow-up ended			
Catheter failed	61 (14.2)[a]	33 (17.3)	28 (11.8)
Modality failed	108 (25.2)	41 (21.5)	67 (28.1)
Kidney transplant	43 (10.0)	16 (8.4)	27 (11.3)
Regained kidney function	5 (1.2)	2 (1.0)	3 (1.3)
Death	39 (9.1)	24 (12.6)	15 (6.3)
Left health plan	12 (2.8)	8 (4.2)	4 (1.7)
Technical failure	7 (1.6)	7 (3.7)	0 (0)
End of study	154 (35.9)	60 (31.4)	94 (39.5)

[a]Of the 61 cases that experienced a catheter failure, 43 (70.5%) occurred within 1-year of initial catheter placement. By insertion technique, n = 27 in the advanced image-guided percutaneous group (14.1%) and n = 16 in the advanced laparoscopic group (6.7%). Among the 61 with a catheter failure by end of study period, median (IQR) for days to catheter failure was significantly shorter for the advanced image-guided percutaneous group compared with the advanced laparoscopic group: 78.0 (28.0-263.0) vs 305.5 (67.0-617.5); *P* = 0.02. For the subset of 43 with catheter failure within 1-year, the median (IQR) number of days remained shorter for the advanced image-guided percutaneous group compared with advanced laparoscopic group: 63.0 (13.0-145.0) vs 96.0 (32.5-229.0); *P* = 0.27.

Table 4. Catheter-Related Complications, by PD Catheter Insertion Technique

Characteristic n (%)	Total Cohort (N = 429)	PD Catheter Insertion Technique: Advanced Image-Guided Percutaneous (n = 191)	PD Catheter Insertion Technique: Advanced Laparoscopic (n = 238)	P^a
Major complications				1.00
None	427 (99.5)	190 (99.5)	237 (99.6)	
Any[b]	2 (0.5)	1 (0.5)	1 (0.4)	
Infectious complications[c]				0.32
None	296 (69.0)	134 (70.2)	162 (68.1)	
Early	23 (5.4)	13 (6.8)	10 (4.2)	
Late	110 (25.6)	44 (23.0)	66 (27.7)	
Noninfectious minor complications[d]				
Bleeding, conservatively managed				0.01
None	418 (97.4)	182 (95.3)	236 (99.2)	
Early	11 (2.6)	9 (4.7)	2 (0.8)	
Late	0	0	0	
Pain				0.70
None	411 (95.8)	183 (95.8)	228 (95.8)	
Early	11 (2.6)	4 (2.1)	7 (2.9)	
Late	7 (1.6)	4 (2.1)	3 (1.3)	
Hernia exacerbation				0.26
None	402 (93.7)	175 (91.6)	227 (95.4)	
Early	4 (0.9)	3 (1.6)	1 (0.4)	
Late	23 (5.4)	13 (6.8)	10 (4.2)	
Pericatheter leak				0.59
None	412 (96.0)	182 (95.3)	230 (96.6)	
Early	10 (2.3)	6 (3.1)	4 (1.7)	
Late	7 (1.6)	3 (1.6)	4 (1.7)	
Superficial cuff extrusion				0.45
None	428 (99.8)	190 (99.5)	238 (100)	
Early	0	0	0	
Late	1 (0.2)	1 (0.5)	0 (0)	
Catheter malfunction				0.14
None	377 (87.9)	163 (85.3)	214 (89.9)	
Early	16 (3.7)	11 (5.8)	5 (2.1)	
Late	36 (8.4)	17 (8.9)	19 (8.0)	

[a]Fisher exact test unless otherwise specified.
[b]Major complications (organ injury) included bowel perforation (advanced image-guided percutaneous) and bladder Trigone puncture during surgery, treated with foley decompression (advanced laparoscopic).
[c]Infectious complications included peritonitis, exit site, tract, and tunnel infections were classified as early (≤30 days from index catheter insertion) or late (>30 days after insertion).
[d]Minor noninfectious complications included pericatheter leak, bleeding (conservatively managed), pain, hernia exacerbation, superficial cuff extrusion, and catheter malfunction. Minor noninfectious complications were classified as early (≤30 days from index catheter insertion) or late (>30 days after insertion).

(1 [4.5%]), and other issues associated with poor inflow and outflow (4 [18.2%]).

DISCUSSION

In an integrated health care system, we found that the advanced laparoscopic group had significantly greater 1-year PD patency compared with the advanced image-guided percutaneous group, with adjusted mean proportion 91% versus 80%, respectively. Despite lower 1-year patency in the advanced image-guided percutaneous group, outcomes still achieved the recommended 1-year patency threshold of 80%[20] after successful placement. The advanced image-guided percutaneous group also had much shorter median time from initial (advanced laparoscopic or advanced image-guided percutaneous) referral to catheter placement and shorter median procedure time. Catheter-related complications were similar between the 2 groups.

Peritoneal dialysis has many advantages for patients newly started on kidney replacement therapy. It offers better preservation of residual kidney function, higher quality lifestyle, and less hemodynamic instability compared with in-center HD.[21] It is a preferred modality for nephrologists, nurses, and patients for initial dialysis therapy.[22-24] However, PD is often not initiated because of lack of operators available to place PD catheters in a timely manner, and instead, many patients end up with a CVC and in-center HD, which may be less optimal for their care. Therefore, having different specialists available to place PD catheters quickly is crucial to meeting patients' needs.

The success of PD is heavily dependent upon timely placement of a functioning PD catheter. Catheter malfunction is 1 of the potential complications of PD catheter placement, often resulting in catheter removal and termination of PD. A well-trained and experienced PD catheter operator is essential for the placement of a functional catheter, as there are nuances to both the advanced image-guided percutaneous and advanced laparoscopic techniques that maximize the chance of a functional and durable PD catheter. Traditionally, general surgeons placed the majority of PD catheters in the United States, limiting availability of operators and making timely placement more challenging. With increased interest in PD, interventional radiologists, interventional nephrologists, urologists, and transplant surgeons are now also placing PD catheters. In addition, for many patients who are unable to tolerate general anesthesia, interventional radiologists who are placing PD catheters under conscious sedation can fill this gap. In many hospitals, only a few surgeons are placing PD catheters. Thus, when surgeons are unavailable, patients may have no choice but to undergo CVC placement to initiate kidney replacement therapy. Having a variety of operators from complementary specialties promotes timely placement of PD catheters in different patient populations.

Insertion of a PD catheter performed by an interventional radiologist (T.D.) as a same day procedure under conscious sedation allows for easier access to PD catheter placement with a reduced requirement for operating room resources. Quach et al[10] reported their 1-year experience of radiologic insertion of 30 Tenckhoff catheters for PD. The majority were inserted successfully as same day cases, and they saw a 67% increase in PD utilization in their population. Twenty-four (80%) out of 30 patients remained on PD at the end of the 1-year study period.

In our study, the advanced laparoscopic group reported a higher 1-year patency compared with the advanced image-guided percutaneous group. This contrasts with a prospective study by Voss et al,[16] in which they randomly assigned 113 patients who are non–dialysis-dependent to receive PD catheter insertion using either fluoroscopic guidance by radiologists or laparoscopy by surgeons. They found no differences in catheter and patient survival at 1 year. Although the differences observed between our study and the Voss study may be because of study design (retrospective vs prospective) and differences in study populations, these collective findings support the need for more prospective (and multicenter) studies that compare PD catheter placement outcomes. In the interim, surgeon training to improve laparoscopic access and optimization of interventional radiologist approaches to reduce PD catheter dysfunction will support greater access to PD for patients who require kidney replacement therapy.

Medani et al[25] performed a retrospective analysis of the outcomes of 313 PD catheter insertions, comparing all percutaneous PD catheter insertions between July 1998 and April 2010 (151 procedures) with all surgical PD catheter insertions between January 2003 and April 2010 (162 procedures). In that study, the incidence of exit-site leaks and peritonitis was higher in the surgical group than the interventional radiologist group.[25] Technical survival at 12 months was 77.7% for interventional radiologists and 68.7% for surgical groups, both lower than in our study.[25] The outcome differences between that study and ours may stem from differences in patient populations and practice patterns.

A major strength of our study is that it is derived from a large, contemporary, and diverse population in an integrated health care system in Northern California, that is similar to the surrounding general population.[26] Our hospital facilities are representative of a community hospital experience in Northern California, compared with tertiary referral medical centers from which many other studies originate. Furthermore, the advanced laparoscopic technique was performed by experienced laparoscopic surgeons and high-volume advanced image-guided percutaneous cases were performed by a small number of interventional radiologists to provide consistency in practice.

Our study has some limitations. Given its retrospective nature, we cannot eliminate selection bias. Furthermore, because many medical centers only had surgeons or interventional radiologists to place PD catheters, the selection of advanced image-guided percutaneous versus advanced laparoscopic was dependent on nephrologists' recommendation and medical center resources and expertise, and patient suitability. Our study could not account for these potential medical center, provider, and patient factors. Furthermore, it was comprised of patients within a single integrated health care system, in which delivery of services is well coordinated. It is unclear whether our results are generalizable to other health care systems where delivery of care historically has been more fragmented. Ideally, a prospective, multicenter randomized study should be conducted to confirm the results.

In conclusion, both advanced image-guided percutaneous and advanced laparoscopic are PD catheter placement techniques that meet international guidelines for placing PD catheters and have very low major complication rates. In our study, the advanced laparoscopic technique boasts superior 1-year catheter survival and had no technical failures at insertion. However, advanced laparoscopic requires experienced laparoscopic surgeons with access to operating rooms, which can result in longer delays to PD catheter placement. The advanced image-guided percutaneous technique is performed in a fluoroscopy suite without general anesthesia and, when successfully placed, demonstrates adequate 1-year catheter survival outcome that meets professional best practice guidelines,[20] albeit significantly lower than the advanced laparoscopic technique. Hence, the advanced image-guided percutaneous technique offers an alternative approach to timely PD catheter placement in hospitals without advanced laparoscopic capacity for more selected patient populations. Overall, either approach may be appropriate, depending on patient factors, setting, available expertise, and local resources. Given the importance of providing patient centered care, future efforts should focus on training more laparoscopic surgeons and improving the long-term patency success of PD catheters placed using the advanced image-guided percutaneous technique to support wider utilization of PD for patients who require kidney replacement therapy.

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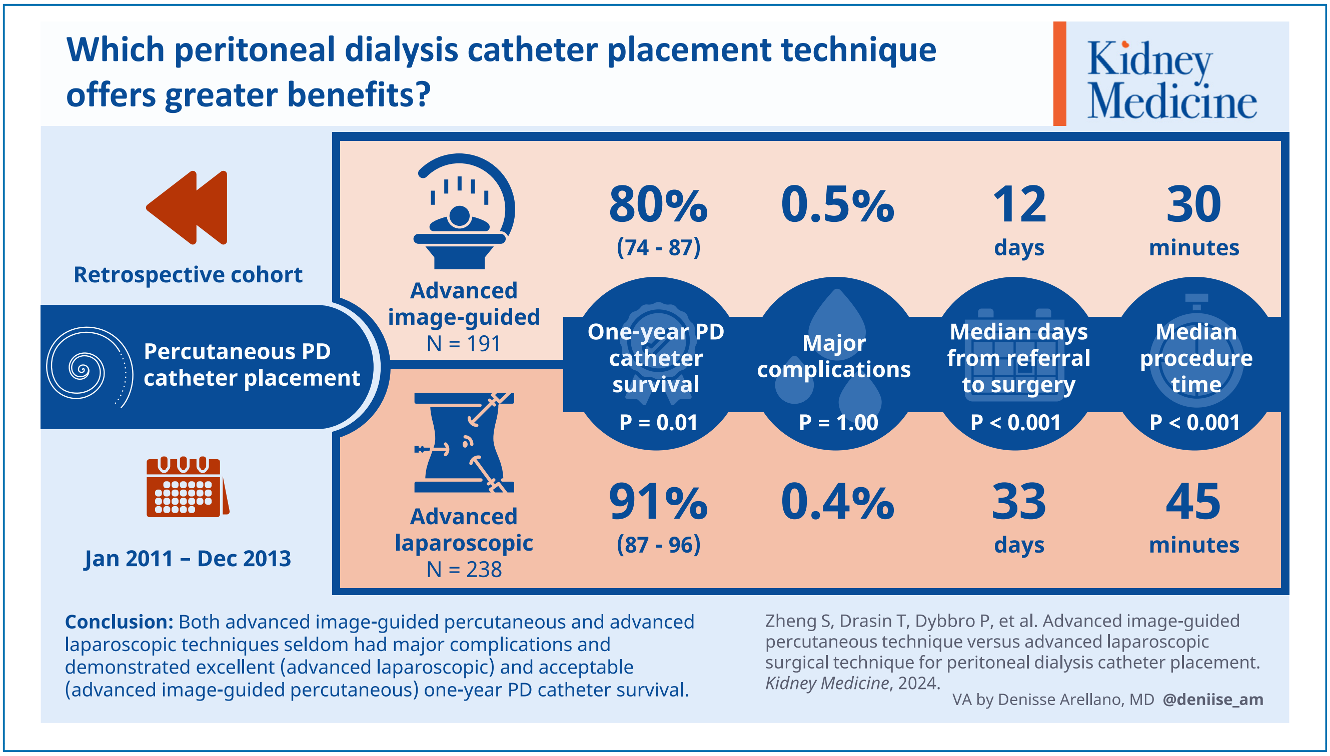
Which peritoneal dialysis catheter placement technique offers greater benefits?
Kidney Medicine
Retrospective cohort
Percutaneous PD catheter placement
Jan 2011 – Dec 2013
Advanced image-guided
N = 191
Advanced laparoscopic
N = 238
80%
(74 - 87)
0.5%
12
days
30
minutes
One-year PD catheter survival
P = 0.01
Major complications
P = 1.00
Median days from referral to surgery
P < 0.001
Median procedure time
P < 0.001
91%
(87 - 96)
0.4%
33
days
45
minutes
Conclusion: Both advanced image-guided percutaneous and advanced laparoscopic techniques seldom had major complications and demonstrated excellent (advanced laparoscopic) and acceptable (advanced image-guided percutaneous) one-year PD catheter survival.
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