Original research article

JVA The Journal of Vascular Access

Cost comparison of four venous catheters: Short peripheral catheter, Long peripheral line, Midline, and PICC for peripheral infusion

The Journal of Vascular Access
1–9

DOI: 10.1177/11297298241258257
journals.sagepub.com/home/jva
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Abstract

Introduction: The use of midline catheters for patients requiring a peripheral IV infusion is sometimes limited by their cost. Although decision trees allow them to be positioned in relation to short peripheral cannulas (SPC), Midlines, and PICCs, their economic impact has not yet been evaluated. A study was conducted to estimate and compare the actual costs of using the three types of catheters for durations of 7, 14, and 21 days.

Methods: A budget impact analysis compared midlines or mini-midlines/long peripheral cannulas (LPCs) with SPCs and PICCs for typical medical indications excluding indications requiring central line (infusion of irritant or vesicant drugs): treatment of peritonitis over 7 days, cystic fibrosis infection over 14 days, and meningitis over 21 days. A micro-costing study identified resources used during catheter care procedures (consumables, medical/nursing care, examinations, mechanical complications). The cost of remote systemic complications was estimated from the French national cost study. Literature review compared data based on published complication frequencies.

Results: Midline is more economic than the SPC (saving of 39€ over 7 days and 174€ over 14 days), and than the PICC (saving of 102€ over 14 days and 95€ over 21 days).

Discussion: Despite a much higher acquisition cost of the Midline than a SPC, the cost of using a Midline is lower. Although this approach cannot be the only argument for choosing a medical device, it can contribute to it in a tense economic context. The micro-costing has been performed in a center placing PICCline using fluoroscopy for catheter tip positioning. The implantation of a PICC with ECG technique does not require an interventional radiology facility and involves significantly lower logistical and personnel costs. This factor is a limitation in this study. However, even with the use of EGC, the cost difference is in favor of Midline.

Keywords

Catheters, budgetary impact, complications, economic evaluation, midline, PICCline, peripheral IV, short peripheral cannulas, long peripheral cannulas

Date received: 10 May 2023; accepted: 27 April 2024

Introduction

There are three types of peripherally inserted catheters from shortest to longest, short peripheral cannulas (SPC), Midline, and peripherally inserted central catheters (PICC).[1] SPC are the most popular catheters due to their low cost, short length <6 cm, with an average duration of use of 2.9–4.1 days. These are usually place at bedside in

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the veins of the forearm. Midlines are longer peripheral venous catheters inserted in the forearm or upper arm with ultrasound guidance. The average dwell time of use of midlines varies between 7.7 and 16.4 days.[2] A distinction has recently made between the Midline measuring between 6 and 25 cm and the mini-Midline/long peripheral catheters (LPC) measuring between 6 and 15 cm. PICC are defined as vascular access devices inserted in veins of the upper extremity that terminate at the cavoatrial junction for treatment exceeding 14 days.[3] In addition, while SPCs often require replacement after a few days, Midlines and PICCs can remain in situ for multiple days or weeks; however, this is not only dependent on the clinical scenario but also on institutional protocols and manufacturer's recommendations.

Choosing the most appropriate catheter is difficult. Catheters are selected in relation to infusion of solutions compatible with the peripheral route. In addition, choices depend on the nature and duration of the treatment, as well as the patient's venous capital. Decision support algorithms have been published, notably by the ERPIUP consensus,[4] SF2H,[5] MAGIC,[6] or GAVECELT,[7] allowing the most appropriate catheter to be selected.

According to the SF2H and MAGIC guidelines,[5,6] SPC should be used for treatments lasting less than 5 days or between 6 and 14 days if placed under ultrasound. The ERPIUP consensus recommends the use of SPC for emergency and/or short duration access (24–48 h). Considering that the life span of a SPC, several SPCs should be inserted into our model for the 7- and 14-day treatments.

Guidelines for using Midlines and PICCs are relatively nuanced. GAVeCelt[7] recommends the use of a Midline for a treatment lasting 7–30 days. In MAGIC, if the duration of treatment is between 8 and 15 days, a Midline should be used, while if the duration is longer than 15 days, a PICC should be used. The ERPIUP recommendations state that Midlines are appropriate when the expected duration is $>$4 weeks. LPCs are appropriate in DIVA patients, or when expected duration is 1–4 weeks.

International recommendations for good practice differ when it comes to choosing the right venous access device for infusion of peripherally compatible infusate.

Depending on the centers and their local practices, it can be observed that, in some indications for peripheral infusion, except for the infusion of irritant or vesicant drug, the three catheters are selected for infusion of a peripherally compatible infusate $<$30 days. In practice, the choice of catheter for peripheral indications compatible with the duration of treatment is often linked to the experience and habit of the insertion teams and the availability of devices.

Given that recommendations are interpreted differently, and that the resources available to hospitals is an important factor in the choice of these devices for infusion of solutions compatible with the peripheral route, can the medico-economic approach help in the choice of catheter?

This evaluation is an interesting way of assessing the pertinence of the choice from another perspective: economic, encompassing all aspects of care, from insertion to the treatment of complications.

The objective of this study is to quantify the costs that will be generated using these three devices by comparing them to each other in the condition of infusion for peripheral drugs excluding indications requiring central line (infusion of irritant or vesicant drugs).

Methods

A budget impact analysis was performed to compare the cost of using three types of catheters for infusion compatible with the peripheral route: SPCs, Midlines, and PICCs. Subsequently, instead of midlines, we introduced LPC, because they are both closer to short catheters and less costly and have a lower risk of systemic complications compared with Midlines. The purpose of budgetary impact analysis is to assess the effects of the introduction of a therapeutic innovation by comparing the total expenditure recorded in an indication before and after its re-introduction.[8–12]

To reflect the recommendations of good practice, several treatment durations have been retained for which these catheters are likely to be used for infusion compatible with the peripheral route. For each of them, a standard indication has been retained as an example. Treatment of 7 days (e.g. Treatment of peritonitis): SPCs versus Midlines; treatment of 14 days (e.g. Treatment of the treatment of infection due to cystic fibrosis): SPCs versus Midlines versus PICCs; Treatment of 21 days (e.g. Treatment of meningitis): Midlines versus PICCs.

The modeling technique adopted to set up the budget impact analysis is the decision tree. This type of modeling describes the different clinical patient pathways that patients are led to follow during their care depending on the clinical events they encounter. These events are the key parameters of the modeling as they have an impact on the cost.

Patient pathways vary according to individual sites, as catheter insertion can be subject to several insertion attempts depending on the state of their venous capital. Before being successfully inserted, the insertion attempts failed up to four times, after we assume that the catheter chosen in the first instance was abandoned and another type of catheter is used. Catheters are inspected daily by a nurse. Catheter insertion may lead to a range of complications due to both mechanical (dislodgement, occlusion, infiltration, venous thrombosis, and phlebitis) and systemic factors (bloodstream infection and pulmonary embolism).[13] If systemic complications occur, treatment is interrupted in our model.

Table 1. Frequencies of complications for SPC, Midlines, LPC, and PICC.

Catheters	SPC (%)	Midline (%)	LPC (%)	PICC (%)
Complications				
Systemic complication				
Bloodstream infection	2.2	0.34	0.4	1.8
Pulmonary embolism	0	1.65	0.2	1.62
Mechanical complication				
Dislodgement	17.5	3.79	3.79	1.50
Infiltration	14.2	0.6	0.6	0
Occlusion	9.2	2.24	2.1	5.8
Thrombosis	0	1.38	1.5	2.4
Phlebitis	22.7	0	0	0

Table 2. Unit costs and time per catheter care sequence.

	SPC		Midline		LPC		PICC	
Micro costing								
Insertion	€7	18 min	€114	54 min	€95	54 min	€160	109 min
Reinsertion (after failure)	€4	14 min	€101	30 min	€82	30 min	€144	53 min
Nursing supervision	€5	20 min/day	€5	20 min/day	€5	20 min/day	€5	20 min/day
Dressing repair	—		€18	20 min	€18	20 min	€178	20 min
Removal	€2	10 min	€2	10 min	€2	10 min	€3	13 min
National cost study								
Systemic complication	€1802		€1217		€1567		€1468	
Peritonitis	€3679		€3679		€3679		€3679	
Infection due to cystic fibrosis	€10,775		€10,775		€10,775		€10,775	
Meningitis	€9286		€9286		€9286		€9286	

Probabilities of events

Probabilities of occurrence of different clinical events have been documented from a literature review and validated by a clinician.[14] They were used to weigh the cost of each clinical event. The total cost of each care pathway is obtained by summing the costs of each event in the pathway, weighted by their probability of occurence. The cost of using a catheter is estimated by summing the weighted costs of all possible patient pathways.

Successful catheter insertion on the first attempt is 73%, 89%, and 90% for SPC, Midlines, and PICCs respectively.[15,16] The respective frequencies of successful catheter insertion were failed up to four attempts, in these same articles.

The average number of attempts to insert a SPC is 2.18[17] compared to 1.21 for a Midline[18] and 1.09 for a PICC.[19]

Frequencies of complications for SPC are real-life data from the Helm's study.[20] Midline complication rates were mainly documented from Chopra's study[21] and from Bahl's study for pulmonary embolism.[16] LPC complication rates for bloodstream infection, pulmonary embolism, occlusion, and thrombosis, were from Swaminathan's study.[22] As the frequencies of infiltration and dislodgement were not documented in Swaminathan's study, we considered for these two types of complication following insertion of the LPC, the rates applied to the Midline. Frequencies of complications related to PICC are from the studies of Swaminathan,[22] Piredda,[23] and Balsorano[24] (Table 1).

Cost valuation

The perspective adopted to evaluate the cost of the various catheters is that of the hospital. Only direct costs directly linked to venous devices were considered.[9,10] The sources of data used for the valuation of costs are multiple (Table 2).

A micro-costing study was carried out by a French hospital (Ambroise Paré) to collect the expenses observed at all stages of care:

- Insertion/Reinsertion (after failure): consumables used, catheter used, time spent by a nurse and/or doctor or resident, paramedical examinations performed (ultrasound and X-ray);
- Nursing supervision: time spent supervising by a nurse;

- Dressing repair: consumables used, and time spent by a nurse;
- Removal: time spent by a nurse.

Costs of medical and nursing care were measured in minutes at each stage of catheter insertion and then valued using the median hourly wage of the profession concerned. The implantation of SPCs is performed by nurses. The insertion of a Midline is carried out under ultrasound guidance by a nurse. PICCs are inserted by a doctor or a PICCnurse under ultrasound guidance. X-ray guidance is required to verify the correct position of the inserted catheter tip, according to the Ambroise Paré hospital practice.

Cost of mechanical complications was assessed by microcosting, insofar as dislodgement, occlusion, infiltration, phlebitis, and thrombosis require the removal of the current catheter and the insertion of a new catheter (of the same type or not).

Costs of systemic complications and illustrative indications were valued from the French National Hospital Cost Study.[25] Infections and pulmonary embolisms are associated with respective Diagnosis Related Group. According to expert opinion, the care provided for systemic complications only extends the patient's length of stay by 3 days on average. We selected DRGs with an average length of stay of less than approximately 3 days.

Results

The patient pathways were modeled using a decision tree. An estimated treatment cost per patient for each catheter was calculated from the probabilities and costs associated with each branch of the tree. The costs of consumables, devices, medical and nurses time, paramedical examinations, mechanical complications, and systemic complications were distinguished.

Seven-day treatment: SPC versus Midline

The use of Midlines allows a saving of €39/patient compared to the use of SPCs over the whole 7-day treatment period.

Although the costs attached to the different sequences of care of SPCs are much lower compared to Midlines (difference of €41 in favor of SPC), Midlines appear to be more economical when we include the expenses related to the care of systemic complications (difference of €81 in favor of the Midlines). Short catheters cause more systemic and mechanical complications (Table 3).

Fourteen-day treatment: Midline versus SPC and Midlines versus PICC

Midlines provide a saving of €175/patient compared to SPCs and €102/patient compared to PICC.

Midlines are less expensive than SPCs when both micro-costing costs and systemic complications are considered.

Midlines are less expensive than PICCs both in terms of resources consumed in catheter care and in care after a systemic complication (Table 4).

Twenty-one-day treatment: Midline versus PICC

The difference in cost is €95/patient in favor of the Midline. In terms of micro-costing, the Midlines is less expensive than the PICCs by €69. The difference is even more pronounced when systemic complications are included, as they are less costly for a patient with Midline (Table 5).

LPC versus SPC versus PICC

The use of a LPC is both more economical than the use of 7- and 14-day SPC and the use of 14- and 21-day PICC. The cost savings of the LPC are greater than those of the Midline due to its lower purchase cost and fewer systemic complications (Tables 6–8).

Discussion

A budget impact analysis was conducted to compare the use of SPC, Midline, LPC, and PICC in three treatments for infusion compatible with the peripheral route, one each of 7, 14, and 21 days.

Even though the purchase cost of SPCs is less expensive than Midlines, the cost of using Midline is less expensive than the cost of using the SPC for a 7-day treatment and for a 14-day treatment. These differences are explained by an higher estimated cost of complications and multiple SPC insertions throughout the treatment. Findings from the Midline data are even stronger for the LPC. The cost of using Midline is lower than PICC for infusion compatible with the peripheral route over 14 and 21 days (excluding indications requiring central line for infusion of vesicant or irritant drugs).

Two studies have evaluated the cost of Midlines compared to other catheters. Caparas[26] found no significant difference in the occurrence of complications between PICC and Midline. In this study, the difference in costs is linked to the different methods of monitoring catheter insertion (ultrasound, radiology, fluoroscopy), or to the use of different types of guides for insertion according to the profile of the catheter fitter. Thus, the PICC costs $90 more per insertion (maximum barrier kit, tip locator, X-ray) than the Midline. It should be noted, however, that intangible costs, such as the cost of immobilizing an operating room or the cost of personnel, were not included in this study.

Raio[27] found a difference of $11.63 compared with SPC for all patients, and $12.20 in patients with complicated vascular access. However, this study did not consider the frequency of complications. Published cost-effectiveness

Table 3. Cost comparison for 7-days treatment. .

	Estimated cost per patient		Incremental cost
	Midline	SPC	Midline vs SPC
Micro-costing			
Consumables	19.21€	23.63€	−4.42€
Device	75.87€	4.18€	71.69€
Medical and nursing time	49.39€	50.55€	−1.16€
Paramedical exams	29.40€	0.15€	29.25€
Mechanical complications	12.40€	66.48€	−54.08€
Total	186.27€	144.99€	+41.28€
National cost study			
Indication: peritonitis	3679.18€	3679.18€	0.00€
Systemic complications	24.22€	104.76€	−80.54€
Total	3703.40€	3783.94€	−80.54€
Total per patient	3889.67€	3928.93€	−39.26€

Table 4. Cost comparison for 14-days treatment.

	Estimated cost per patient			Incremental cost	
	MID	SPC	PICC	MID vs SPC	MID vs PICC
Micro-costing					
Consumables	32.65€	41.04€	32.69€	−8.39€	−0.04€
Device	76.53€	12.79€	96.83€	63.74€	−20.30€
Medical and nursing time	93.45€	100.39€	105.78€	−6.94€	−12.33€
Paramedical exams	29.57€	3.63€	63.51€	25.95€	−33.94€
Mechanical complications	12.38€	111.2€	22.004€	−98.82€	−9.6€
Total	244.58€	269.05€	320.81€	−24.47€	−76.23€
National cost study					
Indication: peritonitis	10,775.16€	10,775.16€	10,775.16€	0.00€	0.00€
Systemic complications	24.19€	174.26€	50.08€	−150.07€	−25.89€
Total	10,799.35€	10,949.42€	10,825.24€	−150.07€	−25.89€
Total per patient	11,043.93€	11,218.47€	11,146.05€	−174.54€	−102.12€

Table 5. Cost comparison for 21-days treatment.

	Estimated cost per patient		Incremental cost
	Midline	PICC	MID vs PICC
Micro-costing			
Consumables	46.02€	46.05€	−0.10€
Device	76.51€	96.87€	−6.17€
Medical and nursing time	145.51€	150.22€	−8.05€
Paramedical exams*	29.50€	63.52€	−33.86€
Mechanical complications	21.63€	31.39€	−8.18€
Total	319.17€	388.05€	−68.88€
National cost study			
Indication: peritonitis	9286.52€	9286.52€	0.00€
Systemic complications	24.22€	50.19€	−25.97€
Total	9310.74€	9366.71€	−25.97€
Total per patient	9629.91€	9724.76€	−94.85€

*Including cost of imaging exam (fluoroscopy) for PICCline tip positioning.

Table 6. Cost comparison for 7-days treatment (LPC vs SPC). .

	Estimated cost per patient		Incremental cost
	LPC	SPC	LPC vs SPC
Micro-costing			
Consumables	19.21€	23.62€	−4.41€
Device	55.18€	4.08€	51.1€
Medical and nursing time	49.39€	50.55€	−1.16€
Paramedical exams	29.40€	0.15€	29.25€
Mechanical complications	10.78€	66.48 €	−55.7€
Total	163.96€	144.88€	+19.08€
National cost study			
Indication: peritonitis	3679.18€	3679.18€	0.00€
Systemic complications	9.40€	104.76€	−95.36€
Total	3688.58€	3783.94€	−95.36€
Total per patient	3852.54€	3928.82€	−76.28€

Table 7. Cost comparison for 14-days treatment (LPC vs SPC vs PICC).

	Estimated cost per patient			Incremental cost	
	LPC	SPC	PICC	LPC vs SPC	LPC vs PICC
Micro-costing					
Consumables	32.65€	41.04€	32.69€	−8.39€	−0.04€
Device	55.69€	12.01€	96.78€	43.68€	−41.09€
Medical and nursing time	93.45€	100.39€	105.78€	−6.94€	−12.33€
Paramedical exams	29.57€	3.63€	63.51€	25.95€	−33.94€
Mechanical complications	10.76€	111.2€	20.76€	−100.44€	−9.99€
Total	222.12€	268.27€	319.52€	−46.14€	−97.39€
National cost study					
Indication: peritonitis	10,775.16€	10,775.16€	10,775.16€	0.00€	0.00€
Systemic complications	9.38€	174.26€	50.09€	−164.88€	−40.71€
Total	10,784.54€	10,949.42€	10,825.25€	−164.88€	−40.71€
Total per patient	11,006.66€	11,217.69€	11,144.77€	−211.02€	−138.1€

Table 8. Cost comparison for 21-days treatment (LPC vs PICC).

	Estimated cost per patient		Incremental cost
	LPC	PICC	LPC vs PICC
Micro-costing			
Consumables	46.02€	46.05€	−0.03€
Device	55.65€	96.86€	−41.21€
Medical and nursing time	145.51€	150.22€	−4.7€
Paramedical exams	29.50€	63.52€	−34.01€
Mechanical complications	18.40€	29.46€	−11.06€
Total	295.08€	386.11€	−91.01€
National cost study			
Indication: peritonitis	9286.52€	9286.52€	0.00€
Systemic complications	9.4€	50.19€	−40.79€
Total	9295.92€	9336.71€	−40.79€
Total per patient	9591€	9722.82€	−131.80€

studies only consider complications directly related to device insertion, and do not consider the medium/long term complications that occur. A holistic approach to the cost of catheter management does not seem to have been carried out to date, either in France or internationally.

Ambroise Pare hospital reflected on the organization of some hospitals in France. Some radiologists place PICCs under ultrasound and fluoroscopy. As fluoroscopy involves higher costs than other PICC positioning techniques, it is likely that the cost associated with the use of a specialist physician and fluoroscopy will tend to increase the difference in cost between Midlines and PICCs, and even more so when the cost of an interventional radiology room where fluoroscopy is performed is included. In fact, the cost of PICC insertion in interventional radiology has two components. The first corresponds to the sum of the costs associated with the insertion of catheters which can be directly linked to the patient. Its amount was the subject of the micro-costing analysis described above. The second covers the operating costs of the interventional radiology room: the cost of the premises, the cost of electricity, and annualized costs equivalent to the historical cost of the initial radiology investments to which should be added the cost of the staff working in the room. Annualizing investments involves calculating the constant annuity corresponding to the annual repayment of a loan at the discount rate. A recent study estimated this "indirect cost" at €98.6 per insertion.[28] A sensitivity analysis was conducted taking into account these indirect costs of using fluoroscopy for PICC insertion. Unsurprisingly, the difference in cost of use between a Midline and a PICC is greater: over 14 days, it is €243 and €229 over 21 days (compared with €102 for a 14-day treatment and €94 for a 21-day treatment when only direct cost of fluoroscopy are retained). However, the use of fluoroscopy for PICC placement is not practiced by all establishments that insert PICCs. Our main study was based on an experimental center (Ambroise Paré) for which we had the facility of analytic accounting for a micro-costing study. A sensitivity analysis was carried out, considering another positioning technique less costly than fluoroscopy and frequently used by PICC operators: the electrocardiogram (ECG) lead system. The use of an ECG lead system reduces the cost of using the PICC. The difference in cost between the Midline and the PICC is therefore smaller, but the midline is still more economical to use than the PICC. For a 14-day treatment, the cost difference is €99 in favor of midlines and €91 for a 21-day treatment). According to international guidelines (INS, ESA, etc.), the use of ECG is recommended because it is more accurate and less dangerous than fluoroscopy.[29–33] The implantation of a PICC with ECG technique does not require an interventional radiology facility and involves significantly lower logistical and personnel costs. However, some establishments, such as Ambroise Paré, still use fluoroscopy due to organizational reasons. This factor is a limitation in this study. In addition to accuracy and safety, this study highlights that the use of ECG also reduces the cost of placing PICCline.

Ambroise Pare was one of the voluntary hospitals where micro-costing could be assessed. The micro-costing study was possible in this organization and not in another. This economic modeling is one example of total cost evaluation of an IV device and comparison with other IV devices in one special place. This cost analysis should be generalized with caution for the other French hospitals or hospitals in other countries. It could be different with another organization. Since September 2013 some nursing teams place all lines after undertaking an advanced practice degree. Many variables can be modified, such as the price of different consumables, the placement technique of PICCs, the operator's profile, the cost of complications, etc. In future studies, it will be possible to modify them and measure the savings generated between intravenous access devices in different hospitals in other countries.

The present study is one of the first economic studies that compares different catheters and notably at several levels: on three-time horizons: 7, 14, and 21 days; at the insertion stage (frequencies of success); and throughout the treatment by comparing the frequencies of occurrence of mechanical and systemic complications.

The consideration of the incidence and cost of complications directly related to catheter placement, and those occurring in the medium term, is a strong point of this study, because few studies have taken them into account, even though they represent a non-negligible cost in the use of catheters, and beyond that, in hospital organization.

Micro-costing is a very precise cost estimation technique whose reflects the exact resources consumed at each stage of a patient's care. However, micro-costing was carried out in a single establishment and the results are therefore center-dependent. Nonetheless, the catheter insertion techniques are as close as possible to actual practices in French hospitals and to international guidelines (insertion of Midlines performed by nurse delegates, change of SPCs between 72 and 96 h, etc.).

A complementary development would be to consider the quality of life of patients associated with clinical events such as mechanical complications and systemic complications, but also the different failures of insertion.

The incidence of complications is a major issue when assessing the economic impact of the use of the three peripherally inserted catheters. The prevention of catheter complications requires particular attention from the medical, nursing, and paramedical teams in charge of the patients. The experience of the practitioner and the conditions of insertion are the factors most relate to the prevention of complications. In the Anglo-Saxon countries, specialized vascular access teams were set up in the 1980s. Some studies have shown the positive impact of these specialized teams on the reduction of complications associated

with use of catheters.[1,34–37] In France, the creation of these specialized teams dedicated to catheter insertion and care was made possible in 2021, on hospital reform and relative to patients, health, and territories by setting up cooperation protocols. It has also been observed in France that there is a reduction in the number of complications when insertion is carried out by a catheter team and that this has a positive impact on the efficiency of the administration of treatments and the associated costs.[38,39] The generalization of these specialized teams is accompanied by a redeployment of resources within the hospital's own departments. This organizational impact should be considered. In the therapeutic project 2019–2024, the place of technological and organizational innovation is at the heart of the institution's strategic orientations.

Acknowledgements

The authors would like to express their gratitude to Dr. Jeanne Reboul-Marty for her support and invaluable advice during the exploration of data from the Medicalisation Program of the Information Systems (PMSI).

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by a research grant from the Vygon laboratory. The writing of the article was done independently by the authors.

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