American Journal of Infection Control 52 (2024) 1289–1295

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

The longer the catheter, the lower the risk of complications: Results of the HERITAGE study comparing long peripheral and midline catheters

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Key Words:
Catheter-failure
Catheter-related bloodstream infection
Catheter-related thrombosis
Fibroblastic sleeve
Long peripheral catheter

Background: Although widely used in clinical practice, long peripheral (LPCs) and midline catheters (MCs) are often misclassified because of their similar characteristics. Comparative studies on these devices are lacking. This study aimed to explore complications risks in polyurethane LPCs and MCs.
Methods: Prospective cohort study. Catheter-failure within 30 days was the primary outcome, catheter-related bloodstream infection (CR-BSI), thrombosis, and fibroblastic sleeve were secondary outcomes. The average number of drugs infused per day was computed to measure the overall intensity of catheters' use.
Results: The catheter-failure incidence was 5.7 and 3.4/1,000 catheter-days for LPCs and MCs, respectively. MCs were associated with an adjusted lower risk of catheter-failure (hazard ratio 0.311, 95% confidence interval 0.106-0.917, $P = .034$). The daily number of drugs infused was higher for MCs ($P < .001$) and was associated with a greater risk catheter-failure risk ($P = .021$). Sensitivity analysis showed a decreased catheter-failure risk for MCs starting from day-10 from positioning. The incidence of CR-BSI (0.9 vs 0.0/1,000 catheter-days), thrombosis (8.7 vs 3.5/1,000 catheter-days), and fibroblastic sleeve (14.0 vs 8.1/1,000 catheters-days) was higher for LPC catheters.
Conclusions: Despite more intensive drug administration, MCs were associated with a longer uncomplicated indwelling time.

BACKGROUND

Between 59% and 70% of hospitalized patients need venous access.[1,2] In most cases, traditional, short peripheral catheters (24-60 mm length, 26-14 G internal diameter) are used, because they represent the safer (very low complication rates), simpler (placement requiring limited expertise), and most cost-effective (potential to administer—with a few exceptions—most medications) choice.[1,3,4] The opportunity to position such a catheter, being limited by nature to very superficial visible or palpable veins, can sometimes be difficult because of the patient's characteristics (eg, edema, obesity, and poor superficial venous "heritage") representing a "difficult intravenous access" (DIVA) condition.[5,6] Moreover, patients may require a medium- or long-term continuum use of the vascular device (weeks or months), which could cause a progressive reduction of the superficial venous pool.[7] All such patients are exposed to the risk of suboptimal care, being undergoing multiple cannulation attempts, or the administration of medications through inappropriate devices (eg, extremely thin catheters, veins of legs or feet), leading to a high risk of complications (eg, extravasation, phlebitis, infections, and failure to administer drugs or to obtain blood samples) and to avoidable suffering.

A valid alternative consists in positioning a longer venous catheter in deep veins of the upper limbs under ultrasound guidance

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Conflicts of interest: None to report.

https://doi.org/10.1016/j.ajic.2024.06.019

and using a guide wire. Based on their length, these catheters have been classified as long peripheral catheters (LPCs: length > 6 cm and ≤ 15 cm) and midline catheters (MCs: length > 15 cm).[8]

As patients with a DIVA condition may be present in many health care settings, in recent years, an increasing number of health care professionals—especially nurses—have been trained and have developed clinical experience in the placement of these devices. Unfortunately, the spread in their use has not been accompanied by a parallel increase in research. Consequently, comparative studies on the safety, reliability, and cost-effectiveness of the different devices are lacking,[9-11] with the existing studies often misclassifying the devices.[8]

Therefore, the aim of the study was to explore the differences in terms of safety and reliability between LPCs and MCs as used in daily clinical practice.

METHODS

Study design, setting, and population

The HERITAGE (long peripHERal and mIdline caTheters uncomplicAted dwellinG timE) study was a prospective cohort study carried out in Cardiac Surgery, Cardiology, and Internal Medicine Departments of the Trieste University Hospital, Italy, where the ultrasound-guided positioning of venous catheters was part of the routine daily nursing clinical practice. All consecutive adult patients receiving either a LPC or an MC—because of a DIVA condition[5,6] or because of the need for a medium-term intravenous therapy (> 7 days)[4,7,12,13]—were considered for inclusion in the study. Catheters positioned in a same patient after removing of the existing one were considered as well. Patients with immediate life-threatening conditions, transferred to a clinical setting where continuing the catheter follow-up was not possible, or who refused to participate in the study, were excluded.

Based on the primary study endpoint, a minimum required sample size of 182 catheters was calculated based on the estimated difference between the overall complication rates of LPCs (19.7%)[10] and MCs (5.3%-5.9%),[14] enabling a type-I probability error of 5% and a desired statistical power of 80%. Expecting the risk of 5% of the patients being excluded due to relevant missing data, an enrollment of at least 200 patients was planned for.

The study was conducted in accordance with the ethical principles enshrined in the Helsinki Declaration. The study protocol was approved by the Independent Regional Ethics Committee (n.2826/2023). All enrolled patients were asked to sign an informed consent form.

Characteristics of the catheters

The following devices were involved:

- PowerGlide PRO polyurethane LPC catheter (Becton Dickinson), available in the following sizes (internal area, external diameter, and length): (1) 20 G (1.15 mm), 8 cm; (2) 18 G (1.35 mm), 10 cm.
- PowerMidline polyurethane MC (Becton Dickinson), available in the following sizes (internal area, external diameter, and length): (1) 18 G (single-lumen), 4 Fr (1.32 mm), 20 cm; (2) 19/21 G (dual-lumen), 4 Fr (1.40 mm), 20 cm; (3) 18/18 G (dual-lumen), 5 Fr (1.67 mm), 20 cm.

Since this study aimed at exploring the endpoints in the context of daily clinical practice, the decision whether to place a LPC or an MC was based on the individual bedside nurse's clinical judgment, according to the characteristics and expected duration of the intravenous therapy and her or his confidence and skill with one or the other type of catheter.

Catheter placement procedure

All catheters were placed by nurses with advanced education and high expertise with regard to vascular access. According to the most updated recommendations,[15,16] the catheter insertion procedure was standardized as follows:

- Preprocedural systematic ultrasound examination of the veins of the arms and the cervical-thoracic districts according to the "RaPeVA" and "RaCeVA" protocols,[17,18] and clear identification of the median nerve and brachial artery.
- Identification of the best vein to cannulate, paying attention to (1) placing the catheter's exit site within the Dawson's green zone[19]; (2) choosing—whenever possible—a vein having an inner size large enough in respect of a catheter-to-vein ratio of 33% or less, both at the insertion point and at the expected catheter's tip level.
- Antiseptic handwashing, use of maximal barrier precautions, and skin antisepsis with 2% chlorhexidine in 70% isopropyl alcohol.
- Ultrasound-guided catheter positioning via the short axis or out-of-plane approach, by adopting a "modified Seldinger technique" for MCs and a "simplified Seldinger technique" for LPCs.
- Final ultrasound assessment of the catheter position up to the tip location.
- Catheter sutureless securement, protection of the exit site using cyanoacrylate glue, and semipermeable transparent polyurethane membrane dressings with chlorhexidine-based gel (3M Tegaderm CHG), application of a needle-free connector to each catheter hub to be covered with a port protector (3M Curos Port Protectors Caps) while the catheter is locked.

Catheter management and surveillance

All intravenous devices were managed by hospital or community clinical nurses based on the same, shared policy. The modality to access the catheter for drug administration or blood sampling and to manage the catheter while locked was standardized according to the most updated best practice.[4,15,16] Briefly, the use of a port protector to cover the needle-free connector was strongly recommended, alternatively a vigorous rubbing (5-15 times) of the needle-free connector was performed before accessing the catheter. Before and after each access, the catheter was flushed with 10 to 20 mL of normal saline using the "stop and go" technique. The catheter dressing, infusion lines, and needle-free connectors were replaced weekly, unless damaged or contaminated, except for the infusions of solutions containing lipids, when infusion lines and needle-free connectors were replaced daily.

The infusion of parenteral nutrition (osmolarity > 900 mOsm/L) through these catheters was forbidden, while all medications associated with a high risk of endothelial damage (eg, pH of < 5 or > 9, osmolarity > 600 mOsm/L)[20] were administered only after an appropriate dilution.

Each catheter was regularly assessed according to the following protocol: daily exit-site inspection; ultrasound evaluation of the catheter position and possible ongoing complications every 3 to 5 days; immediate evaluation in the case of any malfunction or adverse events (persistent withdrawal occlusion, subocclusion, complete occlusion or extravasation from the exit site, and phlebitis). No routine catheter replacement was planned. The catheters were removed as soon as they were no longer needed (ie, when no further intravenous administration or blood sampling was expected) or in the presence of any major catheter-related complication (see below). Conversely, in patients presenting minor complications, possible catheter removal was considered when the catheter

functioning was compromised, or in the presence of phlebitis or exit-site infections.

Catheter outcomes

The primary study outcome was related to catheter-failure, which was defined as catheter removal because of loss of its usability (due to any complication) and requiring a catheter replacement. Catheter-related bloodstream infection and symptomatic catheter-related thrombosis were considered as major complications, while the presence of asymptomatic catheter-related thrombosis, fibroblastic sleeve, or exit-site infection or phlebitis were deemed to be minor complications. All catheter-related complication incidences were reported as the number of cases per 1,000 catheter-days.

Study endpoints

The primary study endpoint was the risk of catheter-failure, calculated as the interval (days) between placement and removal. The observations were censored at 30 days, based on the observed median indwelling times of 13 (interquartile range: 7-21) and 22 (interquartile range: 13-33) days for LPCs and MCs, respectively.

Other collected variables

Data were collected both during the hospitalization and after hospital discharge for patients discharged with a catheter still in place.

The patient's sex, age, and comorbidity condition—computed by the Charlson Comorbidity Index[21]—were collected to describe her or his basic characteristics at hospital admission.

Data on the catheter type (length, internal and external diameter, and number of lumens) and cannulation procedure (insertion site, number of attempts, internal diameter of the cannulated vein at insertion, and tip levels) were documented, and the derived catheter-to-vein diameter ratios were computed.

The type and amount of any fluids or medications administered through the catheters was registered. Accordingly, the overall average daily number of different medications infused through a catheter during its overall indwelling time was computed. For example, for a catheter left in place for 20 days in a patient receiving 3 drugs for 7 days, 1 drug for 10 days, and no medications in the remaining 3 days, the average was 1.6 per day $(3 \times 7 + 1 \times 10 + 0 \times 3)/20$. This variable was created to quantify the theoretical amount of "stress" caused to the venous endothelium due to the administration of multiple medications. The same index was also computed by considering only the infusion of high-risk medications.

The type and the date of detection of any catheter-related complication, as well as the date and reason for catheter removal, were documented. Moreover, any antiaggregant or anticoagulant medication administered to the patient was recorded as they were considered to be potential protective factors against venous thrombosis.

Statistical analysis

The continuous variables were presented as means and standard deviations, according to the normality of the data distribution as assessed by the Kolmogorov-Smirnov test. The difference between the means was analyzed using a parametric nonpaired t test, after determining whether equal variance could be attributed to the subgroups according to Levene's test. The nominal variables were described as a number and percentage, and analyzed though contingency tables and the Pearson's χ test or Fisher exact test, as appropriate.

Unadjusted survival analysis was conducted by comparing Kaplan-Meier curves, while the differences between the catheters' survival rates were calculated using the Mantel-Cox log-rank test. Multivariate Cox proportional-hazard analysis with stepwise forward selection was run to estimate the time-to-event effect of the different catheters on the risk of a catheter-failure, adjusted for baseline confounders showing to be significantly related to the occurrence of catheter-failure in bivariate analyses. The results were presented as a proportional-hazard ratio (HR) with a corresponding 95% confidence interval (CI) and cumulative survival-adjusted curves. Moreover, after observing that virtually no catheter-failure occurred before the 10th day in both subgroups, in order to examine the potential impact of survival bias among the catheter groups, we compared the 9-day and 10- to 30-day catheter outcomes separately for sensitivity analysis.

For all tests, the statistical significance was set at an alpha level of $P < .05$. Statistical analyses were performed using the software SPSS Statistics for Windows, version 24.0 (IBM Corp).

RESULTS

During the study period, a total of 298 potentially eligible patients were considered for inclusion. After applying the exclusion criteria (in 2 patients, the catheter placement failed, in 12, a polyethylene LPC was placed, and 15 were lost to follow-up), 269 subjects (138 LPCs, 51.3%; 131 MCs, 48.7%) constituted the final study population. All patients received antiaggregant or anticoagulant drugs.

Table 1 shows the main characteristics of the patients and catheters. At the insertion point, a statistically significant greater percentage of LPCs exceeded the 33% vein-to-catheter thresholds compared with MCs, while overcoming of the 45% threshold was uncommon and similar between the catheter groups. At the tip level, both the 33% and 45% thresholds were exceeded more frequently in LPCs than in the MC subgroup. A significantly higher average number of drugs was infused daily via MCs compared with LPCs. Overall, the catheters' indwelling time was 20.8 ± 19.2 days and was significantly ($P < .001$) longer for MCs (26.6 ± 23.8 days, max 184 days) than LPCs (15.4 ± 11.1 days, max 66 days).

The incidence of catheter-failure was 5.7 and 3.4 per 1,000 catheter-days for LPCs and MCs, respectively. A higher incidence of all explored outcomes was documented for LPCs compared with MCs (Table 2). Overall, a catheter-failure was associated with the onset of major complications in a minority of cases (catheter-related bloodstream infection: 8.3%, symptomatic catheter-related thrombosis: 8.3%). Other complications determining a catheter-failure were persistent withdrawal occlusion (41.7%), total occlusion (25%), catheter breakage at the extravascular tract (8.3%), extravasation (4.2%), and exit-site inflammation (4.2%), often associated with the presence of asymptomatic catheter-related thrombosis or fibroblastic sleeve.

A catheter-failure was significantly associated with the male sex, catheter-to-vein ratio > 33% at the tip level, and with a higher average number of drugs infused daily through the catheter (Table 3). Compared with LPCs, MCs showed a lower failure risk (log-rank test 5.020, $P = .025$) in crude survival analysis (Fig. 1A) and in univariable Cox statistics. This finding was confirmed (HR 0.311, 95% CI 0.106-0.917, $P = .034$) when the model was adjusted for the baseline variables found to be associated with catheter-failure (sex, catheter-to-vein ratio > 33% at the tip level, Fig. 1B), where neither the patient's sex nor the catheter-to-vein ratio > 33% at the catheter tip resulted in being statistically significant in the model. As expected, the sensitivity analysis showed a decreased risk for catheter-failure for MCs only starting from the 10th day from catheter

Table 1
General characteristics of the study population and differences according to the catheter type

	All catheters (n. 269)	LPCs (n. 138)	MCs (n. 131)	*P* value
Patient characteristics				
Age (y)	70.3 ± 13.3	72.3 ± 11.7	68.1 ± 14.5	.010
Sex (male)	154 (57.2%)	73 (52.9%)	81 (61.8%)	.139
Charlson Comorbidity Index	3.3 ± 2.2	3.2 ± 2.0	3.5 ± 2.4	.309
Department				
Cardiac surgery	143 (53.2%)	66 (47.8%)	77 (58.8%)	.003
Cardiology	51 (19.0%)	21 (15.2%)	30 (22.9%)	
Internal medicine	75 (27.9%)	51 (37.0%)	24 (18.3%)	
Cannulated vein				
Basilic	168 (62%)	75 (44.6%)	93 (55.4%)	<.001
Brachial	69 (26%)	32 (46.4%)	37 (53.6%)	
Cephalic	32 (12%)	31 (96.9%)	1 (3.1%)	
Measures at the insertion level				
Inner caliber of the vein (mm)	4.7 ± 1.4	4.4 ± 1.4	5.0 ± 1.4	.001
Depth of the vein (mm)	11.0 ± 4.0	10.3 ± 3.8	11.6 ± 4.1	.005
Catheter-to-vein ratio (%)	30.9 ± 9.6	32.2 ± 10.5	29.5 ± 8.3	.023
Catheter-to-vein ratio > 33%	81 (30.0%)	51 (37.0%)	30 (22.9%)	.012
Catheter-to-vein ratio > 45%	14 (5.0%)	9 (6.5%)	5 (3.8%)	.318
Measures at the tip level				
Inner caliber of the vein (mm)	7.3 ± 2.8	5.9 ± 2.6	8.8 ± 2.3	<.001
Catheter-to-vein ratio (%)	21.8 ± 10.6	26.5 ± 12.4	16.7 ± 4.7	<.001
Catheter-to-vein ratio > 33%	34 (13.0%)	33 (23.9%)	1 (0.8%)	<.001
Catheter-to-vein ratio > 45%	10 (4.0%)	10 (7.2%)	0 (0.0%)	.002
Average number of drugs infused per day				
Any medication	1.0 ± 0.7	0.7 ± 0.5	1.3 ± 0.8	<.001
High-risk medications only	0.2 ± 0.3	0.1 ± 0.2	0.3 ± 0.4	<.001

LPCs, long peripheral catheters; *MCs*, midline catheters.

Table 2
Incidence per 1,000 catheter-days of the study outcomes

	All catheters	LPCs	MCs
Catheter-failure	4.3	5.7	3.4
CR-bloodstream infections	0.4	0.9	0.0
Catheter-related thrombosis*	5.4	8.7	3.5
Symptomatic	0.4	0.5	0.3
Asymptomatic*	5.1	8.2	3.2
Fibroblastic sleeve*	10.3	14.0	8.1

CR, catheter-related; *LPCs*, long peripheral catheters; *MCs*, midline catheters.
*n. 254.

Table 3
Variables associated with differences in catheter-failure rates

	Catheter-failure		*P* value
	No	Yes	
Patient characteristics			
Age (y)	70.2 ± 13.3	71.1 ± 13.6	.752
Sex (male)	145 (59.2%)	9 (37.5%)	.040
Charlson Comorbidity Index	3.3 ± 2.2	3.1 ± 2.4	.593
Department			
Cardiac surgery	131 (53.5%)	12 (50.0%)	.728
Cardiology	45 (18.4%)	6 (25.0%)	
Internal medicine	69 (28.2%)	6 (25.0%)	
Cannulated vein			
Basilic	156 (63.7%)	12 (50.0%)	.349
Brachial	60 (24.5%)	9 (37.5%)	
Cephalic	29 (11.8%)	3 (12.5%)	
Measures at the insertion level			
Catheter-to-vein ratio (%)	30.8 ± 9.7	31.8 ± 7.7	.620
Catheter-to-vein ratio > 33%	70 (28.6%)	11 (45.8%)	.079
Catheter-to-vein ratio > 45%	13 (5.3%)	1 (4.2%)	.810
Measures at the tip level			
Catheter-to-vein ratio (%)	21.5 ± 10.5	24.1 ± 11.7	.264
Catheter-to-vein ratio > 33%	27 (11.0%)	7 (29.2%)	.011
Catheter-to-vein ratio > 45%	8 (3.3%)	2 (8.3%)	.210
Average number of drugs infused per day			
Any medication	0.9 ± 0.7	1.3 ± 0.8	.021
High-risk medications only	0.2 ± 0.3	0.3 ± 0.4	.102

positioning both in bivariate (log-rank test 4.219, P = .040) and multivariate (HR 0.335, P = .051) analysis.

No statistically significant between-catheter difference was found when the secondary outcomes (catheter-related bloodstream infection, catheter-related thrombosis, and fibroblastic sleeve) were explored (Fig. 1C-E).

DISCUSSION

In the study population, compared with LPCs, MCs showed an overall lower incidence of complications per 1,000 catheter-days and an 85% lower adjusted proportional risk of catheter-failure. Interestingly, the risk seemed superimposable during the first 9 days, while from that moment, the risk clearly increased for the LPCs (Fig. 1). This impression was confirmed by sensitivity analysis (although with a P value of .051 in multivariable regression, probably because of the exclusion of a number of subjects from this analysis). Although confirming previous literature results,[8] this finding was somewhat surprising since we compared catheters made of an identical biomaterial (and produced by the same company), having their length (20 cm for MCs and 8-10 cm for LPCs) as the sole differentiating feature. Precisely this different length seems to offer a plausible explanation for their markedly different degree of reliability.

The aim of respecting a catheter-to-vein ratio less than or equal to 33% at the tip level was essentially always achieved for MCs, being attained less frequently for LPCs (Table 1). This result is consistent with the normal anatomy of the venous system, since the vein size—and consequently its blood flow—is expected to gradually increase while approaching the large thoracic vessels. In bivariate analyses, we found that exceeding the recommended catheter-to-vein ratio was associated with a catheter-failure, confirming previously reported literature results.[22]

Furthermore, we found that a higher average number of drugs infused daily through the catheter was associated with a higher risk for catheter-failure. However, despite theoretically experiencing a higher vein stress (Table 1), overall MCs had a lower catheter-failure

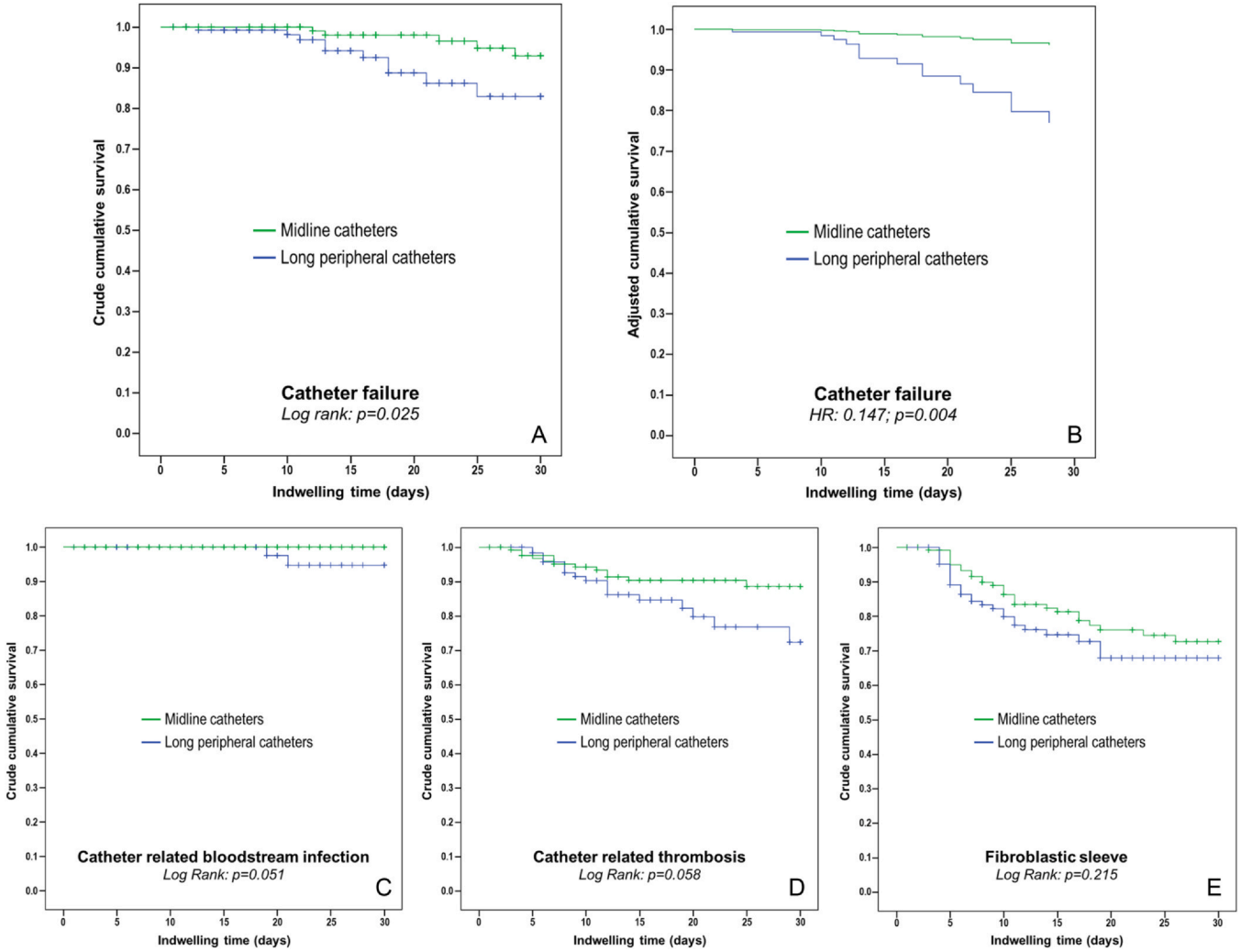

Fig. 1. (A, B) Crude and adjusted Kaplan-Meier survival curves of catheter-failure risk for the compared catheter groups. (C, D, E) Crude Kaplan-Meier survival curves of the secondary study outcomes for the compared catheter groups.

risk compared with LPCs: in other terms, MCs showed a greater reliability, despite being used longer and more intensively. Interestingly, the rate of catheter-failure was similar when considering only the infusion of high-risk medications as a vein stress factor (Table 3): this could be explained by considering that, in our population, all high-risk medications were administered only after appropriate dilution. These results are consistent with the previous literature,[22,23] and seem to suggest that the risk was associated with the number of medications and the continuity with which they were administered, rather than their chemical characteristics.

Based on these findings, we may speculate that the reason for such a greater MC reliability lies in its greater length and, thus, in the different blood flow present at its tip. Indeed, the MC tip predictably reaches the axillary vein at its distal thoracic segment, immediately before the conjunction with the subclavian vein, where a greater blood flow is expected as, at this level, the axillary vein collects the blood drained from other tributary veins (Fig. 2B). Interestingly, it has been demonstrated that almost 60% of people, irrespective of sex and body side, have an accessory axillary vein originating from the lateral brachial, the common brachial or the deep brachial vein in a substantially similar proportion of cases. The presence of this accessory vessel contributes to the venous drainage of the upper limb and can act as an important collateral circulation path in the event of an axillary vein obstruction, for example, due to a thrombosis.[24] Conversely, the length of LPCs allows the tip to be positioned within the cannulated vein (eg, basilic, brachial, and cephalic) or, considering that all catheters were inserted at the Dawson green zone, at most within the very proximal segment of the axillary vein: at this level, the drugs' dilution will only rely on the blood flow of the cannulated vein itself (Fig. 2A).

In summary, the MC tip tends to be placed at a level where a higher catheter-to-vein ratio is easier to ensure, allowing for a faster and less-turbulent blood flow, thus enabling a quicker dilution and transport, and a shorter contact of any administered medications with the vessel wall, consequently reducing the risk of thrombogenesis.[25,26] This reasoning is consistent with previous research, demonstrating that the further the venous segments are from the vena cava, the higher and earlier the risk of thrombosis.[27]

We believe a brief discussion of the results of the secondary study endpoints might be useful. The incidence of catheter-related bloodstream infections was extremely low. However, while no cases were documented with regard to MCs, 2 cases of catheter-related bloodstream infections have occurred in the LPC subgroup. After analyzing the clinical documentation, we noticed that the complications that occurred after the patients were transferred to clinical settings different from those in which the catheter was positioned, where the actual adherence to the protocol for catheter access and maintenance was difficult to assess and monitor. In addition,

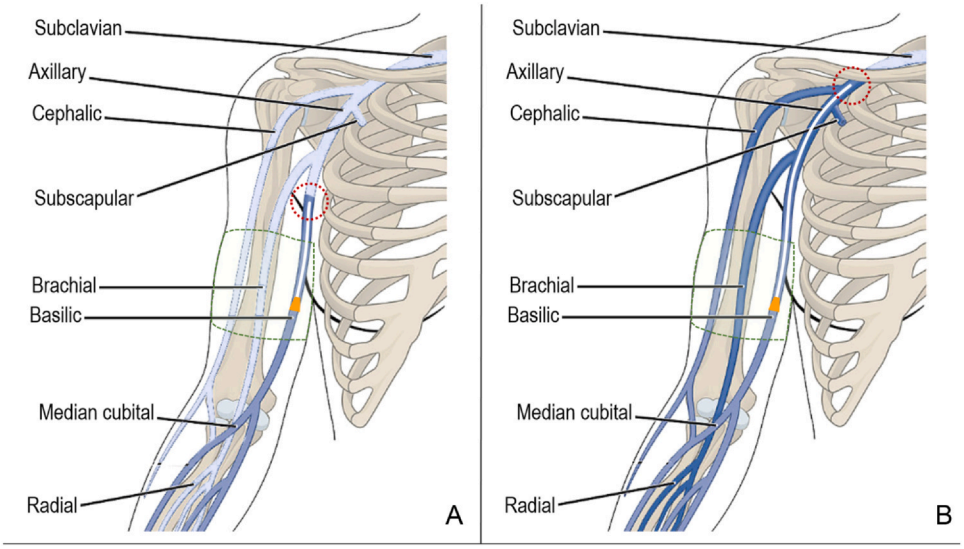

Fig. 2. Schematic example of the different blood flows expected the tip level for long peripheral (A) and midline (B) catheters. Dotted green line: Dawson zone. Dotted red circle: tip catheter area.

considering the responsible isolated microorganisms (ie, *Staphylococcus epidermidis* and *Enterococcus fecalis*), we think that both catheter-related bloodstream infections were due to a contamination ab extrinseco of the devices due to diminished health care providers' attention.

Thrombosis is a common complication associated with vascular access, caused by endothelium damage of the vein. It can remain asymptomatic, manifest itself locally with inflammation or catheter malfunction (persistent withdrawal occlusion, sub/total occlusion, and extravasation), or, although rarely, lead to more serious systemic complications such as pulmonary embolism.[28,29] In our population, the risk of catheter-related thrombosis was similar between MCs and LPCs, although a trend toward a reduced risk in the case of MC seems to emerge by observing the crude Kaplan-Meier curves, which did not achieve statistical significance, probably due to the low sample size.

Fibroblastic sleeve is a phenomenon completely different from catheter-related thrombosis. The high incidence and the early presentation of fibroblastic sleeve found in the present investigation for both types of catheter seems to confirm its pathophysiology, that describes it as a "foreign body reaction" inducing the deposition of fibronectin, a circulating protein produced by the liver, on the external surface of the catheter. Fibronectin attracts blood macrophages that differentiate into smooth muscle cells and fibroblast, and starts to produce collagen,[28,30] leading to the development of a sleeve made of connective tissue around the catheter surface. We think to be of interest having documented that polyurethane MCs and LPCs were equally associated with fibroblastic sleeve incidence, irrespective of their length and the potentially associated blood flow at the tip level.

Based on our results, nurses should choose to place a MC when a medium- to long-term therapeutic plan is expected, especially when the administration of multiple medications is planned, or when they have the need to use dual-lumen devices: the reduced risk of catheter-failure associated with these devices may increase the probability that the therapeutic plan be completed without complications. It should be noted however, that positioning a MC may require longer time and greater skill, impacting on health care organization. Accordingly, we believe that LPCs may play an important role in daily clinical practice: the greater simplicity and speed of LPC positioning allowed by the simplified "Seldinger technique" can make this choice advantageous when less-complex or short-term therapeutic plans have to be managed in DIVA patients. According to our results, an LPC would be appropriate to be used for patients with anticipated intravenous requirements for no more than 9 to 10 days, whereas an MC would be the better choice when a more prolonged therapy is expected.

Limitations

The main limitation of this study is related to its observational design, which intrinsically exposes to the risk of bias (eg, we enrolled a sample of patients in which confounding factors could not be controlled a priori, explaining the presence of several baseline differences in the 2 cohorts) and limits the generalizability of the results. Therefore, particular caution is required when considering the reported associations between the catheter type and the explored outcome, which should be demonstrated by randomized controlled trials. Moreover, there is no evidence that the average number of different medications infused might correlate with venous endothelial stress, therefore, this index should be considered only as representing the more or less-intensive use of the catheter during its indwelling time. Finally, it was not possible to perform a regular ultrasound assessment in the case of patients who were discharged from the hospital, this may have led to an underestimation of some complications such as fibroblastic sleeve and asymptomatic catheter-related thrombosis, which may have appeared at a later time.

CONCLUSIONS

Considering the same biomaterial and equal terms of management, the length of the catheter seems to be the characteristic having the greater impact on the risk of complications. In the present study, the use of MCs was associated with a longer uncomplicated catheter indwelling time, suggesting this should be the first choice for patients needing more complex or longer-duration therapies. Conversely, LPCs should be reserved for use with patients with DIVA conditions and needing for a shorter therapeutic plan.

Further studies are needed to confirm these results in different populations and taking into account catheters of different lengths and made of different biomaterials.

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