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The catheter-to-vein ratio at the tip level, not the catheter type, as a risk factor for a catheter failure. A retrospective comparative study of polyurethane midline and long peripheral catheters

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ABSTRACT

Background: In patients requiring a peripheral venous access for more than seven days, long peripheral catheters (LPCs) or midline catheters (MCs) are recommended. Since MCs and LPCs share many characteristics, studies comparing devices made of the same biomaterial are needed. Moreover, a catheter-to-vein ratio >45% at the insertion point has been recognized as a risk factor for catheter related complications, but no study investigated the effect of the catheter-to-vein ratio at the catheter tip level in peripheral venous devices.

Objectives: To compare the catheter failure risk between polyurethane MCs and LPCs, considering the effect of the catheter-to-vein ratio at the tip location.

Methods: Retrospective cohort study. Adult patients having an expected need for a vascular access of more than 7 days and receiving either a polyurethane LPC or MC were included. The catheter uncomplicated indwelling time within 30 days was considered in survival analysis.

Results: In a sample of 240 patients, the relative incidences of catheter failure were 5.13 and 3.40 cases for 1,000 catheter days for LPCs and MCs, respectively. In univariate Cox regression, MCs were associated to a statistically significant lower risk of catheter failure (HR 0.330; $p = 0.048$). After adjusting for other relevant conditions, a catheter-to-vein ratio >45% at the catheter tip location – not the catheter itself – was an independent predictor of a catheter failure (HR 6.762; $p = 0.023$).

Conclusions: The risk of catheter failure was strongly associated with a catheter-to-vein ratio > 45% at the catheter tip level, irrespective for having used a polyurethane LPC or MC.

Introduction

In patients admitted to the hospital a vascular access is often needed to administer drugs, fluids and blood components, represented by a peripheral intravenous catheter in 60 to 85% of cases.[1,2] Most of the time, traditional short peripheral catheters (SPCs) (<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 for a short-term use.[3–6] However, although seldom serious, complications with SPCs (mainly dislodgement, occlusion, local phlebitis and infiltration) are disappointingly common;[7] consequently, relevant procedures such as intravenous therapy and blood sample collection are interrupted and the patients are likely to be subjected to multiple painful cannulation attempts, which can compromise their superficial venous pool: the so-called "difficult intravenous access" condition (DIVA).[1,2,8] For all these reasons, in patients requiring a peripheral venous access for a medium-term intravenous medication plan (for more than seven days) long peripheral catheters (LPCs) (6–15 cm length) or midline catheters (MCs) (>15 cm length) are the recommended choices.[5,6,9] Both LPCs and MCs must be inserted under ultrasound (US) guidance to reach deeper veins not recognizable through inspection or physical examination.

However, these devices are not free from complication risks. Previous studies showed that polyurethane MCs ensured a significantly longer and uncomplicated duration of use compared with polyethylene LPCs.[10] The authors speculated that the catheter biomaterials

Abbreviations: A-CRT, asymptomatic catheter related thrombosis; CI, confidence interval; CR-BSI, catheter related bloodstream infection; DIVA, difficult intravenous access; LPC, long peripheral catheter; MC, midline catheter; PWO, persistent withdrawal occlusion; RaCeVa, rapid central vein assessment; RaFeVa, rapid femoral vein assessment; RaPeVa, rapid peripheral vein assessment; S-CRT, symptomatic catheter related thrombosis; SPC, short peripheral catheter; US, ultrasound

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may have contributed by affecting the occurrence of complications: polyethylene catheters are characterized by more stiffness and higher infection risks compared with polyurethane.[11] Therefore, studies comparing MCs and LPCs made of the same biomaterial are desirable to confirm these results.

Experimental studies have demonstrated that the presence of a catheter within the vessel could substantially reduce blood flow, thereby increasing the risk of late complications such as thrombosis.[12] Thus, ensuring a catheter-to-vein ratio < 45% at the insertion point, or more conservatively < 33%, has been recommended to reduce the thrombotic risk in peripherally inserted central catheters (PICCs): the higher the ratio, the higher the risk for catheter-related complications.[13–16] The limited studies exploring this risk factor in LPCs and MCs have reported that the catheter-to-vein ratio at the insertion point did not affect the risk of catheter-related complications.[10] However, considering a catheter-to-vein ratio measured at the insertion point could be misleading, since thrombotic events tend to manifest mostly at the catheter tip level.[17] Moreover, a possible blow flow impairment may be more critical at the catheter tip level, as it could prevent a rapid dilution of the administered medications. At present, there are no published studies that have investigated the effect of the catheter-to-vein ratio at the tip location site in reducing the risk of complications in peripheral venous access.

Therefore, the aim of this study was to compare the risk of catheter failure in polyurethane MCs and LPCs, also considering the effect of the catheter-to-vein ratio at the tip location.

Methods

Design, setting and population

This was a retrospective cohort analysis of prospectively collected data. All consecutive adult patients admitted to the Cardiothoracic-Vascular Department of the University Hospital of Trieste (Italy) were considered for enrollment if they received either an LPC or an MC. Patients receiving a vascular device different from those considered in the present study, as well as those with a substantial lack of relevant data, were excluded.

Ethical considerations

The study was conducted according to the Declaration of Helsinki. At hospital admission and at the time of catheter placement, all enrolled patients signed a specific informed consent authorizing the use of her/his clinical data for research purposes. According to the hospital department authorities, formal approval from an institutional review board was not required, as peripheral venous cannulation represented a routine intervention in everyday patient care.

Catheter characteristics, placement procedure and post-insertion management

Since they share many characteristics (e.g., the insertion site and the biomaterial), a clear distinction between MCs and LPCs is not obvious[9] – to the extent that some authors tend to consider the LPCs equivalent to MCs.[18] In the present investigation, the catheters were categorized as MC or LPC based on their length and the adopted placement technique.[10] For the study purpose, the following devices were considered: 1) polyurethane power-injectable 4 Fr, 18 G, 10 cm, single-lumen LPCs (PowerGlide PRO™, Becton Dickinson, Salt Lake City, USA); 2) polyurethane power-injectable 4–5 Fr, 18 G, 20 cm, single or dual-lumen MCs (PowerMidline™, Becton Dickinson, Salt Lake City, USA).

All catheters were inserted by nurses specialized in vascular access. The most appropriate device (i.e., LPC or MC) was chosen based on the characteristics of the cannulated vein. Both LPCs and MCs were considered in patients who were expected to need vascular access for more than seven days.[5] Each placement was performed by adopting standard aseptic techniques (surgical mask, cap, sterile gown when indicated, sterile drape and gloves, sterile transducer cover and US gel) and by scrubbing a wide skin surface around the puncture site with 2% chlorhexidine in 70% alcohol solution.[19,20] Both LPCs and MCs were placed within Dawson's green zone.[21] Further, MCs were inserted using a 'modified Seldinger' technique, while LPCs by a 'simplified Seldinger' technique. In brief, for MCs, a guidewire was introduced through the needle (that was then removed) allowing the insertion of a micro-introducer; after removing the guidewire, the catheter was introduced through the micro-introducer, which was in turn removed using a peel-away method. For LPCs, the guidewire was directly introduced through the needle, being the device available as a needle-guide-catheter complex, allowing the catheter to slide 'over-the-needle' in the vein. In all cases, the effective cannulation was confirmed by both the aspiration of blood and the direct US visualization of the catheter into the vein up to the catheter tip. All catheters were secured to the skin with a sutureless system and the exit sites were covered by a transparent semipermeable dressing with chlorhexidine gluconate gel.

No catheter was routinely replaced and was kept in use as long as needed. Conversely, the catheters were promptly removed when no longer needed or if a failure occurred.[19,20] During the usage period, both LPCs and MCs were managed by bedside nurses based on the same strict hospital policy comprising: using the catheters to administer only drugs compatible with the peripheral route (a detailed list was available in the study setting), avoiding, in particular, the infusion of high-osmolarity (>850–900 mOsm/L) products (e.g., parenteral nutrition); appropriately diluting all antibiotics; vigorously rubbing the needle-free connector before accessing the catheter; flushing the catheters with 10–20 ml of normal saline using a 'stop and go' technique after each use; inspecting daily the catheter exit site for possible complications, and replacing the semipermeable dressing weekly or whenever necessary.

Study variables

Patient demographics and data on past medical history were collected, and the Charlson comorbidity index was calculated.[22]

Data on the catheter type, the number of cannulation attempts, the proximal (at the insertion site) and distal (at the catheter tip location) diameter of the cannulated vein (millimeters between vein inner walls) and the derived proximal and distal catheter-to-vein ratio were recorded.

Conditions considered as potential protective or favoring factors for venous thrombosis development were documented, and patients taking any antiaggregant or anticoagulant drug through an oral, subcutaneous or intravenous route were recorded. Accordingly, all medications administered at least once through the catheter were registered and patients receiving any drug at moderate or high levels of tissue damage risk were identified.[23]

Study outcomes

The primary study outcome was the catheter survival within a time-span of 30 days. The catheters indwelling time was calculated as the interval (days) between the dates of placement and removal. A catheter failure was defined as any condition that forced the catheter's removal while still in use, such as symptomatic-catheter related thrombosis (S-CRT), catheter-related bloodstream infections (CR-BSI), exit site infection or complete catheter obstruction. In detail, S-CRT was diagnosed by both: 1) visualization of a thrombus adhering to the vessel wall around the catheter or the inability to compress the vein during US scan; and 2) the presence of one or more signs or symptoms (e.g., pain, erythema, edema, palpable venous cord).[24–26]

Further, CR-BSIs were diagnosed based on: 1) a positive semiquantitative culture (>15 colony-forming units/catheter segment), whereby the same microorganism (species and antimicrobial susceptibility testing) was isolated from the catheter tip and peripheral blood; or 2) the differential period of catheter versus peripheral blood culture positivity of >2 h (differential time to positivity, although this method has been validated for central catheters).[27] In the absence of a phlebitis scale validated for use in clinical practice,[28] exit site phlebitis was defined by the presence of at least two signs from the following: exit site erythema, pain, swelling or the presence of pus. Complete catheter obstruction was defined in the presence of an impossibility to both infuse and aspirate through the catheter.

Conversely, catheter removal at the end of use without any complication, as well as the unplanned removal of an uncomplicated and still in-use catheter (e.g., accidental removal, patient death) were not considered as a catheter failure. The occurrence of asymptomatic CRTs (A-CRTs), fibroblastic sleeve or persistent withdrawal occlusion (PWO), which did not prevent the catheter from the expected functioning, were not considered as a poor outcome, as they did not lead to a premature catheter removal.

The rates of catheter failure in study groups were calculated as a secondary outcome and expressed as the relative incidence per 1000 catheter days.[29]

Statistical analysis

For continuous variables, descriptive statistics was reported as means and standard deviations. The differences between the means were analyzed using an unpaired (after Levene's test to assess equal variance in the subgroups) or paired Student's *t*-test, as appropriate. The nominal variables were described as a number and percentage, and the possible differences were tested via the Pearson χ test or Fisher's exact test, as appropriate.

Survival analysis was used to estimate the time-to-event effect of the catheter groups (LPCs and MCs) on the 30-days risk of catheter failure. When the patient was discharged home or transferred to another hospital with an indwelling catheter, observations were right-censored at the time of the event (known survival). Crude evaluation was carried out by comparing Kaplan–Meier curves and differences in survival rates between subgroups were assessed with the Mantel-Cox log–rank test. Adjusted comparison was performed by fitting multivariable Cox proportional-hazards models. Given the low number of events per variable, several models were run by progressively adding a limited number of covariates, showing significant relation to the occurrence of a catheter failure in bivariate analyses (i.e., catheter-to-vein ratio, patient's age, number of different infused drugs). Results were reported as adjusted proportional hazard ratios (HRs) with relative 95% confidence intervals (CI) and *p*–values.

For all tests, the statistical significance was set at an alpha level of $p = 0.05$. Statistical analyses were performed using the software SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, US).

Results

Overall, 481 patients who underwent an LPC or MC insertion (from 01/01/2014 to 30/09/2022) were considered for the study. Two hundred and forty-one patients (118 with MC and 123 with LPC) were excluded because they received a device different from those considered in the present investigation or because the catheters were removed within 24 h after placement due to the interruption of the intravenous medication plan. Consequently, 240 patients constituted the final study population. Table 1 shows the main characteristics of patients and catheters. Patients were comparable in terms of age, sex and comorbidity burden. Statistically significant differences were found between catheter groups according to type and depth of cannulated veins. The maximum indwelling time was 74 days for LPCs and 125 days for MCs. Overall, MCs were held in place for a significantly longer time than LPCs. At the insertion level, no difference was found regarding either the veins' inner caliber or catheter-to-vein ratio, while all above differences were statistically significant at tip level. When considering a catheter-to-vein ratio >45%, this parameter was exceeded more frequently in the LPC compared to the MC group, both at the insertion and at the tip level. More than two different drugs were administered more frequently through MCs than LPCs.

Table 1
General characteristics of the enrolled population and differences according to the implanted intravenous devices.

Variable	All catheters	LPC	MC	*p*-value
Patient characteristics				
Age (years)	67.7 ± 11.6	69.2 ± 10.7	66.3 ± 12.2	0.055
Sex (male)	148 (61.7%)	73 (64.0%)	75 (59.5%)	0.473
Charlson comorbidity index	5.8 ± 3.0	5.8 ± 2.8	5.8 ± 3.2	0.938
Cannulated vein				<0.001
Basilic	161 (67.1%)	69 (60.5%)	92 (73.0%)	
Brachial	58 (24.2%)	24 (21.1%)	34 (27.0%)	
Cephalic	21 (8.8%)	21 (18.4%)	0 (0.0%)	
Depth of cannulated vein (cm)	1.2 ± 0.4	1.1 ± 0.3	1.3 ± 0.4	<0.001
Measures at insertion level				
Inner caliber of the vein (mm)	4.7 ± 1.2	4.7 ± 1.2	4.8 ± 1.1	0.328
Catheter-to-vein ratio (%)	31.3 ± 8.5	32.3 ± 9.6	30.4 ± 7.2	0.092
Catheter-to-vein ratio > 45%	12 (5%)	11 (9.6%)	1 (0.8%)	0.002
Measures at tip level				
Inner caliber of the vein (mm)	6.9 ± 1.2	6.1 ± 2.1	7.6 ± 2.1	<0.001
Catheter-to-vein ratio (%)	23.0 ± 9.3	26.3 ± 11.0	20.0 ± 6.1	<0.001
Catheter-to-vein ratio > 45%	5 (2.1%)	5 (4.4%)	0 (0.0%)	0.024
Infusion of more than 2 different drugs	37 (15.4%)	8 (7.0%)	29 (23.0%)	<0.001
Total indwell time (days)	21.6 ± 17.5	17.1 ± 12.3	25.7 ± 20.4	<0.001

Data are described as mean ± standard deviation or number (percentage). LPC: long peripheral catheter. MC: midline catheter.

The most insertion procedures (95.4%) were successfully completed at the first attempt; the remaining at the second. No statistically significant difference was found between catheter groups (success at first attempt: LPCs 93.0%; MCs 97.6%; $p = 0.081$). Compared with that at the insertion site, a statistically significant wider caliber of the cannulated vein at the distal point (i.e., at the catheter tip level) was documented in both the LPC (proximal: 4.7 ± 1.2 mm; distal 6.1 ± 2.1 mm; $p<0.001$) and the MC (proximal: 4.8 ± 1.1 mm; distal 7.6 ± 2.1 mm; $p<0.001$) groups. The condition in which the distal vein caliber was greater than the proximal one was significantly more frequent ($p = 0.026$) for MCs compared to LPCs (Fig. 1).

Overall, a catheter failure was documented in 14 cases (5.8%) and manifested later in patients with an MC (Fig. 2). The relative incidences of catheter failure were 5.13 and 3.40 cases for 1000 catheter days for LPCs and MCs, respectively. In bivariate analyses, a poor catheter outcome was significantly associated with the type of cannulated vein (in particular when the cephalic vein was chosen), as well as having infused more than two different drugs through a catheter, and to a catheter-to-vein ratio >45% at the tip level (Table 2).

In crude survival analysis, MCs showed a lower failure risk (log-rank test 4.503; $p = 0.034$) compared to LPCs (Fig. 3a). This finding was confirmed by univariate Cox proportional-hazard modeling (# 1), showing that MCs were associated with a statistically significant lower risk of catheter failure (HR 0.330; $p = 0.048$). This result was not confirmed when the model was adjusted for other variables associated with catheter failure, while a catheter-to-vein ratio >45% at the tip level was independently predictive of a catheter failure in all

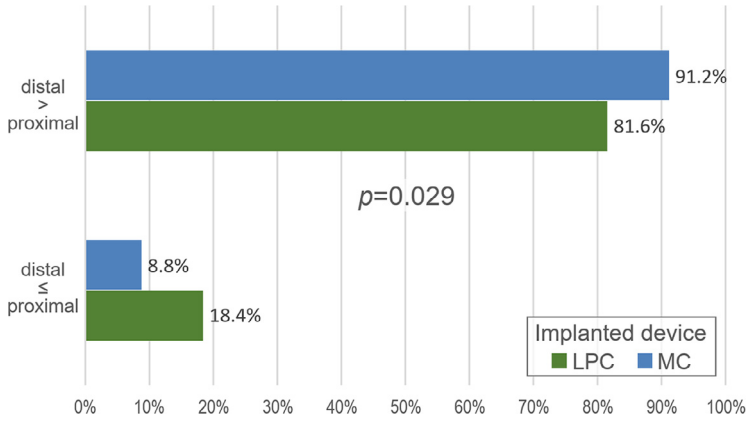

Fig. 1. Different rates in which the distal (catheter tip level) vein caliber was greater or lower/equal to the proximal (catheter insertion point) caliber between catheter groups.

the tested multivariable models (Table 3). Fig. 3b and c show the adjusted Kaplan-Meier survival curves for the catheter groups and catheter-to-vein ratio >45%, respectively, as described by the final regression model (# 5).

Discussion

In our population, MCs showed a statistically significant lower risk of failure than LPCs in univariable analyses. However, after adjusting for other relevant conditions associated with the explored outcome, a catheter-to-vein ratio >45% at the catheter tip location – not the catheter itself – was an independent predictor of a catheter failure in all tested multivariable Cox proportional hazards models. This condition was found to be significantly associated with a 7-fold higher catheter failure risk compared to a smaller catheter-to-vein ratio. To the best of our knowledge, this is the first study that has analyzed the effect of the catheter-to-vein ratio at the catheter tip location on the risk of catheter failure in patients with LPCs and MCs.

A higher catheter-to-vein ratio may represent a critical point for the risk of complications, as an indwelling device can favor thrombogenesis by inducing a slower and turbulent blow flow: the higher the catheter-to-vein ratio, the higher the expected effect of decreasing the blood flow.[12] Moreover, a lower blood flow enables a slower dilution and transport of any medications administered into the vein and, thus, a longer contact of the drug with the vessel wall, so increasing the risk of complications–especially CRTs.[12–16]

It might be expected that the catheter-to-vein ratio at the catheter tip level is more favorable for longer catheters, since anatomically the caliber of venous vessels tends to increase progressively as they approach the large thoracic vessels. However, the final location of a catheter tip is related to different conditions, such as the catheter length, the size of the arm and the point where the vein is accessed,[17] so that the final catheter tip position is often not obvious despite the length of the positioned catheter (e.g., the tip of a 10 cm LPC inserted at the cranial border of the Dowson's green zone could reach the axillary vein; the tip of a 20 cm MC inserted at the caudal border of Dowson's green zone might not reach the axillary vein, especially in patients with long arms or when the brachial or basilic vein join the axillary vein distally). In the present investigation, the length of the MCs was double compared to LPCs, thus determining that an MC was expected to have its tip located in a larger vessel than an LPC, making more likely the possibility of ensuring a lower catheter-to-vein ratio. Consistently, although a statistically significant higher catheter-to-vein ratio at the catheter tip level, compared to the insertion point, was shown for both LPCs and MCs, this condition was more probable for MCs than LPCs. Surprisingly, our data documented that the distal catheter-to-vein ratio was lower or equal to the proximal one in more than 13% of the cases. Therefore, the existence of a larger venous caliber at the tip level than at the insertion point cannot be taken for granted, neither for LPCs nor for MCs (Fig. 1).

In several cases among our population, patients received, via MCs or LPCs, medications considered as moderate to high risk for vascular tissue damage because of their critical values of pH or osmolarity. However, the rate of complications was similar in all patients, regardless of whether or not they were receiving these medications; this result was consistent with previous literature data.[30] Since both LPCs

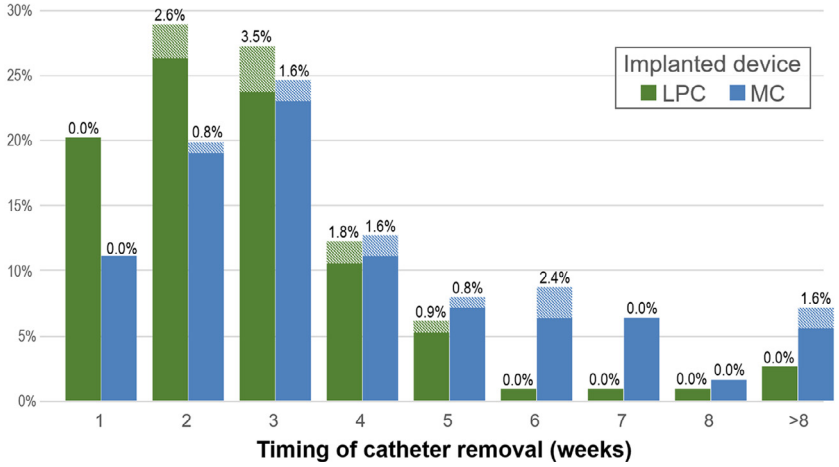

Fig. 2. Rate of catheter failure according to the indwelling time. Dashed areas and percentages: failure rates.

Table 2
Comparison between patients and cannulated vein characteristics according to the catheter outcome.

Variable	Catheter outcome		*p*-value
	Success	Failure	
Patient's age (years)	67.3 ± 11.8	73.6 ± 6.6	0.049
Patient's sex (male)	141 (62.4%)	7 (50.0%)	0.355
Undergoing aAg/aCo therapy	208 (92.0%)	11 (78.6%)	0.112
Cannulated vein			0.017
Basilic	155 (96.3%)	6 (3.7%)	
Brachial	54 (93.1%)	4 (6.9%)	
Cephalic	17 (81.0%)	4 (19.0%)	
Catheter-to-vein ratio > 45% (insertion)	10 (4.4%)	2 (14.3%)	0.149
Catheter-to-vein ratio > 45% (tip)*	3 (1.3%)	2 (14.3%)	0.029
Infusion of more than two different drugs	32 (14.2%)	5 (35.7%)	0.030
Infusion of moderate-high risk drugs	93 (41.2%)	8 (57.1%)	0.240

Data are described as mean ± standard deviation or number (percentage). aAg/aCo: antiaggregant/anticoagulant. *: *n* = 239.

Table 3
Results of Cox regression of catheter failure on study variables.

Cox proportional-hazards model	HR; 95% CI	*p*-value
Model # 1		
Device (Midline catheter)	0.330; 0.110–0.988	0.048
Model # 2		
Vein-to-catheter ratio > 45% (tip)	8.229; 1.834–36.915	0.006
Model # 3		
Device (Midline catheter)	0.403; 0.127–1.274	0.122
Catheter-to-vein ratio > 45% (tip)	5.077; 1.048–24.592	0.044
Model # 4		
Device (Midline catheter)	0.334; 0.104–1.077	0.066
Catheter-to-vein ratio > 45% (tip)	6.663; 1.311–33.86	0.022
Infusion of more than two different drugs	3.287; 1.016–10.633	0.047
Model # 5		
Device (Midline catheter)	0.430; 0.134–1.377	0.155
Catheter-to-vein ratio > 45% (tip)	6.762; 1.308–34.964	0.023
Infusion of more than two different drugs	2.763; 0.847–9.007	0.092
Patient's age	1.081; 1.004–1.164	0.040

HR: hazard ratio. CI: confidence interval.

and MCs are peripheral vascular devices, it is reasonable to assume that this risk can be reduced by administering drugs at moderate or high risk –especially if in continuous infusion– only through a central venous access, i.e. a vascular device whose distal tip is located at the atrio-caval junction.[20,23] Regrettably, as confirmed by our data, this recommendation is often disregarded in clinical practice.[30]

Having the present investigation consider catheters with similar characteristics (both peripheral, both power-injectable, both made of polyurethane), this study aimed at testing the hypothesis that a difference in confirmed outcomes between LPCs and MCs could be associated with the insertion technique: this being the only characteristic –in addition to the catheter length– differentiating the two devices. However, the very high rate of success in cannulation attempts and the substantial lack of immediate complications does not seem to have highlighted any particular risk for either technique.

A final point should be made about patients' age: this study found that older age is a predictor of catheter failure. In a recent review, older age was described as a strong risk factor for the occurrence of thromboembolic events, with an almost 80-fold risk increasing in people aged 85 or over.[31] Unfortunately, older age is often a characteristic of patients needing an US-guided vascular device, for example, because of a DIVA condition, thus this risk factor seems impossible to control.

Implications for practice and research

According to our findings, we suggest performing an in-deep ultrasound assessment of the patient's venous pool before choosing the most appropriate catheter to insert, calculating as precisely as possible what is the best compromise between the vein to be punctured and the catheter length and caliber (Fr) in order to ensure the lowest catheter-to vein ratio at the expected tip level, never exceeding 45%. This proposal may integrate the RaCeVA, RaPeVa and RaFeVa protocols, recommending -inter alia- to exclude by a preliminary US scan the presence of any anatomical vascular anomaly that could increase the risk of acute or late complications.[32–34]

The potential predictive role of the catheter-to vein ratio at the tip level should be confirmed by further large studies. For this to be possible, we suggest systematically collecting the relevant data for each positioned catheter, including the name and the caliber of the vein both at proximal and distal level, as well as information regarding catheter's indwelling time, management procedures, and early and late complications. The creation of prospective, multicentric registries systematically documenting these data could be a powerful tool to improve the quality of research in this field.

Strength and limitations

The main strength of the present study is having tested the hypothesis, for the first time, that an excessive catheter-to-vein ratio at the tip level could have an independent impact on the risk for a catheter failure.

However, there are some limitations to be considered when interpreting our findings. First, we enrolled a convenience sample of patients and adopted an observational and retrospective design, thus exposing the study to the risk of bias. Second, having this investigation consider a time-to-event outcome, in some cases the

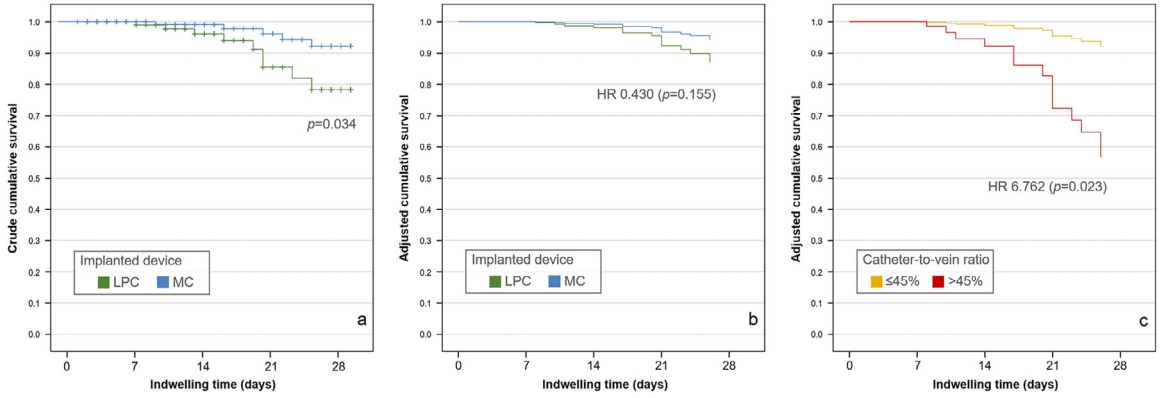

Fig. 3. (a) Crude Kaplan-Meier survival curves for the compared catheter groups. Adjusted Kaplan-Meier survival curves for (b) the catheter groups and (c) catheter-to-vein ratio >45% as described by the final multivariable Cox proportional hazards model (# 5). LPCs, long peripheral catheters; MCs, midline catheters.

observations were censored because of a patient's hospital discharge with an uncomplicated catheter still in use. Consequently, for both the LPCs and MCs the actual complicated or uncomplicated 'survival' times could undoubtedly have been higher, leading to different findings. Finally, this was a monocentric study and some relevant variables (e.g., catheter-to-vein ratio > 45%) had a low incidence in the sample. Therefore, the external validity of our results should be confirmed by further larger and preferably prospective studies.

Conclusions

In the studied population, the risk of catheter failure was strongly associated with a catheter-to-vein ratio exceeding 45% at the catheter tip level, irrespective of having used a polyurethane LPC or MC. Because of the existing inter-individual anatomical differences, choosing a longer device (i.e., a MC) does not ensure *per se* that the catheter tip is placed in a vessel large enough to ensure a catheter-to-vein ratio below the critical threshold. Therefore, regardless of the catheter used, we suggest that adequate blood flow (i.e., a catheter-to-vein ratio <45%) is ensured at the tip level to reduce the risk of complications leading to a catheter failure.

Declaration of Competing Interest

The authors declared no conflict of interest.

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