Aus der Klinik für Gefäßchirurgie und endovaskuläre Chirurgie des
Universitätsklinikums Augsburg

Clinical Evaluation of the PowerGlide Pro Midline Catheter in Patients with Vascular Disease

Dissertation

zur Erlangung des akademischen Grades

Dr. med.

eingereicht an der

Medizinischen Fakultät der Universität Augsburg

von

Yaser Souri

Augsburg, 04. Mai 2023

Clinical Evaluation of the PowerGlide Pro Midline Catheter in Patients with Vascular Disease

Dissertation

For the attainment of the academic degree Dr. med.

Vascular Surgery

Faculty of Medicine, University of Augsburg

Stenglinstrasse 2

86156 Augsburg, Germany

by

Yaser Souri

Augsburg 04.05.2023

Eidesstattliche Versicherung und Erklärung

Hiermit versichere ich an Eides statt, dass die vorliegende Dissertation von mir selbständig und ohne unerlaubte Hilfe angefertigt wurde. Zudem wurden keine anderen als die angegebenen Quellen verwendet. Außerdem versichere ich, dass die Dissertation keiner anderen Prüfungskommission vorgelegt wurde und ich mich nicht anderweitig einer Doktorprüfung ohne Erfolg unterzogen habe.

Statutory declaration and statement

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources. As well I declare that I have not submitted a dissertation without success and not passed the oral exam. The present dissertation (neither the entire dissertation nor parts) has not been presented to another examination board.

Augsburg, 04.05.2023

Dissertation eingereicht am: 04.05.2023

Erstgutachter (Hauptbetreuerin/Hauptbetreuer): Prof. Dr. med. Alexander Hyhlik-Dürr

Zweitgutachter: Prof. Dr. Phlilpp Simon

Tag der mündlichen Prüfung: 31.01.2024

Contents

1 INTRODUCTION

Establishing venous access through a catheter is one of the most widely used procedures in the hospital setting (1). Determinants for the type, size, and location of venous access include the clinical status of the patient, the planned therapeutic agents, and the continuous need for laboratory investigations (2). Moreover, the selection of a venous access device should be based on specific indications for that device, with the goal of minimizing the chances of insertion failure and reducing the possible complications in mind (3).

There are numerous ways of establishing intravenous (IV) access. A peripheral venous catheter (PVC) is inserted in veins located distally on the upper or lower limbs (4). A central venous catheter (CVC) is a catheter with a tip reaching centrally-located veins in the neck, chest, or groin, including the superior vena cava, inferior vena cava, brachiocephalic veins, internal jugular veins, subclavian veins, iliac veins, and common femoral veins (5). A peripherally inserted central catheter (PICC) is a form of venous access that extends through a peripheral vein in an extremity to reach a larger central vein (6).

A midline catheter is a peripheral venous access device, usually 8-20 cm in length, which is placed in a vein in the upper arm and extends to or below the level of the axillary vein but does not reach a central vein (1, 7). The main difference between a midline catheter and a CVC or a PICC line is that the latter two extend to reach central veins, such as the subclavian (2). Midline catheters are inserted using the Seldinger's technique, usually with the assistance of ultrasound (8).

A shorter length of stay in the hospital confers improved outcomes for patients with fewer readmissions and reduced mortality rates (9). Still, many patients, especially those with complicated conditions or those requiring admission to intensive care, require extended hospital stays (10). The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) recommendations propose the use of PVCs for durations less than 5 days (11). Since the use of PVCs is hampered by short dwell time, CVCs are often preferred for medium- to long-time intravenous treatment. However, CVCs are associated with multiple complications that limit their use in the hospital (12). The midline catheter offers a longer dwell time than the PVC (2). In addition, the midline catheter is associated with fewer needle punctures, a lower complication rate (i.e., infection and thrombosis), and a potential cost benefit for hospitals (7). This study further explores the advantages of the midline catheter over other types of catheters.

1.1 STUDY OBJECTIVES

The aim of this study is to investigate the use of midline catheters as a viable option for long-term IV access in the Vascular Surgery department at the University Clinic Augsburg. The department faces challenges due to a patient population that is often older and has multiple comorbidities, resulting in extended hospital stays and the need for long-term IV access. It is crucial to have IV access options that are both comfortable and effective to meet the needs of this patient population. Therefore, this study is motivated by the lack of studies on the utility of midline catheters in long-term IV access for patients with vascular disease. We seek to provide valuable insights into the advantages and limitations of midline catheters. The results of this study will inform clinical practice and help to improve patient care in the Vascular Surgery department at the University Clinic Augsburg.

In this study, we evaluate the PowerGlide Pro Midline Catheter (BD medical technology company, Tullastr.8-12 street in Heidelberg, Germany).

The Power Glide Pro catheter is a sterile, minimally invasive, single-use method for creating intravenous access for patients who foreseeably need one for at least 7 days. The device is intended for short-term use (<30 days) to draw blood and administer fluids intravenously. The catheter consists of an insertion needle with a passive safety mechanism to avoid puncture injuries to the user, a guide wire, and a radiopaque, body-softening polyurethane catheter with a lumen for introducing force. The maximum injection flow rates of 2, 5, and 7 ml / s (for the 22G, 20G, and 18G, respectively) enable a variety of therapies with a single access point.

Primary Endpoint:

The main objective of this study is to analyze the dwell time of midline catheters (Power Glide pro from BD medical company) in patients with vascular disease. Thus, The primary endpoint explored by the study was the duration of catheter stay in days (defined as the time between catheter insertion and removal).

Study hypothesis: the PowerGlide Pro™ Midline Catheter can be inserted for longer periods of time than a standard PVC (the dwell time of the PVC will be obtained from the literature).

Secondary Endpoints:

1) Can certain medications (e.g., vein irritants such as prostaglandins) be administered via midline catheters?
2) Is the midline catheter associated with a lower rate of complications (thrombophlebitis, occlusion)?
3) Can patient satisfaction be improved by using the midline catheter?

1.2 SCIENTIFIC BACKGROUND

1.2.1 Midline Catheters

The midline catheter first used by the Deseret Medical Corporation dates back to the 1950s (13). Becton Dickinson was the manufacturer of the device, whose indication was cannulating patients who required one week of IV therapy (13). Improvements in the design of the device continued until the 1980s (14). Reports of hypersensitivity reactions related to materials used in the manufacturing of the catheter led to the decline of its use in the 1990s (15). Subsequent reconfiguration of the materials and design helped the midline catheter regain its popularity and highlight its advantages over traditional PVCs, including its prolonged use and lower complication rates (8, 14).

The midline catheter is usually made of silicone or polyurethane, has a single or double lumen, and is available in a wide range of sizes (14). Insertion can be carried out with a catheter-over-the-needle technique, by insertion through a tear-away introducer sheath technique, or by the Seldinger technique (16). Radiographic confirmation of the location of the tip is generally not necessary (16).

The indications, contraindications, and complications of midline catheters are similar to those of PVC (16). The recommended dwell time according to the instructions for use (IFU) is <30 days. Previous literature indicates that midline catheters last a median of 7 days, with some reports of catheters that stayed in place for up to 49 days (17, 18, 19). The longer dwell time decreases the need for frequent replacement, which can be associated with increased patient discomfort, costs, and staff workload (20). Additionally, the midline catheter is associated with a low risk of catheter-related infections (19).

1.2.2 Midline Catheters vs. Peripheral Venous Catheters (PVCs)

The peripheral venous catheter (PVC) is a commonly used invasive procedure in the hospital setting, with about 2 billion procedures performed globally each year (21). A PVC is also the preferred venous access in emergency situations due to its convenience

and relatively quick administration. However, the insertion of a PVC is associated with a first-attempt success rate of only 83% according to a 2016 study (22), and an overall failure rate of 35-50% according to a 2015 study (23). Moreover, PVC is generally recommended when the duration of venous access is expected to be less than 5 days (11).

According to a 2017 study from France, PVCs are associated with a complication rate of approximately 52.3% (24). The main complications are phlebitis (20.1%), hematoma (17.7%), extravasation (13.1%), infection (0.4%), and occlusion (12.4%) (24). The rate of these complications, especially phlebitis, decreases with decreasing the duration a PVC is in place (25). Therefore, to reduce the risk of phlebitis and catheter-related infection, it is recommended that the catheter be replaced every 72-96 hours (26, 27, 28).

The midline catheter has a lower phlebitis rate than the PVC (13). One study also found that ultrasound-guided long catheters have a lower failure rate than their short counterparts (29). Despite having a comparable rate of bloodstream infections, the midline catheter has a longer dwell time of (7.69-16.4) days compared to the PVC (2.9-4.1 days) (2). Therefore, it is recommended that a midline catheter or a PICC should be considered instead of a PVC when the duration of therapy exceeds six days (30). Despite costing as much as 3 PVCs, midline catheters may reduce costs when used as alternatives to CVCs or in patients with difficult IV insertions (2).

The midline catheter can be used to administer fluids and medications that are usually administered with a PVC, with the added benefit of a larger diameter of the target vessel (basilic or cephalic vein) (14, 31, 32). The dilution of medication caused by the larger vessel diameter accounts for the reduced incidence of chemical phlebitis, infiltration, and patient discomfort (13, 33, 34, 35, 36).

Lastly, the Seldinger technique provides an easier method for the insertion of the midline catheter compared to the “cannula-over-needle” technique associated with traditional PVCs (37). The more convenient insertion, the relatively more biocompatible materials, and the length of the catheter make the midline catheter more suited for cannulations of longer durations (37).

1.2.3 Midline Catheters vs. Central Venous Catheters (CVCs)

CVCs are commonly used vascular access devices in the acute care setting (38). This type of catheter is primarily used to infuse fluids and certain medications, monitor central venous pressure, and as an alternative when other vascular access devices fail

or are unable to be secured (39). Examples of medications administered using a CVC include chemotherapy, long-term antibiotics, or total parenteral nutrition (40). Despite its prevalent use, around 15% of patients will encounter complications associated with the insertion of a CVC (38). Complications include infection (5-26%), thrombosis (2-26%), occlusion, and mechanical complications (5-19%), which usually occur during insertion (38, 41, 42). Central line-associated bloodstream infection (CLABSI) is a particularly feared complication of CVCs, especially in the ICU setting (43). Furthermore, even among experienced hands, CVCs can have a failure rate of 10.1%, according to a 1986 study (44). Ultrasound or Doppler ultrasound guidance increases the insertion success rate, decreases the rate of complications during insertion, and decreases the need for multiple insertion attempts (45). It is also common practice to radiographically confirm the tip location after the insertion of a CVC.

A study of 693 patients found that, compared to CVCs, the use of midline catheters resulted in statistically significant lower rates of catheter-related infections (3.5% vs. 0.2%), fewer mechanical complications (2.6% vs. 0.3%), lower crude mortality rates (5.3% vs. 17.3%), less line-related readmissions (0.2% vs. 2.8%), and fewer transfers to the ICU after line placement (5% vs. 9%) (46). Additionally, ultrasound-guided midline catheter placement for patients in intensive care can help facilitate earlier removal of a central line and decrease the incidence of CLABSI (47).

1.2.4 Midline Catheters vs. Peripherally Inserted Central Catheters (PICCs)

PICCs are considered a safe and effective alternative to CVCs for the administration of peripherally incompatible infusates and long-term administration of medications (11, 48). According to the MAGIC recommendations, PICCs are appropriate if the duration of insertion is expected to be more than 6 days and preferred to midline catheters if the duration is expected to be more than 14 days (11). However, the use of PICCs is not without risk. A French study that focused on 127 PICC insertions found that the main complications included occlusion (7%), rupture (1.6%), accidental withdrawal (2.4%), infection (3.1%), and venous thrombosis (2.4%) (49).

A study at a large academic center that compared 206 PICCs to 200 midline catheters inserted in a total of 367 patients found that midline catheters are associated with a higher rate of non-life-threatening complications compared to PICCs (50). However, PICCs were associated with more serious complications, such as bacteremia (50). A second study comparing midline catheters to PICCs found that PICCs are more appro-

priate and less problematic for catheterizations beyond 14 days (51). Another meta-analysis of 167 studies found that the prevalence of catheter-related infections was comparable between midline catheters and PICCs (52). Overall, the PICC has been more thoroughly studied and implemented into everyday practice, while the midline catheter needs further supportive evidence to replace PICCs, especially for longer catheterizations.

1.2.5 Midline Catheter Use in the Administration of Vasopressors and Vasodilators

Due to fears of extravasation and subsequent tissue necrosis, vasopressors are considered unsafe to be administered through a PVC and are traditionally infused using a CVC (53). However, the placement of a CVC can hinder the timely administration of vasopressors as it is time-consuming and sometimes difficult to perform in the emergency department (54, 55). A retrospective study published in 2021 concluded that midline catheters are considered a safe and efficacious alternative to CVCs for the administration of vasopressors (56).

Due to the higher osmolarity and vesicant properties of some peripheral vasodilators, patients suffering from peripheral arterial disease may suffer from redness and irritation at the site of administration of these medications. Midline catheters may offer a safer and more reliable option, particularly for those with a longer duration of treatment. According to our knowledge, no studies have specifically investigated the efficacy of midline catheters in the administration of vasodilators.

2 METHODS

This is a single-center prospective observational study that aims to describe the data collected on patients receiving midline catheter insertions. This study does not have a control group and, thus, is not a comparison study. This study was performed on patients admitted to the University Clinic Augsburg (Universitätsklinikum Augsburg) in the time frame between January 1st, 2018, and November 30th, 2020.

2.1 ETHICAL AND LEGAL ASPECTS

The study is carried out in accordance with the Declaration of Helsinki in its current version. Before the start of the study, the study protocol was submitted to and approved by the Clinical Ethics Committee of the Ludwig-Maximilians-University (project number: 18-813) for professional advice.

Before the start of the study, the participants are informed in writing and orally about the nature and scope of the planned study, in particular about the possible benefits and possible disadvantages. Participants' consent is documented by signing a declaration of consent. The standard consent form (supplemental materials) includes patient identification, procedure clarification, and the date of the consent. The consent can be withdrawn at any time, without giving reasons and without any consequences for the participant dropping out. If a participant withdraws from the study, any pertaining data that has already been obtained will be destroyed, or they will be asked whether they agree to the analysis of the data. Patients will not receive any compensation in this study.

All patients are coded with a sequential number (pseudo anonymized). The data to be evaluated are saved with this code only in an Excel spreadsheet on a PC with restricted access in the Department of Vascular Surgery and then evaluated. Only authorized persons have access to the original data.

2.2 PATIENT SELECTION

We aimed to recruit a total of 50 patients to participate in the study. Participation in this study did not change anything in the course of treatment for all included patients.

Inclusion Criteria

To be included in the study, patients must meet all of the following criteria:

- Patients admitted to the vascular surgery service at the University Clinic Augsburg during the time frame mentioned before.
- Patients older than 18 years of age.
- Patients had a midline catheter inserted for one of the following three indications:
    1. The need for IV access with an expected duration of 7 days or more.
    2. The need for Alprostadil (brand name Prostavasin, UCB S.A., Belgium) therapy in patients with peripheral arterial disease.
        - Alprostadil therapy is administered to patients with peripheral arterial disease whose Rutherford classification (57) is ≥4, who cannot undergo interventional or operational revascularization. The Rutherford classification is used to classify patients with peripheral arterial disease according to symptoms:
            - Stage 0 – Asymptomatic
            - Stage 1 – Mild claudication
            - Stage 2 – Moderate claudication
            - Stage 3 – Severe claudication
            - Stage 4 – Rest pain
            - Stage 5 – Minor tissue loss with ischemic nonhealing ulcer or focal gangrene with diffuse pedal ischemia
            - Stage 6 – Major tissue loss – Extending above transmetatarsal level, functional foot no longer salvageable
        - Alprostadil therapy is administered through an infusion of 20 µg twice daily that can be increased to 40 µg twice daily, with each infusion lasting 3-4 hours.
    3. Patients with difficult standard PVC insertions due to poor conditions of the veins or without a visible or palpable vein for the insertion of a standard PVC.

Exclusion Criteria

Patients who meet any of the following criteria were excluded from the study:

- Patient with life-threatening conditions.
- Patients who require a CVC.
- Patients who are allergic to any of the materials used in the catheter, mainly polyurethane.

- Patients on dialysis or patients with chronic kidney disease whose GFR is below 30 ml/min (to preserve the veins for future possible arteriovenous shunt operations).
- Patients with conspicuous puncture sites, e.g., local infection, skin lesions, previous treatments, or operations at the puncture site that prevents proper stabilization or insertion of the catheter.
- Patient with thrombosis or thrombophlebitis in the puncture area.

2.3 COLLECTION OF DATA

The data was collected using three forms filled out by the healthcare provider responsible for the insertion, maintenance, and removal of the midline catheter. The first form, titled “Insertion,” was filled out at the time of insertion. The second form, titled “Course,” was filled out daily while the midline catheter was inserted. The third form, titled “removal,” was filled out a the time of removal of the midline catheter. The three forms are found in the supplemental material. The data collected is directly related to the endpoints of the study (see below).

Other patient-related data, including clinical notes, laboratory results, and comorbidities, were collected by examining patients’ medical records and stored digitally.

Insertion Form

The data collected at the time of the insertion include:

- Patient identification
- The date of insertion
- The type of medication administered along with the type of infusion (continuous or intermittent) and dosage. Types of medications listed included:
    - Antibiotics
    - Anticoagulants
    - Cardiac medications
    - Others
- Target vessel
- The presence or absence of sonographic assistance
- The diameter and length of the catheter
- Depth of the vein (defined as the distance from skin to the center of the vein)
- The diameter of the vein

- The number of attempts until successful catheterization
- The duration of time required to insert the catheter in minutes (defined at the time period starting with vein assessment for placement of the catheter until the placement of the securing patch on the cannula)
- Patient comfort score on a scale from 1-10 using a standardized visual analog scale (VAS) (58)
- Additional notes

Course Form

The data collected during the course of treatment (while the midline catheter was still inserted):

- Patient identification
- Daily puncture site condition
- Weekly sonographic check for the catheter condition checking for possible complications (e.g., thrombosis, thrombophlebitis)
- Weekly leukocyte count and C-reactive protein (CRP)

Removal Form

The data collected at the time of removal of the midline catheter:

- Patient identification
- Date of removal
- Reason for removal
- The duration of the catheter in days
- Result of microbiological examination of the catheter tip after removal

2.4 CATHETER INSERTION

The procedure of insertion of the Midline Catheter Power Glide Pro™ was based on the “Instructions for Use.” The conductors of the study were trained by personnel from BD on the proper techniques for the insertion of a PowerGlide Pro™ Midline Catheter. The conductors of the study performed multiple successful midline catheter insertions under supervision before commencing the study. Two catheter sizes were used: 18G and 20G, along with two lengths: 8 cm and 10 cm. The insertion, maintenance, and removal processes were similar to previous studies (59). The following processes must be observed when using the catheter:

Catheter Insertion

After acquiring consent, the midline catheter was inserted using instructions in the manual provided by the manufacturing company (supplemental materials). All catheters were inserted by the vascular surgery team. All sterility precautions were followed while inserting the catheter. After choosing the correct gauge size and length, the following steps were followed:

1. A tourniquet is applied proximal to the target vein.
2. The target vein for catheterization was identified using ultrasound. The target vein should have a diameter of at least 2 mm.
3. The puncture site is sterilized.
4. The catheter is inserted using the Seldinger technique under ultrasound guidance:
    a. The needle is removed from the plastic housing.
    b. The needle is inserted into the vein, and blood return is observed.
    c. The guidewire is fully advanced using the push-off button until the wings fully deploy.
    d. The catheter is fully advanced over the needle and guidewire using the catheter wings.
    e. The catheter tip position is monitored and adjusted using ultrasound.
    f. With the catheter wings held in place, the housing is fully removed from the catheter.
    g. While the proximal end of the wing is held to stabilize the device, the wings are lifted up and folded back.
    h. The wings are then removed.
    i. The injection cap is immediately placed.
5. The catheter is fixed in place with a special plaster (StatLock Stabilization Device). The StatLock Stabilization Device works by clamping the catheter in place, ensuring that it stays in the desired position. The system consists of a secure base that is applied to the patient's skin and a locking mechanism that is attached to the catheter. The locking mechanism is then engaged with the base, creating a secure and stable connection that reduces the risk of catheter dislodgement and movement.

Catheter Management

The standard catheter care includes:

- Daily clinical checks for the puncture site for reddening, swelling, warmth, or signs of thrombosis.
- Dressing changes every 7 days or after signs of contamination. During dressing changes, the catheter was cleaned with 82% alcohol/0.5% chlorhexidine swap.
- Catheter flushing with 10 ml NaCl after every medication administration to avoid clogging.
- Patch change every 5-7 days.
- Weekly laboratory check (leukocyte count and CRP) and ultrasound checks of the catheterized vein for signs of thrombosis or thrombophlebitis.

Catheter Removal

The catheter is properly removed after completion of therapy or if complications arise that necessitate the removal of the catheter. Catheter-related pain, extravasation, and occlusion were the documented complications that necessitated removal of the catheter. The results and complications, if any, are documented.

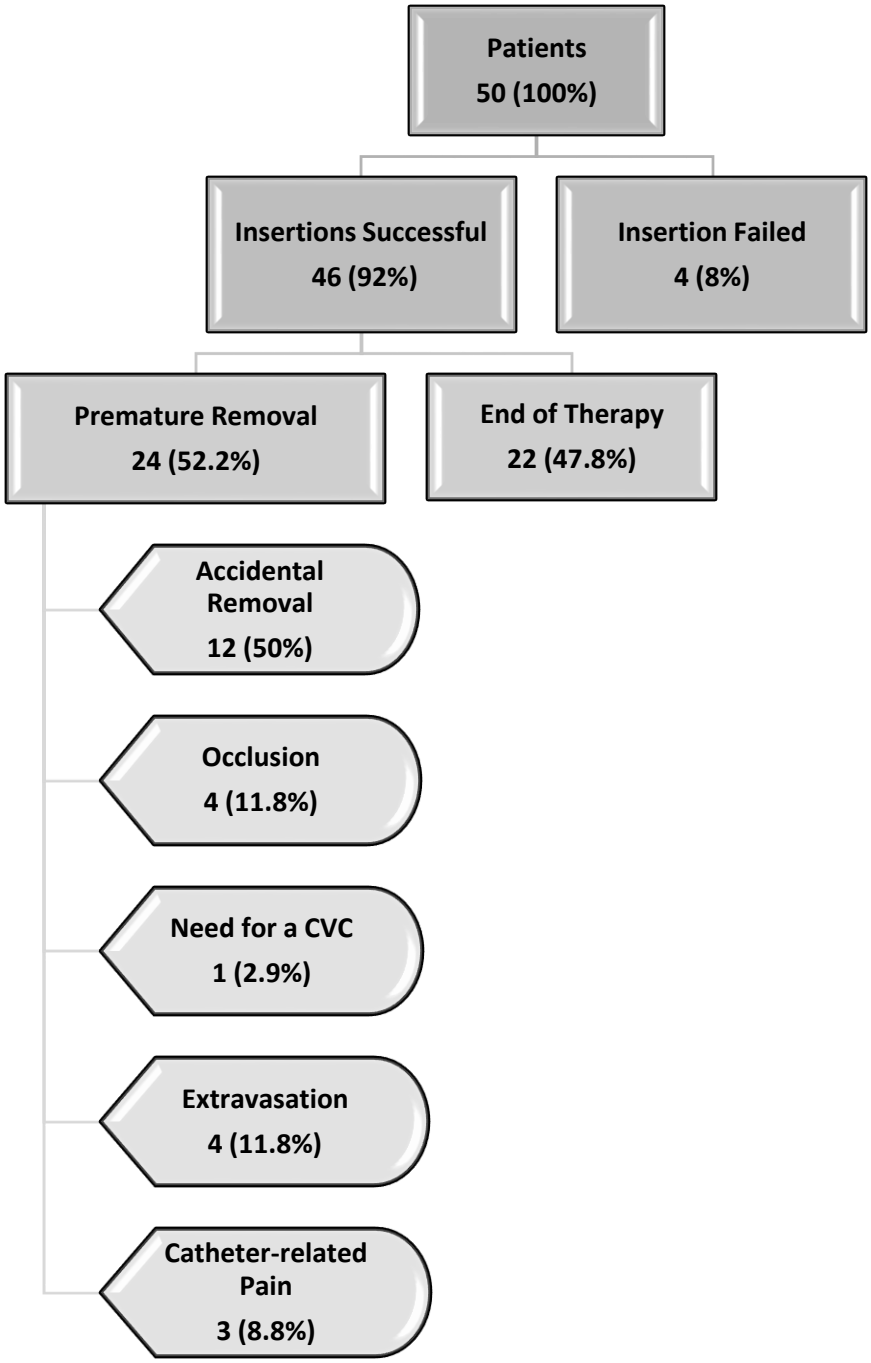
The removed catheter and the tip are sent to the microbiology department for examination. A macroscopic assessment of the catheter tip observing for signs of a thrombus formation is carried out directly by the removing health care provider.

2.5 Statistical Analysis

All patient data were recorded on a Microsoft Excel sheet. Statistical tests, including regression analyses and Mann-Whitney tests, were carried out on the SPSS software. Findings are presented in the format of median or mean ± standard deviation if appropriate.

3 RESULTS

Graph 1 summarizes all the patients included in the study and their outcomes. Patients who failed the insertion process were excluded from subsequent analysis of the study's primary endpoint.



GRAPH 1: Summary of all patients included in the study (n=50).

3.1 PATIENT DEMOGRAPHICS

During the course of the study, 50 patients receiving midline catheter insertions were enrolled. Patient characteristics are shown in Table 1. These characteristics are representative of the patient population usually admitted to the vascular service at the University Clinic Augsburg. Comorbidity is defined similarly to a 2020 study from Denmark studying the clinical performance of midline catheters as diabetes mellitus, cardiovascular conditions (hypertension, ischemic heart disease, arrhythmia, history of stroke, hypercholesterolemia, history of deep vein thrombosis), inflammatory (vasculitis, lupus) and neoplastic conditions, and use of anticoagulants and/or antiplatelets (59).

TABLE 1: Patient characteristics of the study population.

Patient characteristics (n = 50)	
Age (y)	67.4 ± 12.9
Females (n)	19 (38%)
Comorbidities	48 (96%)
Anticoagulants/antiplatelets	48 (96%)
Hypertension	35 (70%)
Cardiovascular conditions*	27 (54%)
Diabetes Mellitus	16 (32%)
Inflammatory and neoplasms**	11 (22%)

* Hypertension, ischemic heart disease, arrhythmia, history of stroke, hypercholesterolemia, history of deep vein thrombosis
** Vasculitis, lupus.
Data are presented as mean ± standard deviation or number (n) (%).

3.2 DWELL TIME AND REMOVAL

Table 2 summarizes the main indications for the removal of the midline catheter. The most frequent reason for removal was the end of therapy (47.8%), while the most frequent cause of premature removal was accidental removal by the patients (26.1%). For different reasons, patients whose catheters were removed accidentally were not re-included in the study after the removal of the catheter.

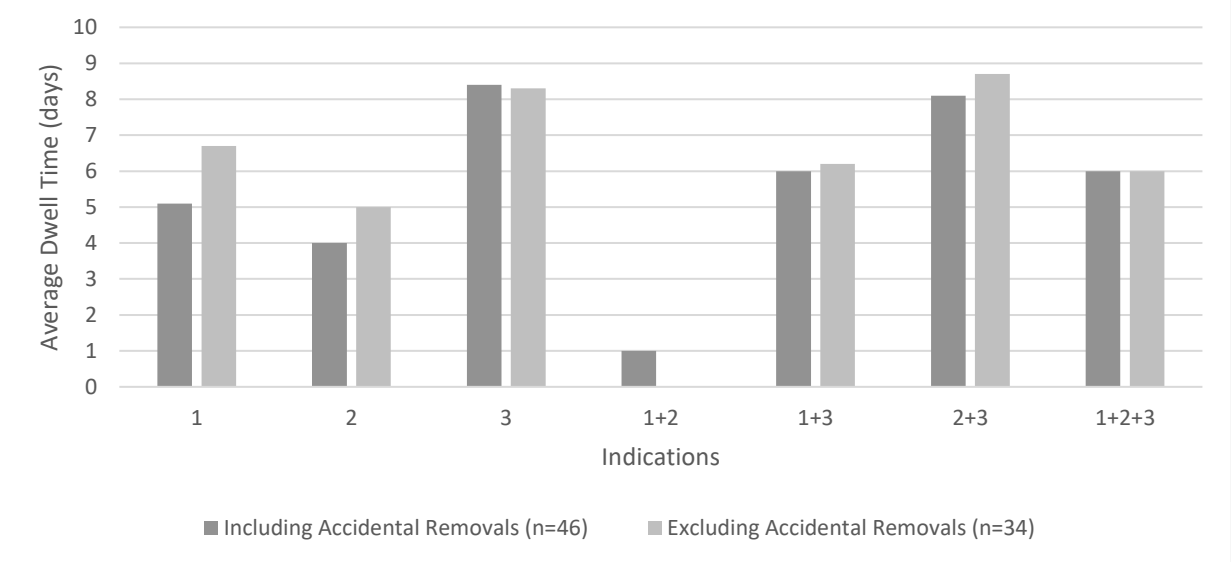
TABLE 2: Indications for the removal of the midline catheter.

Indication	Number of patients (n=46) (% of total)
End of therapy	22 (47.8%)
Accidental removal	12 (26.1%)
Extravasation	4 (8.7%)
Occlusion	4 (8.7%)
Catheter-related pain	3 (6.5%)
The need for a CVC	1 (2.2%)

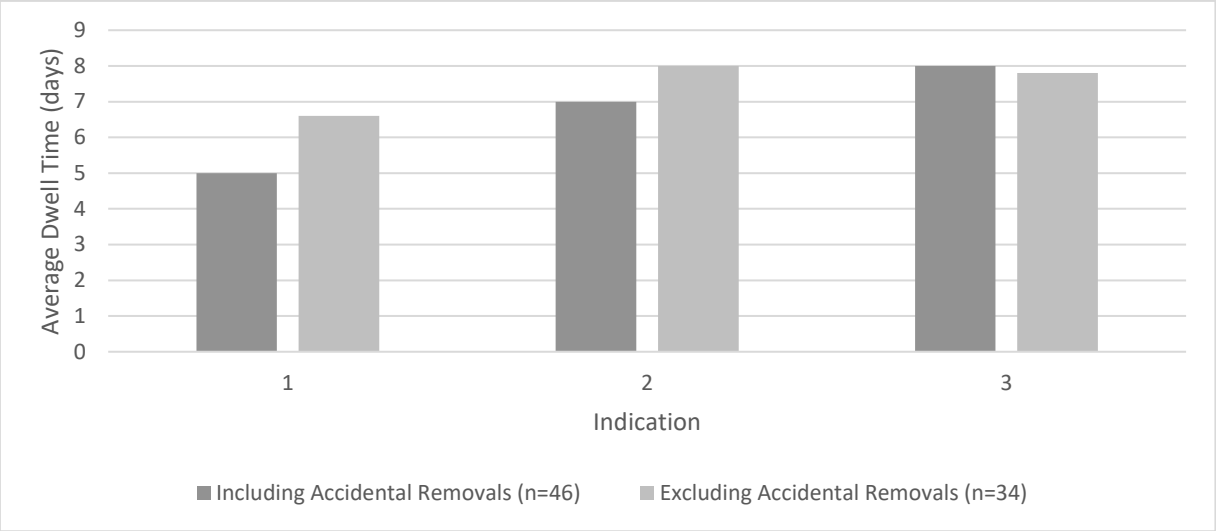
* CVC = Central venous catheter.
* Four patients were included in the study but failed the catheterization process.

The overall complication rate was (11/46 = 23.9%). During the course of the 46 successful catheterizations, only one patient (2.2%) had local findings of irritation (swelling) near the catheter site. Daily checks of the catheter site yielded no additional findings for the other 45 patients.

The total dwell time for the 46 patients with successful catheterizations was 282 days, with an average of 6.1 ± 4.2 days and a median of 5 days (range 1-17 days). When excluding the 12 patients (26.1%) whose catheters were removed accidentally, the average dwell time increases to 7.3 ± 4.1 days, with a median of 6 days. Multiple factors were plotted against the dwell time for the midline catheter. Graphs 2 (a) and 2 (b) show that patients who had a difficult standard PVC insertion had the longest average midline catheter dwell times.



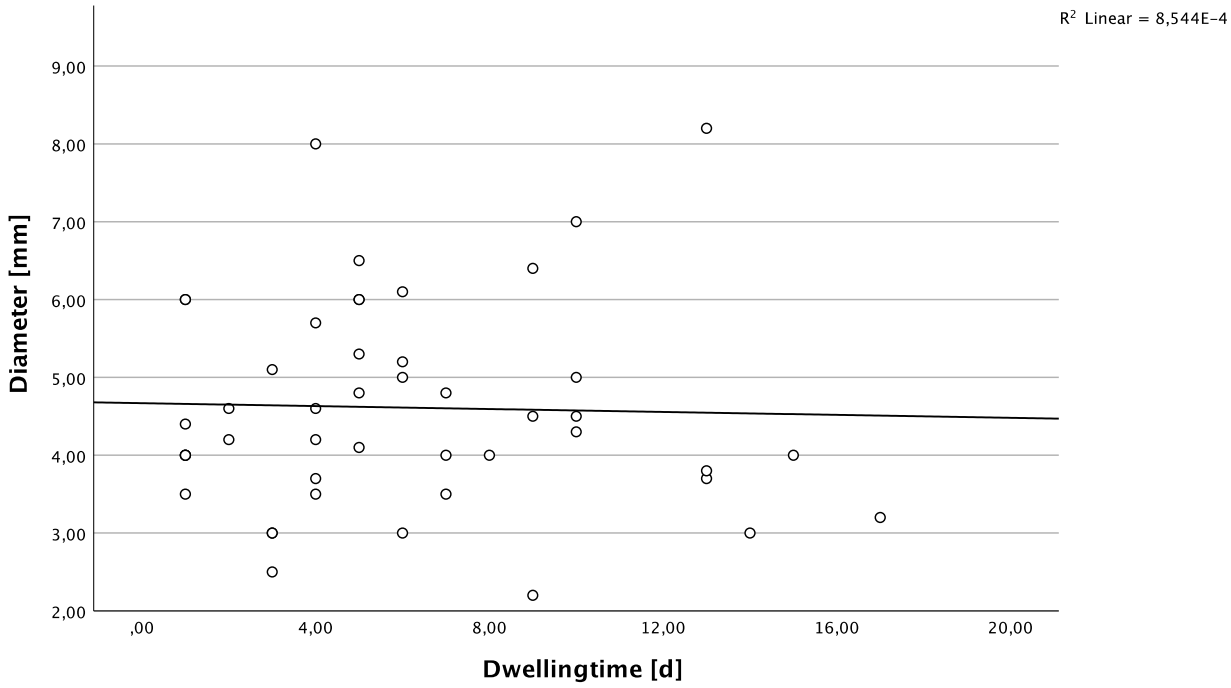
***GRAPH 2 (a)**: Column chart: Indication for catheter insertion vs. Average catheter dwell time (days). 1= Alprostadil Therapy; 2= Antibiotic Therapy; 3= Difficult Standard PVC Insertion.*



***GRAPH 2 (b)**: Column chart: Indication for catheter insertion (clustered*) vs. Average catheter dwell time (days).*
1= Alprostadil Therapy; 2= Antibiotic Therapy; 3= Difficult Standard PVC Insertion.
** Clustered means that patients who had more than one indication for insertion were counted as multiple patients for each indication.*

Graphs 3 and 4 depict the relationship between the depth and diameter of the catheterized vein (mm) and dwell time (days), respectively. The linear regression analysis of the relationship between dwell times and vein depth and diameter yielded an R-squared value of 0.004 ($p = 0.67$) and 8.5×10^{-4} ($p = 0.847$), respectively, indicating a very weak statistically insignificant correlation between these two variables and average dwell times.

***GRAPH 3**: Scatter plot: Sonographic depth of the vein (mm) vs. Catheter dwell time (days).*
Regression analysis: R-squared = 0.04, p = 0.67

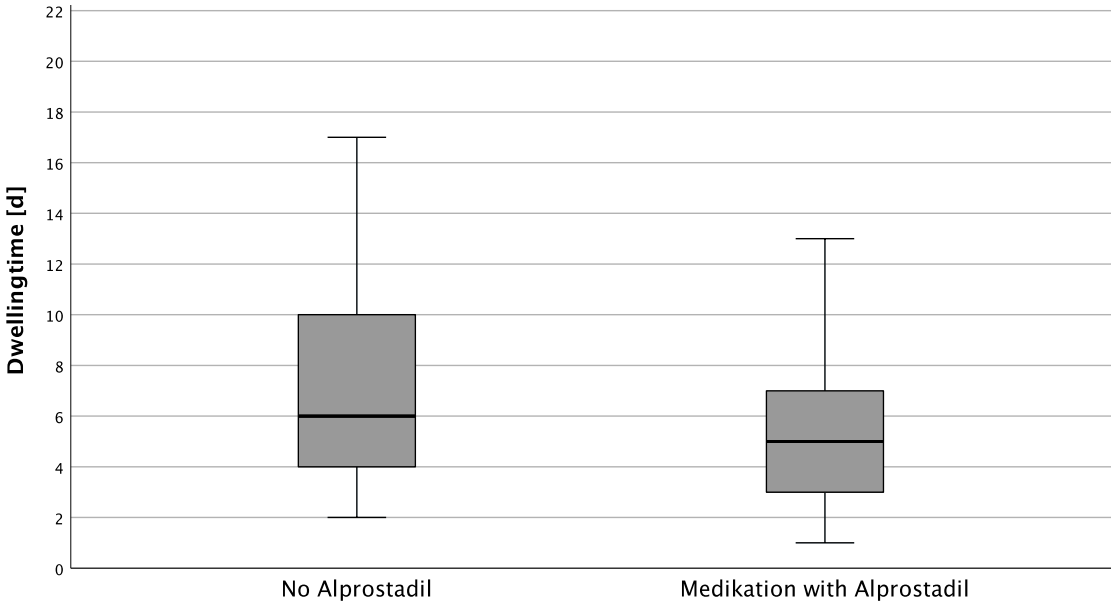


***GRAPH 4**: Scatter plot: Sonographic diameter of the vein (mm) vs. Catheter dwell time (days). Regression analysis: R-squared = 0.01, p = 0.847*

Out of 46 catheters, 14 (30.4%) were sent for microbiological examination to check for infection. 2 (4.3%) returned positive for contamination. One of the two patients was a drug abuser who had an inguinal abscess; the other was a patient with an infected bypass graft. Neither of these patients showed evidence of a catheter-related blood-stream infection. The other 32 catheters were not sent for examination.

3.2.1 Alprostadil Therapy

33 patients (66%) required a midline catheter for the administration of Alprostadil, 4 of which failed catheterization. The average dwell time for these 29 patients was 5.2 ± 3.6 days, which increased to 6.6 ± 3.3 days when excluding patients whose catheters were removed prematurely by accident. 17 patients did not receive Alprostadil therapy, and their average dwell time was 7.7 ± 4.7 days. Graph 5 shows that the difference in dwell times (2.6 days) was statistically insignificant (p = 0.061).



***GRAPH 5**: Dwell time (days) by indication:*
- Alprostadil group (n=29): mean dwell time = 5.17 ± 3.56 days.
- No Alprostadil group (n=17): mean dwell time = 7.76 ± 4.71 days.
- Mann-Whitney test, p = 0.061

Out of 29 patients, only 1 patient had findings suggesting irritation near the injection site (swelling), calculated to be an incidence of 3.4%.

3.3 INDICATIONS, VEIN CHARACTERISTICS, DURATION, AND PAIN

The main indications for the insertion of the midline catheter are summarized in Table 3. Numerous patients had more than one indication. For example, some patients required antibiotic therapy and had a difficult standard PVC insertion. The distribution of patients in term of the veins used for catheterization are mentioned in Table 4.

36 patients (72%) were catheterized successfully upon the first attempt. 8 patients (16%) received a second attempt, and 2 patients (4%) required three attempts for successful catheterization. Four patients (8%) failed catheterization entirely and were not included in the subsequent analysis of dwell time or indication for removal. The median number of trials required for successful catheterization was 1. Overall, 46 patients were catheterized successfully, meaning the success rate was 92%.

TABLE 3: Indications for the midline catheter insertion.

Indication	Number of Patients (n = 50) (% of total)
1) Prostavasin (Alprostadil) therapy	24 (48%)
2) Difficult standard PVC insertion	7 (14%)
3) Antibiotic therapy	2 (4%)
Indication 1 + 2	1 (2%)
Indication 1 + 3	7 (14%)
Indication 2 + 3	8 (16%)
Indication 1 + 2 + 3	1 (2%)

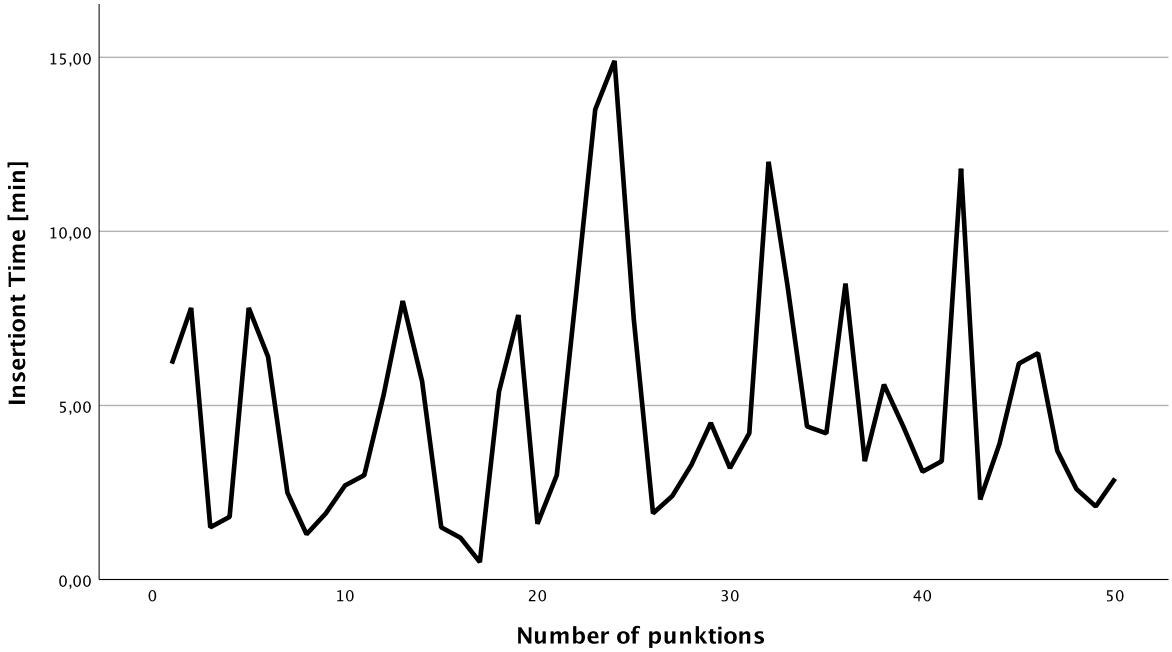
* Many patients had more than one indication.
* Prostavasin is the brand name of alprostadil.
* Four patients were included in the study but failed the catheterization process.
* PVC = peripheral venous catheter.

TABLE 4: Target veins for catheterization.

Target vein	Number of patients (n=50) (% of total)
Basilic vein	34 (68%)
Brachial vein	7 (14%)
Cephalic vein	6 (12%)
Median cubital vein	3 (6%)

The average depth of the veins used for catheterization was 7.7 ± 3.3 mm. Ultrasound guidance was used for all catheter insertions except for two (96%), which were superficial veins (1 mm and 2 mm) that could be catheterized directly. The average diameter of the veins with the tourniquet applied was 4.7 ± 1.3 mm. the 8-cm catheter was used in 15 patients, while the 10-cm was used for the remaining 35 patients.

The average duration of insertion was 285.7 ± 187.7 seconds. The high variability in insertion time was expected due to the variation in patient characteristics, veins, and compliance. Graph 6 depicts the trend in the duration of insertion with the progress of time. There was no apparent decrease in the duration of insertion with increasing expertise of the catheter inserter.



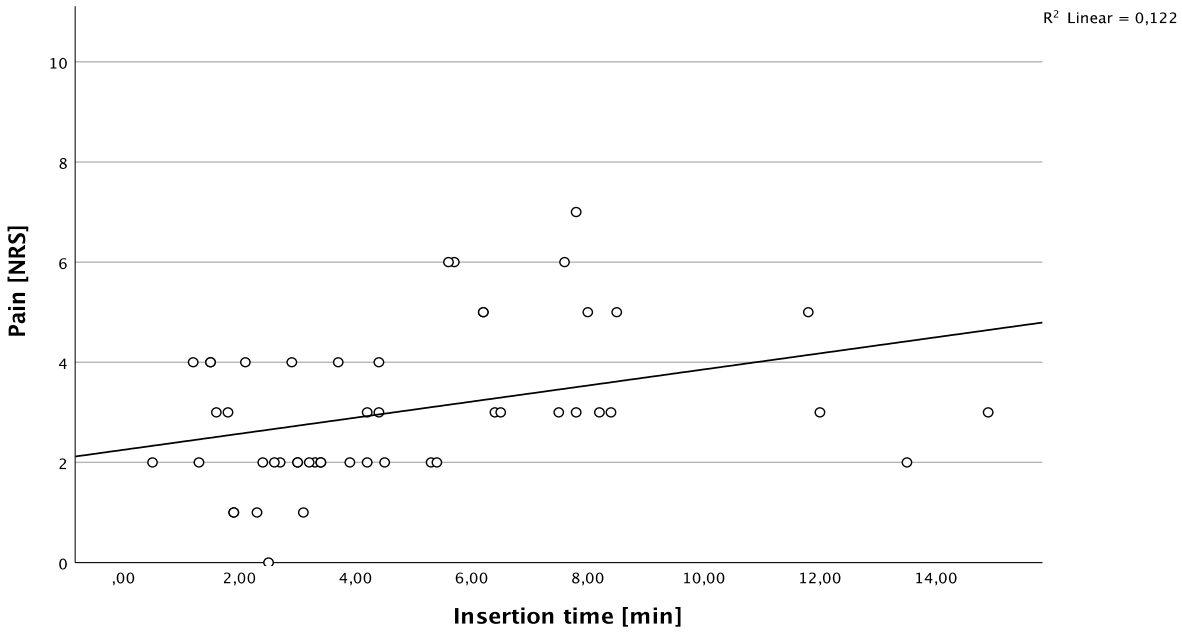
***GRAPH 6**: Learning curve: Patient number in chronological order vs. Duration of insertion (min).*

Table 5 summarizes the results of the pain scores reported by patients upon the insertion of the midline catheter according to a standard visual analog scale. The median pain score across the patient population was 3.

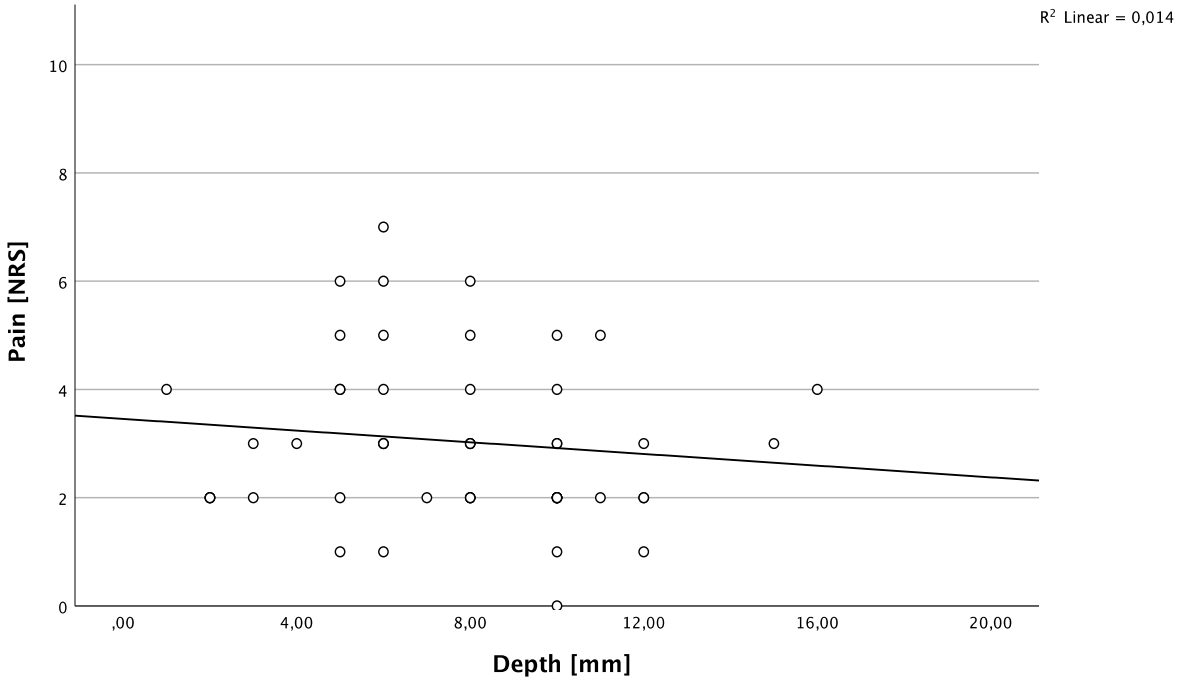
TABLE 5: Pain score upon insertion of the midline catheter (n=50).

Pain score on the visual analog scale (1-10)	Number of Patients (% of total)
0	1 (2%)
1	4 (8%)
2	17 (34%)
3	12 (24%)
4	7 (14%)
5	5 (10%)
6	3 (6%)
7	1 (2%)

Graph 7 portrays the relationship between the duration of insertion and reported pain. The linear regression analysis of this relationship showed a statistically insignificant R-squared value of 0.122 (p = 0.09). Graph 8 explores the relationship between the pain of the insertion process and the depth of the catheterized vein. With a statistically insignificant R-squared value of 0.014 (p = 0.41), pain doesn't seem to correlate with either the duration of insertion or the depth of the catheterized vein.



***GRAPH 7**: Scatter plot: Duration of insertion (min) vs. Reported pain score (1-10) (Visual Analog Scale). Regression analysis: R-squared = 0.122, p = 0.09*



***GRAPH 8**: Scatter plot: Sonographic depth of the vein (mm) vs. Reported pain score (1-10) (Visual Analog Scale).*
Regression analysis: R-squared = 0.014, p = 0.41

4 DISCUSSION:

The background of this study is rooted in the challenges faced by the Vascular Surgery department at the University Clinic Augsburg. The patient population seen in this department is often older and has multiple comorbidities, which can lead to extended hospital stays and a need for long-term IV access (for example, to administer antibiotics or prostaglandin therapy). Given the nature of the patient population, it is essential to have IV access options that are both comfortable and effective. This need for a solution is what motivated the current study, which aimed to investigate the use of midline catheters as a viable option for long-term IV access. The average dwell time was 6.1 ± 4.2 days, and 5.2 ± 3.6 days for patient who received Alprostadil. The use of midline catheters in 50 patients was associated with a low complications rate as shown in Table 2. The results of the study support the prolonged use of midline catheter for vascular patients, especially those receiving Alprostadil therapy for peripheral arterial disease.

4.1 DWELL TIME

The average dwell time reported in our study was comparable to some studies discussing the efficacy of midline catheters (59, 60) but 10 days shorter than the average dwell time of midline catheters in a 2021 study published in the journal of Critical Care Medicine (61). This variance can be attributed to multiple factors. First, the patient populations receiving the midline catheterizations across the studies were different, with unique demographical characteristics. Moreover, almost half of the patients in our study had their catheters removed due to the end of therapy, suggesting that the catheter was functioning and could have stayed for longer periods of time.

The high volume of accidental removals also shortened the dwell time, as the catheters were functioning before removal. The reason behind the high frequency of accidental removals was the poor patient compliance of the relatively old patient population.

Despite these limitations, the calculated average dwell time in our study was approximately 6 days and increased to 7 days when excluding patients whose catheters were accidentally removed. This was still longer than the recommended dwell time for PVCs, which is at most 5 days (37). This suggests that midline catheters offer a favorable alternative to PVCs for patients who require IV access for extended periods of time in the hospital.

4.2 ALPROSTADIL THERAPY

At the University Clinic Augsburg, the mainstay of administration of Alprostadil for patients with peripheral arterial disease was through a CVC. The insertion process of a CVC requires experienced personnel, extensive preparation, and specific techniques. Moreover, CVCs are associated with a myriad of complications that include vascular, cardiac, pulmonary, and placement complications (62). Some of these complications can be immediately life-threatening. On the other hand, the insertion of a midline catheter is relatively easier, requiring less expertise and a smaller number of involved professionals. The one-hand Seldinger technique made it possible for one provider to insert the midline catheter without assistance (59). In addition, the peripheral insertion of the midline catheter avoids the central complications associated with a CVC.

The infusion of irritant medications peripherally remains controversial due to the lack of robust evidence for the optimal way to administer different medications. Amongst other side effects, Alprostadil is known to cause pain at the injection site (63). At our institution, administering Alprostadil through a PVC was usually associated with thrombophlebitis, erythema, and swelling of the surrounding skin, and significant pain at the cannulation site, requiring frequent catheter replacement. Most patients who attempted to receive Alprostadil through a PVC at our hospital eventually had a CVC inserted to continue the medication. Thus, the availability of an alternative method of administration for Alprostadil that avoids the potential complications of a CVC and the side effects of a PVC can ease the administration of the medication and improve patient outcomes.

Multiple studies have described the utility of midline catheters in the administration of irritant medications. One study on the performance of midline catheters found that there was no statistically significant difference in dwell times between patients who received irritant medications (consisting of Vancomycin and Dicloxacillin) and those who did not receive irritant medications (59). In general, the higher flow rate through the midline catheter dilutes irritant medications and might protect against chemical phlebitis (33). However, according to our knowledge, there are no published studies that specifically discuss the use of midline catheters to administer Alprostadil.

Although there were a limited number of patients who received Alprostadil, our study suggests that midline catheters may be a feasible option for administering Alprostadil. Patients who received Alprostadil had shorter average dwell times compared to the rest of the patient population (5.2 days vs. 7.7 days). Despite a relatively short

average dwell time of 5 days, this is still longer than the average dwell time for a PVC, especially when delivering potentially irritating medications. Only one patient had catheter-related complaints, and patients had dwell times comparable to the rest of the study participants. Only one patient reported pain severe enough to warrant catheter removal. The low rate of complications of administering Alprostadil therapy through midline catheters compared to the patients' usual dissatisfaction with the Alprostadil administration through a PVC further supports the utility of the midline catheter in infusing irritant medications.

More studies that assess the administration of Alprostadil through midline catheters with larger patient populations are required to comment on whether midline catheters are the most effective method of administration of this medication.

4.3 INSERTION TIME

The duration of the midline catheter insertion process may be a poor predictor of the utility of the midline catheter due to the number of variables that affect it, both internally in one study and externally across different studies. The setting in which the catheter is studied, the patient population receiving catheterization, and the characteristics of the healthcare providers who insert the catheter can affect the duration of insertion. For example, one study published in 2016 reported the mean time required to insert 8- or 10-cm-long midline catheters in 66 patients as 9.5 minutes (37), while another 2019 study on the use of mini-midline catheters in 50 patients found that the average duration of insertion was 10 minutes (64). This contrasts with our study, which reported an average insertion time of midline catheters of approximately 3 minutes. However, the other studies focused on patients in the emergency department who had veins challenging to cannulate. In spite of the older patient population in our study, whose veins were more likely to be thin, tortuous, and difficult to access, we still had a generally quick insertion process, probably owing to the high level of expertise of the catheter inserter. One physician from the Vascular Surgery department with extensive expertise in catheter insertion (experience in the ICU and ultrasound-guided CVCs) was responsible for the insertion of all catheters.

Visual inspection of the chronological curve in Graph 2 reveals no decrease in insertion time with the progression of the study over two years. However, having only one physician with adequate experience inserting the catheters means our results are

not generalizable. The presence of more providers who are less familiar with the ultrasound-guided process of the insertion of the midline catheter may have yielded different results. The presence of only one experienced inserter may have underestimated the insertion time, but it made the comparison of patients in terms of pain during insertion and catheter outcomes more reliable.

A 2016 article on the insertion time of PVCs found that the median duration of insertion for PVCs was 60 seconds (65). While the PVC might be faster to insert, one has to consider the advantages of the midline catheter, especially the longer dwell time. Moreover, the midline catheter insertion time was calculated starting with vein assessment and ending with securing the catheter in place. The need for ultrasound guidance and proper vein assessment means the midline catheter will inherently take longer to insert.

4.4 Catheter Complications & Outcomes

The midline catheter has many documented complications that may necessitate catheter removal and replacement, including catheter occlusion, infection, venous thrombosis in the ipsilateral arm, extravasation or infiltration of infused liquids, pain, catheter dislodgement, and phlebitis (51, 59). Our study recorded only occlusion, pain, extravasation, and bloodstream infection.

Overall, our study reported slightly higher rates of occlusion and extravasation but a lower rate of catheter-related pain than other studies. Factors that play a role in this observation may include the relatively older patient population with a high prevalence of comorbidities in our study. In addition, the catheter maintenance protocols, including regular flushing of the catheter every 12 hours and after each use, were not strictly adhered to, leading to increased rates of occlusion and catheter dysfunction.

A meta-analysis of 987 articles on the complications of midline catheters found a very low rate of catheter-related infections (0.28/1000 catheter days), with 64% of studies not reporting any infections with the use of midline catheters (61). This is congruent with our study, where none of the patients had any signs of a catheter-related bloodstream infection. However, the high rate of premature removal and relatively shorter dwell times in our study may underestimate the true incidence of catheter-related infections with the use of midline catheters.

Microbiological examinations of about one-third of the catheter tips were carried out after catheter removal to identify asymptomatic colonization of the catheter. Although only two patients with preexisting infectious diseases had positive catheter-tip cultures, the true number may be higher since most catheters were not sent for this examination.

Patients whose catheters were accidentally removed were not demographically different from the rest of the patient population. From a total of 12 patients whose catheters were accidentally removed, 9 received PVCs instead due to the unavailability of personnel who where adequately trained for the insertion of a midline catheter, leading the on-duty physicians to opt for a PVC. One patient declined further treatment and was discharged, and the remaining two patients were disoriented and refused catheterization with the midline catheter. These cases provide further proof of the nonadherence difficulty faced throughout this study.

Of note, the one patient who eventually required a CVC was transferred to the ICU, where there is strict protocol for the optimal vascular access devices used to administer life-saving medications.

4.5 CONCLUSION

Based on the data presented in the study, it can be concluded that the PowerGlide Pro™ Midline Catheter is a viable alternative to traditional peripheral venous access devices for patients who require intravenous therapy for a longer period of time or have poor peripheral venous status. The technical success rate of the catheter placement was high (92%), and the procedure was associated with minimal pain. The average catheter dwell time of 6.1 days was longer than that of a traditional peripheral venous catheter, making the PowerGlide Pro™ Midline Catheter a suitable option for patients requiring intravenous therapy for more than seven days.

The study also found that the PowerGlide Pro™ Midline Catheter had a lower complication rate compared to central venous catheters, making it a safer alternative for patients. The most common reasons for catheter removal were the completion of therapy and accidental dislodgement. Although no significant difference was found between catheter dwell time and the type of medication administered, the catheter was found to be suitable for the administration of special medications, such as prostaglandins or antibiotics. However, we still advise using a CVC for the administration of peripherally irritant medications such as Alprostadil for periods longer than 7 days.

Overall, the PowerGlide Pro™ Midline Catheter offers an expanded range of options for intravenous therapy, particularly for patients with poor peripheral venous status or who require intravenous therapy for a prolonged period. The catheter can be easily placed using either direct puncture or ultrasound guidance and is associated with minimal pain. With its low complication rate and extended dwell time, the PowerGlide Pro™ Midline Catheter has the potential to reduce the need for central venous catheters in some cases, thereby minimizing the risks associated with more invasive procedures.

Table 5 comparing midline catheters, central venous catheters, and peripheral venous catheters provides a concise summary of the most commonly used intravenous access devices. Each of these three modalities has its own set of advantages and disadvantages. The choice of access device should be tailored to the individual patient's needs to achieve optimal outcomes. Factors such as the patient's condition, the expected duration of treatment, availability of trained staff, and the nature of the administered fluids should be taken into consideration to ensure that the most appropriate and cost-effective option is utilized.

In conclusion, the findings of this study support the use of the PowerGlide Pro™ Midline Catheter in vascular surgery. The catheter offers a safe and effective alternative to traditional peripheral venous access devices and central venous catheters for patients who require intravenous therapy for a longer period of time or have poor peripheral venous status. Further studies are needed to confirm these findings and to determine the long-term outcomes and cost-effectiveness of using the PowerGlide Pro™ Midline Catheter in clinical practice.

TABLE 6: Comparison of the midline catheter to PVC and CVC.

Cost of midline catheter	vs. PVC	Higher.
	vs. CVC	Lower.
Difficulty of Insertion of midline catheter	vs. PVC	Requires more expertise and training.
	vs. CVC	Requires less expertise and training.
Complications of midline catheter	vs. PVC	Comparable or slightly higher.
	vs. CVC	Associated with less life-threatening conditions.
Dwell Time of midline catheter	vs. PVC	Longer.
	vs. CVC	Shorter.

* PVC = peripheral venous catheter; CVC = central venous catheter.

4.6 STUDY LIMITATIONS

Our study was conducted at only one center, whereas a multi-center study might yield more generalizable data. Since we did not compare the midline catheter patient to a control group, this means that our study is purely descriptive, with no ability to draw conclusions on the superiority of different vascular access devices. The presence of only one catheter inserter may have distorted some of the study observations. Moreover, the small number of patients included in the study may affect the validity of conclusions drawn from it. The presence of a large portion of patients whose catheters were accidentally removed also distorts the complete picture of the midline catheter efficiency.

4.7 FUTURE CONSIDERATIONS

Larger-scale multi-center studies are required to properly assess the efficiency of the midline catheters and their potential use for administering irritant medications such as Alprostadil. The presence of control groups with proper randomization may be the key to producing efficient guidelines on using different vascular access devices in different settings.

5 SUMMARY

Background: The PowerGlide Pro™ Midline Catheter is a special peripheral venous access device that is placed on an extremity. The catheter has a length of 8 or 10 cm, allowing the tip to reach far into the venous system without reaching central veins.

Objective: The aim of this study was to conduct an observational study and evaluate the duration of the midline catheter placement. Secondary endpoints included suitability for specific medications (e.g., prostaglandins or antibiotics), assessment of complications, and patient satisfaction.

Materials and Methods: Between January 2019 and November 2021, 50 patients were included in the study. The catheter can be implanted either through a direct puncture or under ultrasound guidance. The device has an integrated guide wire for placement using the Seldinger technique. Patient demographic information, as well as data on placement, complications, duration, reasons for removal, and pain, were collected.

Results: Placement was technically successful in 92% (n=46) of cases. In all cases, arm veins were punctured (34 basilic veins, 7 brachial veins, 6 cephalic veins, and 3 median cubital veins). The average duration of placement was 6.1 days (1-17 days). Pain during placement was reported as a median of 3 on the visual analog scale (VAS). The procedure took an average of 286 seconds (4 minutes and 46 seconds). Reasons for catheter removal included treatment completion in 22 cases, accidental removal in 12 cases, extravasation and occlusion in 4 cases each, pain in 3 patients, and removal of the catheter for a central venous catheter in one case. A significant difference between duration and medication administered could not be demonstrated.

Discussion and Conclusion: The Midline Catheter can be placed technically successfully with minimal pain. The longer maximum duration compared to a standard peripheral venous catheter makes it particularly suitable for patients requiring a longer duration of intravenous therapy. Compared to central venous catheters, the complication spectrum during placement is lower. The Midline Catheter offers the possibility of an extended duration of intravenous therapy. Patients who require intravenous therapy for more than 7 days or have poor peripheral vein status may benefit from this catheter. In some cases, the placement of a central venous catheter can be avoided.

6 ZUSAMMENFASSUNG

Hintergrund: Der PowerGlide Pro™ Midline-Katheter ist ein peripher venöser Zugang, das an einer Extremität platziert wird. Der Katheter hat eine Länge von 8 oder 10 cm, so dass die Spitze weit in das Venensystem hineinreichen kann, ohne zentrale Venen zu erreichen.

Ziel der Studie: Unser Ziel war, eine Beobachtungsstudie durchzuführen und die Liegedauer des Midline-Katheters zu bewerten. Zu den sekundären Endpunkten gehörten die Eignung für bestimmte Medikamente (z. B. Prostaglandine oder Antibiotika), die Bewertung von Komplikationen und die Patientenzufriedenheit.

Material und Methoden: Zwischen Januar 2019 und November 2021 wurden 50 Patienten in die Studie eingeschlossen. Der Katheter kann entweder durch eine direkte Punktion oder Ultraschallgesteuert implantiert werden. Der Katheter verfügt über einen integrierten Führungsdraht für die Anlage in Seldinger-Technik. Erfasst wurden demografische Patientendaten sowie Daten zur Anlage, Komplikationen, Dauer, Gründen für die Entfernung und Schmerzen.

Ergebnisse: Die Anlage war in 92 % (n=46) der Fälle technisch erfolgreich. In allen Fällen wurden Armvenen punktiert (34 Vena basilica, 7 Vena brachialis, 6 Vena cephalica und 3 Vena mediana cubiti). Die durchschnittliche Liegedauer betrug 6,1 Tage (1-17 Tage). Die Schmerzen während der Anlage wurden auf der visuellen Analogskala (VAS) mit einem Mittelwert von 3 angegeben. Die Katheteranlage dauerte durchschnittlich 286 Sekunden (4 Minuten und 46 Sekunden). Die Gründe für die Entfernung des Katheters waren in 22 Fällen das Ende der regulären Therapie, in 12 Fällen die akzidentelle Entfernung, in jeweils 4 Fällen Paravasat und Katheterverschluss, in 3 Fällen Schmerzen und in einem Fall die Entfernung des Katheters bei Notwendigkeit für einen zentral Venösenkatheter. Ein signifikanter Unterschied zwischen der Liegedauer und den verabreichten Medikamenten konnte nicht nachgewiesen werden.

Diskussion und Schlussfolgerung: Der Midline-Katheter kann technisch erfolgreich und mit minimalen Schmerzen gelegt werden. Die im Vergleich zu einem peripher-venösen Standardkatheter längere Liegedauer macht ihn besonders geeignet für Patienten,

die eine längere intravenöse Therapie benötigen. Im Vergleich zu zentralen Venenkathetern ist das Komplikationsspektrum bei der Anlage geringer. Der Midline-Katheter bietet die Möglichkeit einer verlängerten Dauer der intravenösen Therapie. Patienten, die eine intravenöse Therapie für mehr als 7 Tage benötigen oder einen schlechten peripheren Venenstatus haben, können von diesem Katheter profitieren. In einigen Fällen kann das Legen eines zentralen Venenkatheters vermieden werden.

7 REFERENCES

1. Cheung E, Baerlocher MO, Asch M, Myers A. Venous access: a practical review for 2009. Canadian Family Physician. 2009;55(5):494-6.
2. Adams DZ, Little A, Vinsant C, Khandelwal S. The midline catheter: a clinical review. The Journal of emergency medicine. 2016;51(3):252-8.
3. Moureau N, Chopra V. Indications for peripheral, midline and central catheters: summary of the MAGIC recommendations. British Journal of nursing. 2016;25(8):S15-S24.
4. Egan G, Healy D, O'Neill H, Clarke-Moloney M, Grace PA, Walsh SR. Ultrasound guidance for difficult peripheral venous access: systematic review and meta-analysis. Emergency Medicine Journal. 2013;30(7):521-6.
5. Rupp SM, Apfelbaum JL, Blitt C, Caplan RA, Connis RT, Domino KB, et al. Practice guidelines for central venous access: a report by the American Society of Anesthesiologists Task Force on Central Venous Access. Anesthesiology. 2012;116(3):539-73.
6. Levigoureux E, Charbonnel J, Latour J, Rosay H, editors. The PICC line, a new approach for venous access. Annales Pharmaceutiques Francaises; 2013.
7. Alexandrou E, Ramjan LM, Spencer T, Frost SA, Salamonson Y, Davidson PM, et al. The use of midline catheters in the adult acute care setting–clinical implications and recommendations for practice. Journal of the Association for Vascular Access. 2011;16(1):35-41.
8. Caballero C, Pérez C. Medial venous catheter or midline (MVC). Revista de enfermeria (Barcelona, Spain). 2014;37(1):36-41.
9. Han TS, Murray P, Robin J, Wilkinson P, Fluck D, Fry CH. Evaluation of the association of length of stay in hospital and outcomes. International Journal for Quality in Health Care. 2022;34(2):mzab160.
10. Toptas M, Sengul Samanci N, Akkoc İ, Yucetas E, Cebeci E, Sen O, et al. Factors affecting the length of stay in the intensive care unit: our clinical experience. BioMed research international. 2018;2018.
11. Chopra V, Flanders SA, Saint S, Woller SC, O'Grady NP, Safdar N, et al. The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results From a Multispecialty Panel Using the RAND/UCLA Appropriateness Method. Ann Intern Med. 2015;163(6 Suppl):S1-40.
12. Patel AR, Patel AR, Singh S, Singh S, Khawaja I. Central line catheters and associated complications: a review. Cureus. 2019;11(5).
13. Anderson NR. Midline catheters: the middle ground of intravenous therapy administration. Journal of Infusion Nursing. 2004;27(5):313-21.
14. Griffiths V. Midline catheters: indications, complications and maintenance. Nursing Standard (through 2013). 2007;22(11):48.
15. Control CfD, Prevention. Adverse reactions associated with midline catheters--United States, 1992-1995. MMWR Morbidity and mortality weekly report. 1996;45(5):101-3.
16. Vanek VW. The ins and outs of venous access: Part I. Nutrition in clinical practice. 2002;17(2):85-98.
17. Harwood IR, Greene LM, Kozakowski-Koch JA, Rasor JS. New peripherally inserted midline catheter: a better alternative for intravenous antibiotic therapy in patients with cystic fibrosis. Pediatric pulmonology. 1992;12(4):233-9.
18. Fontaine PJ. Performance of a new softening expanding midline catheter in home intravenous therapy patients. Journal of Intravenous Nursing: the Official Publication of the Intravenous Nurses Society. 1991;14(2):91-9.
19. Mermel LA, Parenteau S, Tow SM. The risk of midline catheterization in hospitalized patients: a prospective study. Annals of internal medicine. 1995;123(11):841-4.

20. Rickard CM, Webster J, Wallis MC, Marsh N, McGrail MR, French V, et al. Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. The Lancet. 2012;380(9847):1066-74.
21. Rickard CM, Marsh N, Webster J, Runnegar N, Larsen E, McGrail MR, et al. Dressings and securements for the prevention of peripheral intravenous catheter failure in adults (SAVE): a pragmatic, randomised controlled, superiority trial. Lancet. 2018;392(10145):419-30.
22. van Loon FH, Puijn LA, Houterman S, Bouwman AR. Development of the A-DIVA scale:: a clinical predictive scale to identify difficult intravenous access in adult patients based on clinical observations. Medicine. 2016;95(16).
23. Helm RE, Klausner JD, Klemperer JD, Flint LM, Huang E. Accepted but unacceptable: peripheral IV catheter failure. Journal of Infusion Nursing. 2015;38(3):189-203.
24. Miliani K, Taravella R, Thillard D, Chauvin V, Martin E, Edouard S, et al. Peripheral venous catheter-related adverse events: evaluation from a multicentre epidemiological study in France (the CATHEVAL Project). PloS one. 2017;12(1):e0168637.
25. Atay S, Şen S, Cukurlu D. Phlebitis-related peripheral venous catheterization and the associated risk factors. Nigerian journal of clinical practice. 2018;21(7):827-31.
26. Maki DG, Ringer M. Risk factors for infusion-related phlebitis with small peripheral venous catheters: a randomized controlled trial. Annals of internal medicine. 1991;114(10):845-54.
27. Lai KK. Safety of prolonging peripheral cannula and iv tubing use from 72 hours to 96 hours. American journal of infection control. 1998;26(1):66-70.
28. Consortium RINI, TAGER IB, GINSBERG MB, ELLIS SE, WALSH NE, DUPONT I, et al. An epidemiologic study of the risks associated with peripheral intravenous catheters. American journal of epidemiology. 1983;118(6):839-51.
29. Elia F, Ferrari G, Molino P, Converso M, De Filippi G, Milan A, et al. Standard-length catheters vs long catheters in ultrasound-guided peripheral vein cannulation. The American journal of emergency medicine. 2012;30(5):712-6.
30. O'grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, et al. Guidelines for the prevention of intravascular catheter-related infections. Clinical infectious diseases. 2011;52(9):e162-e93.
31. Anderson NR. When to use a midline catheter. Nursing2022. 2005;35(4):68.
32. Intravenous Nurses Society [INS]. (1997). Position paper: Midline and midclavicular catheters. Journal of Intravenous Nursing, 20(4), 175-178.
33. Gorski LA, Czaplewski LM. Peripherally inserted central catheters and midline catheters for the homecare nurse. Journal of Infusion Nursing. 2004;27(6):399-409.
34. Lawson, T. (1998). Infusion of IV medications and fluids via PICC and midline catheters: Influences of tip position on the success of infusion. Journal of Vascular Access Devices, 3(2), 11-17.
35. Lawson T. Infusion of IV medications and fluids via PICC and midlinc catheters Influences of tip position on the success of infusion. Journal of Vascular Access Devices. 1998;3(2):11-7.
36. Myers J, Kyle K. Intermediate-term intravenous therapy: a pilot study. Journal of Post Anesthesia Nursing. 1993;8(1):21-5.
37. Scoppettuolo G, Pittiruti M, Pitoni S, Dolcetti L, Emoli A, Mitidieri A, et al. Ultrasound-guided “short” midline catheters for difficult venous access in the emergency department: a retrospective analysis. International Journal of Emergency Medicine. 2016;9(1):1-7.
38. McGee DC, Gould MK. Preventing complications of central venous catheterization. New England journal of medicine. 2003;348(12):1123-33.
39. Jamshidi R, editor Central venous catheters: Indications, techniques, and complications. Seminars in pediatric surgery; 2019: Elsevier.
40. Smith RN, Nolan JP. Central venous catheters. Bmj. 2013;347.

41. Tsotsolis N, Tsirgogianni K, Kioumis I, Pitsiou G, Baka S, Papaiwannou A, et al. Pneumothorax as a complication of central venous catheter insertion. Annals of translational medicine. 2015;3(3).
42. Merrer J, De Jonghe B, Golliot F, Lefrant J-Y, Raffy B, Barre E, et al. Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. Jama. 2001;286(6):700-7.
43. Wenzel RP, Edmond MB. The impact of hospital-acquired bloodstream infections. Emerging infectious diseases. 2001;7(2):174.
44. Sznajder JI, Zveibil FR, Bitterman H, Weiner P, Bursztein S. Central vein catheterization: failure and complication rates by three percutaneous approaches. Archives of internal medicine. 1986;146(2):259-61.
45. Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. Critical care medicine. 1996;24(12):2053-8.
46. Mushtaq A, Navalkele B, Kaur M, Krishna A, Saleem A, Rana N, et al. Comparison of complications in midlines versus central venous catheters: are midlines safer than central venous lines? American journal of infection control. 2018;46(7):788-92.
47. Deutsch GB, Sathyanarayana SA, Singh N, Nicastro J. Ultrasound-guided placement of midline catheters in the surgical intensive care unit: a cost-effective proposal for timely central line removal. journal of surgical research. 2014;191(1):1-5.
48. Griffiths VR, Philpot P. Peripherally inserted central catheters (PICCs): do they have a role in the care of the critically ill patient? Intensive and critical care nursing. 2002;18(1):37-47.
49. Vidal V, Muller C, Jacquier A, Giorgi R, Le Corroller T, Gaubert J, et al. Prospective evaluation of PICC line related complications. Journal de radiologie. 2008;89(4):495-8.
50. Xu T, Kingsley L, DiNucci S, Messer G, Jeong J-H, Morgan B, et al. Safety and utilization of peripherally inserted central catheters versus midline catheters at a large academic medical center. American journal of infection control. 2016;44(12):1458-61.
51. Seo H, Altshuler D, Dubrovskaya Y, Nunnally ME, Nunn C, Ello N, et al. The safety of midline catheters for intravenous therapy at a large academic medical center. Annals of Pharmacotherapy. 2020;54(3):232-8.
52. Lu H, Hou Y, Chen J, Guo Y, Lang L, Zheng X, et al. Risk of catheter-related bloodstream infection associated with midline catheters compared with peripherally inserted central catheters: A meta-analysis. Nursing Open. 2021;8(3):1292-300.
53. Stratton L, Berlin DA, Arbo JE. Vasopressors and inotropes in sepsis. Emergency Medicine Clinics. 2017;35(1):75-91.
54. Carlbom DJ, Rubenfeld GD. Barriers to implementing protocol-based sepsis resuscitation in the emergency department—results of a national survey. Critical care medicine. 2007;35(11):2525-32.
55. O'Neill R, Morales J, Jule M. Early goal-directed therapy (EGDT) for severe sepsis/septic shock: which components of treatment are more difficult to implement in a community-based emergency department? The Journal of emergency medicine. 2012;42(5):503-10.
56. Prasanna N, Yamane D, Haridasa N, Davison D, Sparks A, Hawkins K. Safety and efficacy of vasopressor administration through midline catheters. Journal of Critical Care. 2021;61:1-4.
57. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. Journal of vascular surgery. 1997;26(3):517-38.
58. Delgado DA, Lambert BS, Boutris N, McCulloch PC, Robbins AB, Moreno MR, et al. Validation of digital visual analog scale pain scoring with a traditional paper-based visual analog scale in adults. Journal of the American Academy of Orthopaedic Surgeons Global research & reviews. 2018;2(3).

59. Bundgaard Madsen E, Sloth E, Skov Illum B, Juhl-Olsen P. The clinical performance of midline catheters—an observational study. Acta Anaesthesiologica Scandinavica. 2020;64(3):394-9.
60. Nielsen EB, Antonsen L, Mensel C, Milandt N, Dalgaard LS, Illum BS, et al. The efficacy of midline catheters—a prospective, randomized, active-controlled study. International Journal of Infectious Diseases. 2021;102:220-5.
61. Tripathi S, Kumar S, Kaushik S. The practice and complications of midline catheters: a systematic review. Critical Care Medicine. 2021;49(2):e140-e50.
62. Kornbau C, Lee KC, Hughes GD, Firstenberg MS. Central line complications. International journal of critical illness and injury science. 2015;5(3):170.
63. Jain A, Iqbal OA. Alprostadil. 2019.
64. Gilardi E, Giannuzzi R, WoldeSellasie K, Piano A, Pittiruti M, Scoppettuolo G. Mini-midline in difficult intravenous access patients in emergency department: A prospective analysis. The Journal of Vascular Access. 2020;21(4):449-55.
65. Piredda M, Biagioli V, Barrella B, Carpisassi I, Ghinelli R, Giannarelli D, et al. Factors affecting difficult peripheral intravenous cannulation in adults: a prospective observational study. Journal of Clinical Nursing. 2017;26(7-8):1074-84.

APPENDIX

I. ABBREVIATIONS

CRP	C-reactive protein
CVC	central venous catheter
GFR	glomerular filtration rate
ICU	intensive care unit
IV	intravenous
MAGIC	The Michigan Appropriateness Guide for Intravenous Catheters
PICC	peripherally-inserted central catheters
PVC	peripheral venous catheter
VAS	Visual Analog Scale

II. KEY WORDS

Midline catheter; dwell time; alprostadil; intravenous; venous access.

III. GRAPHS INDEX

IV. TABLES INDEX

I. SUPPLEMENTAL MATERIAL

1. “Insertion” Form

Patientenkleber

Fragebogen Powerglide Pro

-Anlage-

Datum:

IV-Medikation:

Medikamentenart	Kurzinfusion	Dauerinfusion	Dosierung
Antibiotika			
Gerinnung			
Prostavasintherapie			
Andere:			

Zielgefäß:

o CEPH

o BAS

o BRACH

o AC

o UPPER

o LOWER

o LEFT

o RIGHT

o OTHER

Sonographisch gesteuert: ja nein

Kanülendurchmesser und -länge:

o 18 Gauge

- o 8 cm
- o 10cm

o 20 Gauge

- o 8 cm
- o 10cm

Gefäßtiefe unter der Haut (Von der Insektionsstelle bis zur Mitte des Gefäßes) in mm:

Gefäßdurchmesser in mm:

Punktionsversuche:

Gesamtdauer in Minuten (Zeitlicher Aufwand gemessen ab Beurteilung der Venenverhältnisse zur Anlage eines venösen Katheters bis das Pflaster geklebt wurde):

Patientenkomfort bei Anlage:

Schmerzen: (VAS) 0 1 2 3 4 5 6 7 8 9 10

Bemerkungen:

2. “Course” Form

Patientenkleber

Fragebogen Powerglide Pro

-Verlauf-

Tägliche Kontrolle der Einstichstelle:

	Tag 1	Tag 2	Tag 3	Tag 4	Tag 5	Tag 6
Stattgefunden						
Befund der Einstichstelle						
Komplikationen						

	Tag 7	Tag 8	Tag 9	Tag 10	Tag 11	Tag 12
Stattgefunden						
Befund der Einstichstelle						
Komplikationen						

Wöchentliche Sono-Kontrolle/Pflasterwechsel:

Woche 1: /

Woche 2: /

Woche 3: /

Laborparameter:

	Woche 1	Woche 2	Woche 3	Woche 4
CRP				
Leukos				
Auffälligkeiten				

Bemerkungen:

2. “Removal” Form

Patientenkleber

Fragebogen Powerglide Pro

-Entfernung-

Datum:

Grund für Entfernung:

- Thrombophlebitis
- Okklusion
- Kathetersepsis
- Paravasat
- Schmerzen
- Akzidentiell entfernt
- Therapie regulär beendet
- ZVK wird benötigt
- Andere:

Liege/Verweildauer Katheter: Tage

Ergebnis Untersuchung der Katheterspitze in der MiBi:

-
-
-

Bemerkungen: