



Original article

Repair of damaged central venous catheters is safe and doubles catheter survival: a home parenteral nutrition patient cohort study



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SUMMARY

Background & aims: Repeated central venous catheter loss due to complications, including material breakage, compromises the options to obtain adequate vascular access in home parenteral nutrition (HPN) patients. It remains unclear whether repair of damaged catheters is an effective strategy to extend catheter survival, avoid surgical replacement and maintain venous access. The aim of this study was to evaluate the effectiveness and safety of catheter repair in our cohort of intestinal failure patients.

Methods: We conducted a retrospective analysis of all catheter repairs that were performed between 2006 and 2017 at our tertiary referral centre for intestinal failure. Primary outcome was the additional median catheter survival after catheter repair, as calculated with Kaplan–Meier analyses. Secondary outcomes included risk for central line-associated bloodstream infections (CLABSIs) and risk factors for catheter damage, as calculated with Poisson regression analyses. CLABSI rates in post-repair periods were compared with pre-repair periods. Pre- and post-repair periods were either short-term (30 days), or long-term (whole catheter period).

Results: A total of 58 repairs in 41 catheters of 35 HPN patients were included in the analysis. The median time to first repair was 452 days (interquartile range (IQR) 206–1134). After first repair, catheter survival additionally increased by 510 days (IQR 147–1195). Repairs did not increase the short-term risk for CLABSIs: incidence rates were 1.23 and 1.26 CLABSIs/1000 catheter days for the 30 days pre- and post-repair periods, respectively (rate ratio, 1.05; 95%CI, 0.15–7.44; $P = 0.96$). For the whole pre- and post-repair catheter period, incidence rates were 0.12 and 0.59 CLABSIs/1000 catheter days, respectively (rate ratio, 3.55; 95%CI, 1.10–11.45; $P = 0.03$). The overall CLABSI incidence rates in undamaged versus repaired catheters were 0.84 and 0.31 CLABSIs/1000 catheter days, respectively (rate ratio, 0.47; 95%CI, 0.23–0.94; $P = 0.03$). A lower age at catheter start and femoral catheterization were associated with a higher risk for catheter damage.

Conclusions: Repair of damaged catheters is often successful and an effective strategy to prolong and maintain venous access in HPN patients. On the short-term, no increase in CLABSI incidence was observed. Despite a possible increase in CLABSI incidence on the long-term, overall CLABSI rates of repaired catheters remained well below the overall CLABSI incidence of undamaged catheters. The identification of two risk factors for catheter damage may help to prevent future catheter damage.

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Abbreviations: CI, confidence interval; CLABSI, central line-associated bloodstream infection; CVC, central venous catheter; HPN, home parenteral nutrition; IQR, interquartile range; SD, standard deviation.

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1. Introduction

Chronic intestinal failure (IF) patients depend on life-long treatment with home parenteral nutrition (HPN) and/or fluids, often supplied via subcutaneously tunneled central venous catheters. Despite ongoing technical improvements, catheter-related complications, including central line-associated bloodstream infections (CLABSIs) and venous thromboses, remain a frequent and major threat to patient— as well as catheter survival. Another problem, although less frequent, is mechanical damage to catheters and/or catheter breakage. Damage most often occurs at the external portion of the catheter, which ranges from the proximal thin catheter tube, to the assembly hub in case of a multi-lumen catheter, the thicker protective clamping sleeve, and the distal female adapter. Several causes for catheter damage have been reported in the literature, such as natural wear of material after prolonged use, catheter rupture during flushing attempts to unblock occluded catheters, use of sharp objects such as scissors, repeated clamping maneuvers, and frequent bending of the external catheter segment [1–3]. Importantly, catheter breakage poses a risk for hemorrhage and air embolisms, interferes with daily delivery of treatment, and compromises catheter survival [4]. Repeated catheter loss due to complications, including material breakage, may eventually lead to treatment failure because of a permanent loss of vascular access. As such, repair of broken catheters, whenever feasible, is instrumental to maintain venous access.

The use of catheter repair kits was first reported in 1980 and has since been described in the setting of oncology, hemodialysis and HPN [1,2,5,6]. These repair kits can only be used in case of damage at the external portion of the catheter, and as long as the remaining catheter segment is long enough to allow adequate attachment of the repair tube part. Several kits are available on the market, but all have in common that a new external part is glued to the remaining catheter segment. Despite widespread use of catheter repair kits, there is a lack of evidence to support their use. For instance, there is little evidence whether catheters, once repaired, maintain for long periods thereafter. In addition, it is unclear if repaired catheters more often cause complications, such as CLABSIs. The studies that are available show low incidences of repair-related complications within 30 days after repair [1,2,7–9]. A study from Lundgren et al., however, observed a significant mean increase of 9.9 to 24.5 CLABSIs/1000 catheter days in the pre- and post-repair periods, respectively [10]. Furthermore, insight in factors associated with catheter damage aids in identifying patients with a higher risk for catheter damage and may help to prevent these complications in clinical practice.

The aim of this study was to describe the effectiveness and safety of catheter repair procedures in our cohort of chronic IF patients. A second objective was to explore possible risk factors associated with catheter damage.

2. Methods

2.1. Design and population of the Nijmegen IF registry

We made use of a recently established single-centre web-based database, consisting of adult IF patients who have been under treatment at our tertiary referral centre for IF since 1976. The Radboudumc is the largest referral IF centre out of two expert centres in the Netherlands. The primary aim of the database is to map catheter- and nutrition-related complications of HPN patients, and elucidate factors that affect these complications. Data collection is performed retrospectively from medical charts and all patient data are anonymously entered in the database. The database contains information on patient— and catheter characteristics, type

and frequency of nutrition, catheter-related complications, and hospital admissions. Currently, almost 400 patients are included in the database.

2.2. Study design and population analysis

In the present cohort study, all adult patients (≥ 18 years) with a benign underlying disease leading to long-term intestinal failure between January 2006 and November 2017 were included. Patients with intra-abdominal desmoid or neuroendocrine tumours were included as well, given the chronic nature of their underlying disease [15]. We included non-malignant patients for sake of uniformity, since almost all ($>95\%$) of our HPN patients have a benign underlying disease leading to IF. In addition, oncology patients represent a distinct HPN population, because of their higher *a priori* risk for infections [11]. The time period was chosen, because in 2006 the use of 2% taurolidine as catheter lock solution was introduced. Only newly inserted catheters with 2% taurolidine were included in the analyses. In addition, patients had to receive ≥ 1 month of parenteral nutrition and/or fluids (saline and/or glucose) via a subcutaneously tunnelled Hickman catheter (C. R. Bard, Inc.). All nontunnelled catheters, subcutaneous port systems, arteriovenous fistulae, and unknown catheter types were excluded from analyses.

2.3. Data collection

The following data were used from the Nijmegen IF Registry: patient characteristics (sex, age, pathophysiological mechanism of intestinal failure), catheter characteristics (type, date of insertion and removal, reason for removal, vein used for catheter insertion), and complications (CLABSIs). More specifically, repair-related data (date, cause, damage location, repair success) have been prospectively collected by a dedicated specialized nurse (RV) in a separate Excel database since 2000.

2.4. Ethical statement

Concerning ethical approval of the Nijmegen IF Registry, and thereby these analyses, the research ethics committee of the Radboudumc in Nijmegen, the Netherlands approved the use of the database (reference number 2015-1890). The study was conducted in accordance with good clinical practice guidelines and the code of conduct for medical research [12]. The STROBE guidelines were followed to report this study [13].

2.5. Catheter training and management

Before start of HPN-treatment, during a training period of 1–2 weeks in our centre, all patients were trained by specialized nurses in aseptic handling of catheters and HPN/fluid administration. This training has been implemented according to a standardized protocol and is in line with recent ESPEN guidelines [14]. A detailed explanation of our catheter care protocol can be found elsewhere [15]. None of our technical procedures changed during the study period. During their training, patients were specifically instructed to reduce the risk for catheter damage. For example, clothes should cover their catheter, clamps should be used only at the designated clamping sleeve, luer lock connectors should be screwed onto the female adapters with care, and patients are warned not to pinch off their catheter. Furthermore, use of Kocher clamps is only allowed in case of an emergency and with a gauze protecting the catheter. For many years, the Hickman catheter has been used foremostly in our centre. This large-bore (9.6 French, if feasible single-lumen) subcutaneously

tunneled catheter is preferably inserted in the right jugular or subclavian vein. Luer lock connectors are usually replaced every week.

2.6. Repair indication and procedure

Catheter repair was indicated in case of mechanical damage of the outer sheath (e.g. tear) or a total rupture of the catheter, with or without evidence of leakage. In addition, the length of the remaining catheter segment had to be undamaged and at least 5 cm to permit repair and to prevent retraction under the skin line. Catheters were repaired using a commercial repair kit according to the instructions of the manufacturer (C. R. Bard, Inc.) at the outpatient department. No blood cultures were drawn from the catheter before the procedure, nor did the patients receive prophylactic antibiotics or anticoagulants, as has been suggested in other studies [2,16,17]. In case a catheter was damaged, it was immediately clamped between the catheter exit site and the damaged area, and if possible taped, until repair was performed. Generally, repairs were performed within the same or next day, almost always by one of our specialized nurses (RV). Aseptic techniques were used during the whole repair procedure. The external segment of the catheter was cleansed with antiseptics and placed on sterile drapes. After masking, hand washing, and putting on sterile gloves and an overcoat, the damaged external portion of the catheter was cut off at a 90° angle. Next, a catheter replacement segment with a metallic stent attached was inserted into the catheter lumen. Adhesive was applied with a syringe onto the outside of the catheter around the spliced joint. Then, a splice sleeve was pulled over the splice site, and adhesives were applied underneath the splice sleeve at both ends. Subsequently, the repair site was splinted with a tongue blade and taped for 24 hours. At home, patients carefully unpacked and inspected the catheter repair site. HPN was restarted when 10 mL 0.9% saline could be flushed into the catheter without any problems.

2.7. Outcomes and definitions

Primary objective was to assess the effectiveness of catheter repair, as described by the median increase in catheter survival time after repair procedure. Secondary outcomes included risk for CLABSIs after repair, and risk factors for catheter damage. The definition of a CLABSI was based on the current Centers for Disease Control and Prevention (CDC) guidelines for surveillance for bloodstream infections [18,19]. A CLABSI was defined as the presence of a systemic infection or sepsis (such as fever, hypotension and/or chills) without any other infectious focus than the catheter, in conjunction with at least one positive blood culture from the catheter and/or a peripheral vein. In case a common commensal (e.g. coagulase-negative *Staphylococcus* species) was cultured, at least two blood cultures had to be positive from the catheter and/or peripheral vein. A CLABSI was considered a repair-related complication if it occurred within 30 days after a repair procedure. Furthermore, a re-break was defined as a break at the repair-site within 30 days after repair. A repair was technically successful when the catheter could readily be flushed and used for HPN, without leakage or re-break at the repair-site within 24 hours after repair. Time to first repair was defined as the time between catheter insertion and a first repair procedure. The additional time after first repair was defined as the time between a first repair and the last observation or removal of a catheter.

2.8. Statistical analysis

Baseline characteristics were summarized using descriptive statistical methods and compared with a Chi-square test or Mann-Whitney *U* test. Nonparametric continuous variables, such as

catheter survival, were presented as medians with interquartile range (IQR). Time-to-event endpoints and overall catheter survival were calculated with Kaplan–Meier analyses to correct for non-removed catheters, and compared using a log-rank test. Risk for CLABSIs was assessed through a case-crossover design in which patients served as their own controls. CLABSI rates in post-repair periods were compared with pre-repair periods. Pre- and post-repair periods were either short-term (30 days), or long-term (whole catheter period). Pre- versus post-repair CLABSI rates were expressed as incidence rate ratio (CLABSIs per 1000 catheter days) with 95% confidence intervals, and analyzed with the use of a random effect Poisson regression analysis with patient and catheter as levels to adjust for paired data structure. Pre- and post-repair periods were compared within one catheter. Occasionally, several catheters were inserted within one patient. Comparisons between repaired and undamaged catheters were made with the use of a random effect Poisson regression analysis with patient as level and catheter days as offset (after correction for statistically significant different baseline characteristics, or a change of $\geq 10\%$ on unadjusted estimates by a covariate). Random effect Poisson regressions analysis was also used to identify risk factors for damaged catheters. Potential risk factors for damaged catheters included sex, pathological mechanism of intestinal failure, age at start catheter, HPN experience, vein used for catheter insertion, type and frequency of nutrition, and the use of sodium hydroxide solution for catheter unclogging. Risk factors which showed in the univariable Poisson regression analysis a *P* value of ≤ 0.2 were included in the final multivariable Poisson regression analysis. A two-tailed *P* value < 0.05 was considered statistically significant. All statistical analyses were performed with SPSS statistical software package version 22.0 (SPSS Inc., Chicago, IL), or R software version 3.2.4 (The R Foundation for Statistical Computing) for the Poisson regression analyses.

3. Results

Between 2006 and 2017, a total of 527 catheters were inserted in 216 HPN patients (Fig. 1). The median number of catheters per patient was two (range 1–11). Of these, 477 catheters remained undamaged, while 50 (9.5%) catheters were damaged at least once. In total, 67 damages occurred during 228682 catheter days, resulting 0.29 damages/1000 catheter days (95%CI, 0.23–0.37) (Fig. 1). In the majority of cases (69%), the distal catheter segment (female adapter or clamping sleeve) was damaged. Catheter damage was often caused by screw thread failure ($n = 14$) or friction between the rigid adapter and the flexible clamping sleeve ($n = 24$). Nine (18%) damaged catheters were removed without a repair attempt. In total, 58 repairs were performed in the remaining 41 catheters from 35 patients. Except for age at catheter start and the use of sodium hydroxide solution, baseline characteristics were similar between patients with repaired catheters and undamaged catheters (Table 1).

3.1. Effectiveness of catheter repair

The median time to damage in damaged, unrepaired catheters (324 days, IQR 185–657) was similar to damaged, repaired catheters (452 days, IQR 206–1134) ($P = 0.14$) (Fig. 2). When combined, the median time to catheter damage was 411 days (IQR 185–1132), which was prolonged when compared with the overall survival of undamaged catheters (208 days IQR 58–598) ($P = 0.01$). After a damaged catheter was repaired, its additional survival increased with a median of 510 days (IQR 147–1195). Interestingly, catheter survival curves before and after first repair were almost overlapping (Appendix Fig. 1). The overall survival of repaired catheters was 1152 days (IQR 413–2524) and was significantly longer than undamaged catheters ($P < 0.001$).

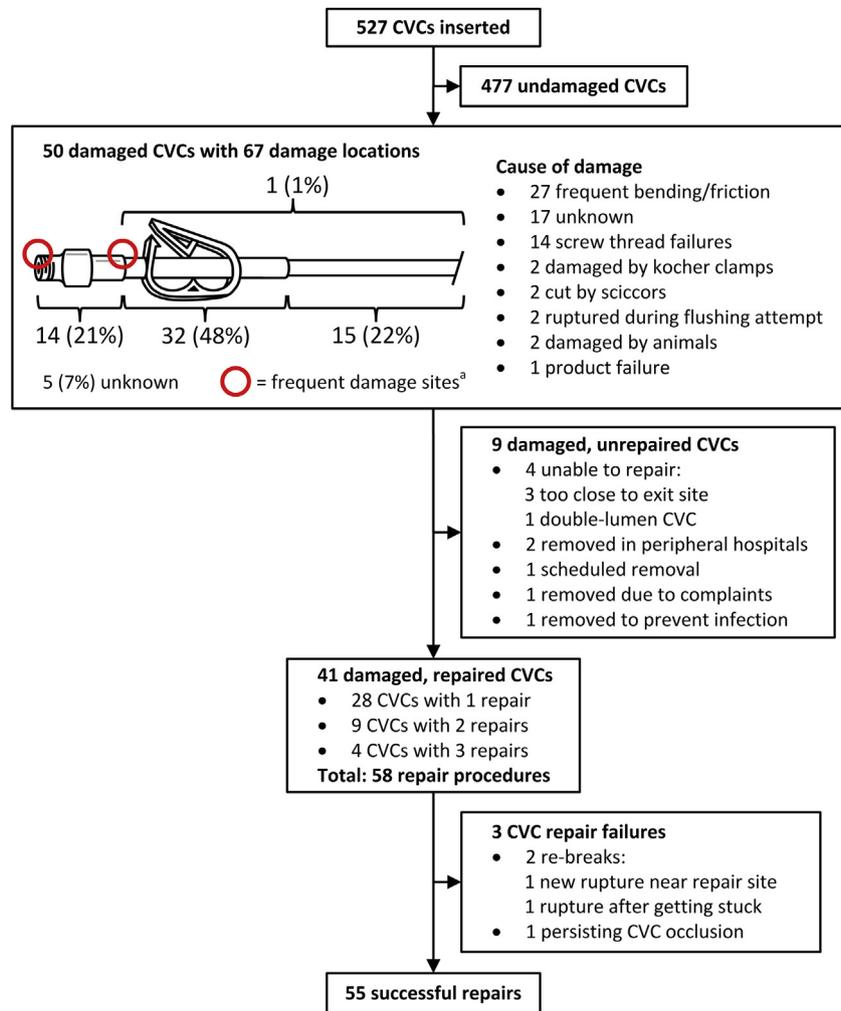


Fig. 1. Flow-chart of damaged and undamaged catheters. CVC; central venous catheter.

^aMost frequent damage sites were either the catheter screw thread ($n = 14$) or the junction between the rigid adapter and the flexible clamping sleeve ($n = 24$).

Reasons for catheter removals are shown in [Appendix Table 2](#). In undamaged catheters, a larger proportion (24%) of catheters was removed due to a CLABSI when compared with repaired catheters (17%). In contrast, the proportion of non-removed catheters (27%) was higher in repaired catheters compared with undamaged catheters (15%).

3.2. Safety of catheter repair

Three complications (two re-breaks and one persisting catheter occlusion) occurred within 24 hours after repair. Therefore, 55 (95%) repairs were technically successful. Two CLABSIs occurred in the post-repair period and were considered a repair-related complication.

In [Table 2](#), CLABSI rates within 30 days before and after repair are shown. There was no increase in CLABSI rate 30 days post-repair when compared with the 30 days pre-repair CLABSI rate ($P = 0.96$). During the whole pre- and post-repair period, an increase in the post-repair CLABSI rate was observed ($P = 0.03$). The overall CLABSI rate in repaired catheters was significantly lower when compared with undamaged catheters ($P = 0.02$). Similar observations between repaired and undamaged catheters were made in a post-hoc analysis for catheter-related venous thromboses. In contrast, no difference in catheter occlusion rates was found ([Appendix Table 1](#)).

3.3. Risk factors for catheter damage

Univariable and multivariable Poisson regression analyses are shown in [Table 3](#). A lower age at catheter start was associated with a higher risk for catheter damage (rate ratio per year, 0.96; 95%CI, 0.94–0.98; $P < 0.001$). Femoral catheterization was negatively associated with catheter damage when compared with jugular catheterization (rate ratio, 2.13; 95%CI, 1.06–4.29; $P = 0.03$) and subclavian catheterization (rate ratio, 3.86; 95%CI, 1.46–10.23; $P = 0.007$).

4. Discussion

This single-centre cohort study provides for the first time more robust long-term clinical data that repair of damaged catheters is an effective and safe strategy, and prevents the replacement of damaged catheters in a substantial number of instances and considerably prolongs catheter survival.

The effectiveness of catheter repair was demonstrated by an increase in median catheter survival of 510 days, which doubled the original catheter survival at first repair ([Appendix Fig. 1](#)). Remarkably, already the median time to damage (411 days) was prolonged when compared with undamaged catheters (208 days). A reason for this difference may be that patients or their caregivers better cared for their catheters, resulting in prolonged catheter survival

Table 1
Baseline patient- and catheter characteristics of repaired and undamaged catheters^a.

	Non-repair group n = 216	Repair group n = 35	P value
Patient characteristics			
Female — no. of patients (%)	121 (67)	27 (77)	0.23
Pathological mechanism — no. (%)			
Short bowel syndrome	74 (41)	16 (46)	0.17
Gastrointestinal motility disorder	61 (34)	16 (46)	
Mechanical obstruction	10 (6)	0 (0)	
Extensive small bowel mucosal disease	15 (8)	0 (0)	
Intestinal fistula	15 (8)	1 (3)	
Other	6 (3)	2 (6)	
Medical history — no. of patients (%)			
Diabetes	18 (8)	2 (6)	0.60
Catheter characteristics			
Age at start catheter — median years (IQR)	56 (45–66)	48 (37–56)	0.001
Place of insertion — no. of CVCs (%)			
Jugular vein	296 (62)	28 (68)	0.79
Subclavian vein	97 (20)	6 (15)	
Femoral vein	59 (12)	6 (15)	
Other	5 (1)	0 (0)	
Unknown	20 (4)	1 (2)	
Type of infusion — no. of CVCs (%)			
Nutrition	404 (85)	36 (88)	0.64
Fluids	54 (11)	5 (12)	
Unknown	19 (4)	0 (0)	
Infusions — no. per week			
≤2	10 (2)	1 (2)	0.25
3	17 (4)	3 (7)	
4	31 (7)	3 (7)	
5	27 (6)	6 (15)	
6	28 (6)	3 (7)	
7	347 (73)	25 (61)	
Unknown	17 (4)	0 (0)	
Medication — no. of CVCs (%)			
Use of anticoagulants ^b	282 (59)	26 (63)	0.62
Unknown	9 (2)	0 (0)	
Use of immunosuppressants ^c	93 (20)	6 (15)	0.48
Unknown	9 (2)	0 (0)	
Use of sodium hydroxide solution	7 (2)	3 (7)	0.04

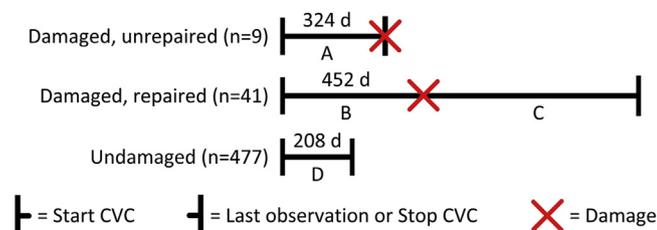
CVC, central venous catheter; HPN, home parenteral nutrition; IQR, interquartile range.

Age at start catheter was compared using the Mann-Whitney-U test. All other characteristics were compared using the Chi-square test.

^a Note that patients may have had multiple (repaired and/or undamaged) catheters and may have been included in both the repair and non-repair group.

^b Anticoagulants comprise anti thrombotic drugs, such as acetylsalicylic acid, phenprocoumon, or warfarin.

^c Immunosuppressants comprise drugs that suppress or reduce the strength of the body's immune system, for example, adalimumab, methotrexate, or prednisolone.



Catheter survival		Median days (IQR)	Mean days ^b
A	Damaged, unrepaired CVCs	324 (185–657)	446
B	Damaged CVCs at first repair	452 (206–1134)	788
A and B	All damaged CVCs	411 (185–1132)	726
C	Additional time after repair	510 (147–1195) ^a	828
B and C	Overall survival repaired CVCs	1152 (413–2524) ^a	1616
D	Overall survival undamaged CVCs	208 (58–598)	468

Fig. 2. Survival of damaged and undamaged catheters. CVC, central venous catheter; IQR, interquartile range. Catheter survival was calculated with Kaplan–Meier survival curves to correct for non-removed catheters. Reasons for CVC removal are shown in Supplementary Table 2. ^aNote that the additional median time after repair (C) does not equal the absolute difference between the median time at first repair (B) and the overall median time of repaired catheters (B and C) due to non-parametric data distribution. ^bMean catheter survival is shown for comparison with literature.

and –eventually– material wear and/or catheter damage. Given that catheter survival data is often highly skewed, the studies that are available mainly report mean catheter survival, which overestimates the catheter dwell time. This was exemplified in Fig. 2, where the mean survival time of repaired catheters (1616 days) is virtually prolonged by 1.5 years when compared with the overall median survival time (1152 days). In addition, the available scarce literature is very heterogeneous in terms of catheter types (centrally or peripherally inserted catheters) as well as patient populations (HPN, peritoneal dialysis or mixed groups, pediatric or adult), which may affect catheter survival time. This should be kept in mind when comparing results of various studies. In general, most studies have reported an increase in catheter survival time after repair varying from 75 to 800 days, which is in line with our results [2,7–9].

Repair procedures were generally safe in the short-term. The number of repair-related complications within 30 days was low; only two (3.4%) CLABSIs occurred in 58 repairs, and 30 days post-repair CLABSI rates did not differ when compared with pre-repair CLABSI rates. In addition, we did not observe any serious repair-related complications, such as migration of metallic stents, as has been described in two case reports [20,21]. The number of repair-related complications was comparable to other studies, where in 0–9% of the catheters a CLABSI within 30 days after repair was

Table 2
Incidence of CLABSIs in repaired and undamaged catheters.

	Repaired catheters (n = 41)				Repaired catheters (n = 41)				Undamaged vs. Repaired catheters			
	30 days pre-repair	30 days post-repair	Adjusted rate ratio ^a	P value	Total days pre-repair	Total days post-repair	Adjusted rate ratio ^b	P value	Undamaged (n = 477)	Repaired (n = 41)	Adjusted rate ratio ^c	P value
CLABSIs	2	2			4	13			147	17		
Total days	1631	1585			32299	22216			174167	54515		
CLABSIs rate (95%CI) ^d	1.23 (0.20–3.78)	1.26 (0.21–3.89)	1.05 (0.15–7.44)	0.96	0.12 (0.04–0.29)	0.59 (0.32–0.96)	3.55 (1.10–11.45)	0.03	0.84 (0.71–0.99)	0.31 (0.18–0.48)	0.44 (0.22–0.90)	0.02

CI, confidence interval; CLABSI, central line-associated bloodstream infection.

^a 30 days pre- and post-repair periods were compared using Poisson regression analysis, in which was corrected for repairs in catheters at patient level.

^b Total pre- and post-repair periods at first repair were compared using Poisson regression analysis, in which was corrected for catheters at patient level.

^c Undamaged and repaired catheters were compared using Poisson regression analysis, in which was corrected at patient level and for one or more of the following confounders; age at start catheter, vein catheterization, infusion frequency, and use of sodium hydroxide solution.

^d CLABSI rate was expressed in events per 1000 catheter days.

reported [1,2,7,9,22]. In the study from Lundgren et al. however, a significant mean increase of 9.9 to 24.5 CLABSIs/1000 catheter days in the pre- and post-repair periods, respectively, was observed [10]. A pre-selection bias may have played a role here, as infected damaged catheters were removed instead of repaired [9]. To our knowledge, we have identified all damaged, unrepaired catheters in this study. Only one of nine damaged, unrepaired catheters was removed purely to prevent a possible infection. This catheter was

damaged by a pet (cat) and we did not want to risk a potential zoonosis.

The long-term pre-repair period and the overall period of repaired catheters showed a very low CLABSI rate (after correction for possible baseline confounders) when compared with undamaged catheters. Similar results were found for catheter-related venous thromboses (Appendix Table 1). These observations support the previously mentioned hypothesis that patients

Table 3
Univariable and multivariable Poisson regression analysis of factors associated with catheter damage.

Dependent variable	Independent variables	Rate ratio (95%CI)	P value
Univariable Poisson regression analysis CVC damage	Gender		
	Female	Reference	
	Male	0.74 (0.35–1.58)	0.45
	Underlying disease		
	Short bowel syndrome	Reference	
	Motility disorder	1.79 (0.90–3.58)	0.10
	Other	0.66 (0.18–2.52)	0.55
	Motility disorder	Reference	
	Other	0.37 (0.10–1.39)	0.14
	Age at start CVC (years)	0.95 (0.93–0.97)	<0.001
	HPN experience at start CVC (years)	0.94 (0.86–1.04)	0.23
	Vein catheterization		
	Jugular	Reference	
	Subclavian	0.54 (0.23–1.25)	0.15
	Femoral	1.90 (0.91–4.00)	0.09
	Subclavian	Reference	
	Femoral	3.55 (1.25–10.08)	0.02
Type of infusion			
Nutrition	Reference		
Fluids	1.23 (0.47–3.19)	0.67	
Infusion frequency (days per week)	1.01 (0.81–1.24)	0.82	
Use of sodium hydroxide solution			
Yes	Reference		
No	0.86 (0.27–2.77)	0.80	
Multivariable Poisson regression analysis CVC damage	Underlying disease		
	Short bowel syndrome	Reference	
	Motility disorder	1.25 (0.67–2.32)	0.48
	Other	0.66 (0.19–2.37)	0.53
	Motility disorder	Reference	
	Other	0.53 (0.15–1.89)	0.33
	Age at start CVC (years)	0.96 (0.94–0.98)	<0.001
	Vein catheterization		
	Jugular	Reference	
	Subclavian	0.55 (0.25–1.24)	0.15
	Femoral	2.13 (1.06–4.29)	0.03
Subclavian	Reference		
Femoral	3.86 (1.46–10.23)	0.007	

CI, confidence interval; CVC, central venous catheter; HPN, home parenteral nutrition.

Risk factors which showed in the univariable Poisson regression analysis a P value of ≤ 0.2 were included in the final multivariable Poisson regression analysis.

better cared for their catheters. At first glance, the relative higher CLABSI rate in the long-term post-repair period may seem puzzling. We cannot exclude that repairs have a negative effect on CLABSI rates on the long-term. However, it is important to note that the risk for complications becomes higher over time and that complications are frequently the reason why catheters are eventually removed. Therefore, it can be appreciated that the CLABSI rate at the end of a catheter is relative higher compared to the start of a catheter.

The repair success rate of 95% found in this study was slightly higher when compared to most rates observed in previous studies (72–98%) [8,9,17,22]. According to the repair kit manual, a repaired catheter may be used again for infusion after four hours, although the repair site will not achieve full mechanical strength for 48 hours. We standardly splint and tape the joint for 24 hours before we let the patient unpack and inspect the repair site. It may be possible that this has contributed to a higher success rate. In addition, it should be noted that the type of catheters used in other studies differ from our study which could have influenced the repair success rate as well.

It is well recognized that the necessity for an adequate venous access remains the Achilles' heel of long-term HPN support. Especially infectious problems, and to a lesser degree catheter-related occlusions, pose a permanent threat to both patient and catheter survival. In this vein, it seems obvious that any simple and highly successful intervention, such as catheter repair, that prevents catheter replacement and its associated (surgical) complications and cost, is of key importance. In addition, as shown in this study, catheter repair seems an effective and safe strategy. Although we cannot rule out a possible higher risk for CLABSIs on the long-term, the overall CLABSI risk was still lower in patients with repaired catheters. In light of the previously mentioned beneficial effects of catheter repair, it is our opinion that both physicians and patients should be aware of this simple strategy to maintain venous access, and that there is no reason to withhold catheter repair in HPN patients with a damaged catheter.

Two risk factors, including a lower age at catheter start and femoral catheterization, were independently associated with catheter damage. Our results are in line with a study from Blasiak et al. who found a larger number of damaged catheters (1.6 ± 1.1) in younger HPN patients when compared with older patients (1.3 ± 0.7) ($P = 0.05$) [16]. An explanation why younger patients are at higher risk may be a more active lifestyle and/or less caution when handling catheters. In this light, it is important to emphasize that CLABSI rates were less likely to affect outcomes in younger patients, as we observed relatively higher CLABSI rates in patients with a lower age (Supplementary Appendix Table 3). Femoral catheterization, at least in non-tunneled catheters, has been previously associated with an increased risk for infectious and thrombotic complications when compared with subclavian catheterization [23–25]. Interestingly, in the present study, femoral catheterization was associated with a higher risk for catheter damage as well, when compared with jugular or subclavian veins. A likely explanation for these findings is that femoral catheters are more difficult to handle as they are covered with underwear and may bend more frequently while walking and sitting. In addition, patients with femoral catheters might be more ill since the femoral site is usually chosen for patients with a contraindication to a cervicothoracic insertion. This might affect patient's catheter handling and increase the risk for damage. Identification of these risk factors as well as frequent damage sites may help educate patients, especially during catheter-training, to prevent future catheter damage.

A strong point of this study is that it concerns well documented data from a single-centre registry where practices on catheter

handling did not change over the observation period. Other strengths include the prospectively collected repair data, and the few in- and exclusion criteria, which ensured that the majority of patients was included and that we minimized selection of patients or catheters. At the same time we recognize that the retrospective and single-centre origin of our data also has its limitations. For example, infection rates may be difficult to translate to other HPN-centres or patient populations. Also, the relative low number of catheter repairs and complications may have played a role when comparing short-term pre- and post-repair periods. Another limitation is that we could not correct for complications at the end of long-term post-repair periods, which seemingly resulted in an unexpected increase in the long-term post-repair CLABSI rate. Therefore, we cannot exclude a possible negative effect of repairs on the long-term.

Although not investigated in this study, our results make one wonder whether –preventive– catheter repair, when performed at some time in high risk patients/catheters without damage, might establish an effective strategy to extend catheter survival and prevent infections –and possibly occlusions–, especially since many of these problems arise from the catheter hub segment [14]. The same applies with respect to salvage rates of infected catheters: once successfully treated (or even more aggressively, as part of the treatment procedure) replacement of the outer catheter segment might improve treatment results. It is obvious that such preventive strategy would require further research. Concerning catheter survival in general, the overlapping survival curves in Appendix Fig. 1 suggest that catheter repair with removal of the catheter hub results in a survival probability that is similar to that of a new device.

In conclusion, repair of damaged catheters is easy and highly successful. It seems an effective and safe strategy, and provides a valuable addition to our armamentarium to maintain venous access in HPN patients. The identification of two risk factors for catheter damage, including a lower age at catheter start and femoral catheterization, may help to identify patients at risk for catheter damage and prevent future catheter damage.

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Conflict of interest

GW reports grants from Fresenius Kabi, Baxter international and B Braun Medical outside the submitted work. GW is consultant for Shire.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.clnu.2018.08.005>.

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