Ultrasound-based prediction of cephalic vein cutdown success prior to totally implantable venous access device placement

Wojciech Staszewicz, MD,[a] Surrenaido P. Naiken, MD,[a] André Mennet, MD,[a] Jeremy Meyer, MD, PhD,[a] Marc Righini, MD,[b] Philippe Morel, MD,[a] *and* Christian Toso, PD, MD, PhD,[a] *Geneva, Switzerland*

ABSTRACT

Background: Surgical venous cutdown is a method for totally implantable venous access device (TIVAD) insertion. The main drawback of this technique is its higher failure rate when compared with the percutaneous approach, which is mostly related to anatomic variations of the cephalic vein. The aim of this study was to assess preoperative ultrasound imaging as a tool to predict cephalic vein cutdown failure for TIVAD insertion.

Methods: Ultrasound and operative reports of a cohort of patients undergoing TIVAD insertion by cephalic vein cutdown were reviewed. Ultrasound venous (vein visibility, diameter, length, subcutaneous depth, vein path, and subclavian junction visibility) and patient variables were tested by logistic regression as predictors of TIVAD insertion failure.

Results: One hundred sixty consecutive patients underwent cephalic vein cutdown for attempted TIVAD insertion. An inability to visualize the vein on the preoperative ultrasound examination (odds ratio, 4.39; 95% confidence interval, 1.57-12.30; $P < .05$) and depth of the vein (odds ratio, 1.07; 95% confidence interval, 1.00-1.15; $P = .042$) were predictors of failure of TIVAD insertion by cephalic vein cutdown.

Conclusions: Preoperative ultrasound examination allows identifying patients at risk of failure of TIVAD insertion by cephalic vein cutdown. Preoperative ultrasound examination constitutes an efficient tool for choosing the most appropriate surgical approach and improving patient comfort. (J Vasc Surg: Venous and Lym Dis 2019;7:865-9.)

Keywords: Implantable port; Ultrasound; Venous access; Cephalic vein

Totally implantable venous access devices (TIVAD) are commonly used for the administration of intravenous chemotherapy, long-term antibiotics and parenteral nutrition. An efficient and complication-free placement of such devices is required for their use in often fragile patients.[1,2]

The percutaneous approach (subclavian, axillary, or internal jugular vein puncture) and the surgical vein exposure (open cephalic or external jugular vein cutdown) are commonly used techniques for TIVAD insertion, each presenting specific advantages and risks. Pneumothorax, hemothorax, and accidental arterial puncture are the most severe early complications associated with the percutaneous technique. These complications can occur in up to 8% of the procedures, but lower rates (close to 2%) have been reported with the use of ultrasound guidance.[3,4] The open venous cutdown technique, commonly looking for the cephalic vein in the deltopectoral groove, is free from potentially life-threatening immediate complications, but its high failure rate, reaching up to 30%, is a serious drawback.

Unsuccessful cutdown procedures require switching to another vein location or to a percutaneous approach. This negatively affects patient comfort, prolongs operation duration, and impairs the aesthetic result by potentially adding new incisions.[5] Such events are mostly related to the cephalic vein anatomic characteristics and to patients' variables.[6] Therefore, a preoperative assessment of the vein position and characteristics could help to select the best approach for each individual patient, minimizing the risks of failure and complications.

The aim of the present study was to determine whether ultrasound-defined cephalic vein and patient characteristics could predict the difficulty and the failure of TIVAD insertion by surgical venous cutdown.

METHODS

Patients. Consecutive patients undergoing elective or emergency TIVAD implantation with preoperative venous ultrasound from December 2012 to February 2013 were included. The present study was approved by the local ethics committee (n°12-156).

Ultrasound assessment. Ultrasound assessment was performed by the surgeon before TIVAD implantation by cephalic vein cutdown. A dedicated sonography

From the Division of Digestive Surgery,[a] and Division of Angiology and Haemostasis,[b] University Hospital of Geneva and Faculty of Medicine.

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Correspondence: Wojciech Staszewicz, MD, Department of Surgery, Geneva University Hospitals, Rue Gabrielle-Perret-Gentil, 1211 Geneva (e-mail: wojciech.staszewicz@hcuge.ch).

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report form was filled up and added to the patient's record. Ultrasound was performed using a SonoSite S-series (SonoSite, Inc, Bothwell, Wash) machine equipped with a linear 5- to 10-MHz probe. The cephalic, subclavian, and jugular veins, as well as the overlying subcutaneous tissue, were assessed. Regarding the cephalic vein, the assessed variables included: vein visibility, diameter, length, distance to skin, vein path (straight vs tortuous), subclavian junction visibility (Fig 1). The ultrasound findings did not affect the choice of the initial procedure; all patients underwent cephalic vein cutdown as the initial preferred approach.

Patient management and surgical procedure. All patients were seen in a dedicated outpatient clinic, where the indication for TIVAD was confirmed and the side of implantation decided. The first choice approach for all patients was the cephalic vein open cutdown under local anesthesia. All procedures were performed by either an experienced surgeon or an advanced supervised resident. Local anesthesia was performed with 1% lidocaine (Rapidocain). When needed, additional injections were made on demand during the procedure. A 2-cm incision was performed over the cephalic vein site (Fig 2), the vein was isolated, partially opened, and the catheter was inserted until it reached the right atrium under radioscopic guidance. In case of failure to find or catheterize the cephalic vein, the technique was switched to the best alternative vein according to preoperative ultrasound findings (external jugular cutdown, or jugular or subclavian ultrasound-guided puncture).

Data collection and statistical analysis. Data related to ultrasound findings, demographics (body mass index [BMI], age, gender) and operative course (cephalic cutdown success/failure, use of other venous access, total operative time, time from skin incision to successful catheterization, local anesthetic volume, and complications) were recorded. The Fisher and Mann-Whitney *U* tests were conducted to determine differences between groups of patients. Predictors of failure of TIVAD insertion by cephalic vein denudation were identified by univariate logistic regression. Standard alpha level of 0.05 indicated statistical significance. Analyses were conducted using SPSS 18.0 (SPSS, Chicago, Ill) and STATA v15 (StataCorp, College Station, Tex).

RESULTS

The records of 160 consecutive patients undergoing elective or emergency TIVAD implantation by cephalic vein cutdown who had preoperative venous ultrasound were assessed. Table I shows the patient characteristics, indications for TIVAD, vein presence on ultrasound examination, and procedure course. Overall, the cutdown technique failed in 16% of patients, requiring a shift to the percutaneous ultrasound-guided approach (jugular internal or subclavian vein) or the external jugular vein open cutdown. All complications were observed in patients with failed cephalic vein cutdown (3/26 vs 0/134; $P < .001$). Complications included one subclavian artery puncture and two pectoral hematomas.

Patients with a visible cephalic vein on ultrasound imaging (137/160 patients [86%]) had more successful TIVAD insertion by cephalic vein cutdown (success rate: 121/137 [88%] vs 10/23 [43%] when the vein was not visible; $P < .001$). Patients with a failed TIVAD insertion by cephalic vein cutdown required a higher rate of use of additional means for facilitating TIVAD placement, including the use of a guidewire, the injection of contrast agent, a Trendelenburg positioning, and mobilization of the shoulder ($P = .005$).

An inability to visualize the vein on the preoperative ultrasound examination (odds ratio [OR], 4.39; 95% confidence interval, 1.57-12.30; $P < .05$) and depth of the vein (OR, 1.07; 95% confidence interval, 1.00-1.15; $P = .042$) were predictors of failure of TIVAD insertion by cephalic vein cutdown. Multivariate analysis could not be performed because the depth of the vein could not be assessed if the vein was not visible on ultrasound imaging (collinearity). Other variables (age, gender, BMI, diameter of the vein, length of the vein, nonvisibility of the vein junction, tortuosity of the vein, resident performing the surgery) were not predictors of TIVAD insertion failure (Table II).

To approximate the difficulty of the surgery and patient comfort, we further analyzed procedure duration and the volume of local anesthesia fluid (Supplementary Table I, online only). The duration of the procedure was significantly shorter (33.3 ± 15.3 minutes vs 45.8 ± 14.3 minutes; $P = .001$) and required less anesthesia fluid (18.8 ± 8.2 mL vs 24.3 ± 7.8 mL; $P = .005$) when the vein was visible on ultrasound imaging. In patients with a visible cephalic vein, the further identification of the junction of both cephalic and subclavian veins, and the morphology of the cephalic vein path (straight vs tortuous) were not associated with procedure duration or the volume of anesthetic fluid.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center prospective study
- **Key Findings:** One hundred sixty patients underwent cephalic vein cutdown for totally implantable venous access device (TIVAD) insertion. Inability to visualize the vein on the preoperative ultrasound imaging (odds ratio, 4.39; 95% confidence interval, 1.57-12.30; $P < .05$) and depth of the vein (odds ratio, 1.07; 95% confidence interval, 1.00-1.15; $P = .042$) were predictors of failure of TIVAD insertion.
- **Take Home Message:** Surgeons performing TIVAD insertion by venous cutdown should adapt their operative strategy according to preoperative ultrasound findings.

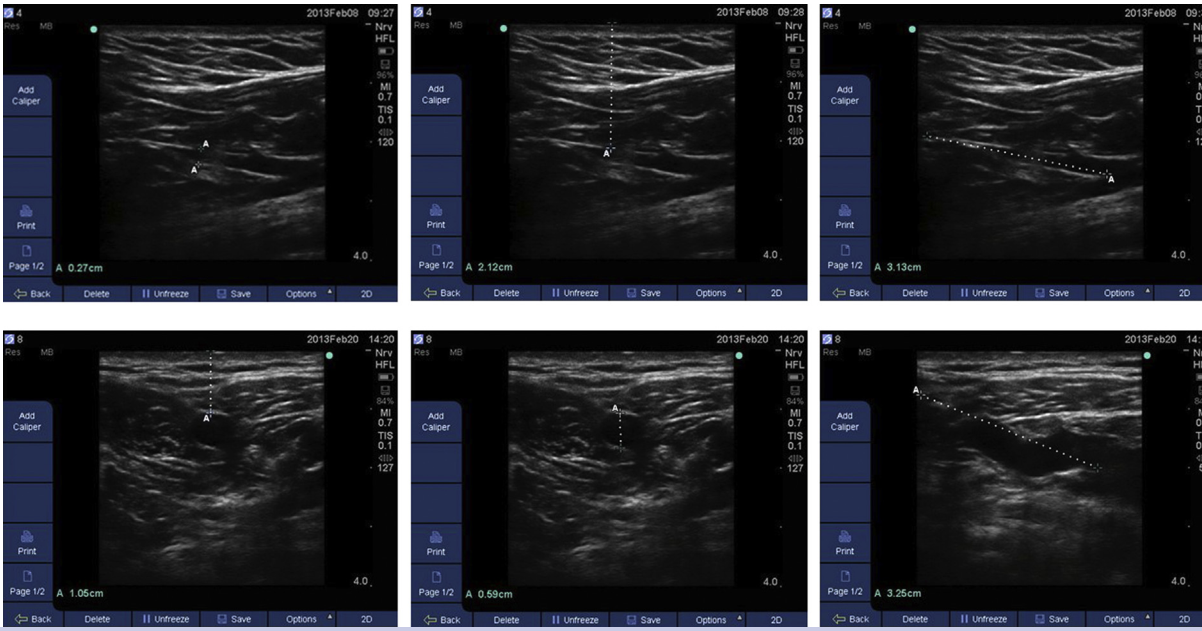

Fig 1. Measurement of ultrasonographic parameters of the right cephalic vein in two different patients. First row: cephalic vein diameter, depth of subcutaneous tissue, length of cephalic vein at the site of totally implantable venous access device (TIVAD) insertion. Second row: depth of subcutaneous tissue, cephalic vein diameter, length of cephalic vein at the site of TIVAD insertion.

In an effort to look for variables predicting a clinically accepted procedure time (in view of patient comfort), subsequent analyses were conducted looking at patients with surgical durations (from skin incision to the end of dressing) of 25 or less minutes vs more than 25 minutes (Supplementary Table II, online only). All procedures lasting 25 minutes or less were successful, and those lasting more than 25 minutes required a conversion to alternative surgical insertion methods. Procedures lasting 25 minutes or less were associated with a lower BMI ($P < .001$) and more superficial vein location ($P = .008$). In addition, shorter procedures required less anesthesia fluid (14.3 ± 4.2 mL vs 22.1 ± 8.7 mL; $P < .001$), and fewer additional perioperative maneuvers (1 vs 31; $P < .001$; Supplementary Table II, online only). Moreover, the part of the surgery sensitive to vein quality, for example, the time from skin incision up to appropriate positioning of the catheter in the vena cava, was almost three times shorter in the those in the 25-minute or less group (8.9 ± 2.7 minutes vs 24.4 ± 11.9 minutes; $P < .001$).

Fig 2. Right cephalic vein exposed in the deltopectoral groove after skin incision.

DISCUSSION

Performed under direct visual control, TIVAD placement by cephalic vein cutdown has traditionally been considered safer and easier than the percutaneous approach.[7] However, its higher failure rate and the longer procedure time are its main drawbacks, and some therefore still favor a percutaneous strategy.[8]

Ultrasound guidance is gaining in popularity, and it is currently recommended for any percutaneous central catheter insertion.[9] Similarly, it is increasingly used for safer percutaneous TIVAD placement. However, even in experienced hands, guided by ultrasound imaging or not, the potential for serious complications of the percutaneous approach cannot be fully avoided, with rates of pneumothorax, hemothorax, and arterial puncture of up to 3%.[10] In addition, the percutaneous approach does not circumvent the need for a skin incision and prefascial subcutaneous pocket creation (which could also be used for direct vein visual control). For these reasons, a number of authors believe that the open approach should be favored.[11]

The present study demonstrates that preoperative ultrasound cephalic vein assessment constitutes a reliable

Table I. Patient demographics (N = 160)

	Success (n = 134; 84%)	Failure (n = 26; 16%)	*P* value
Gender			
Female	83 (62%)	14 (54%)	.512
Male	51 (38%)	12 (46%)	
Age, years	60.3 ± 13.9	60.9 ± 13.4	.830
BMI	24.6 ± 5.3	24.5 ± 5.2	.900
Indication for TIVAD			
Chemotherapy	131 (98%)	25 (96%)	.185
Antibiotic therapy	0 (0%)	1 (4%)	
Parenteral nutrition	2 (2%)	0 (0%)	
Missing data	1	0	
Vein visible on ultrasound imaging			
Visible (n = 137)	121 (90%)	16 (62%)	<.001
Nonvisible (n = 23)	13 (10%)	10 (38%)	
Additional procedures[a]			
Yes	21 (16%)	11 (42%)	.005
No	113 (84%)	15 (58%)	
Immediate complications	0	3	<.001
Surgeon skills			
Registrar	41 (31%)	11 (44%)	.245
Resident	93 (69%)	14 (56%)	
Missing data	0	1	

BMI, Body mass index; *TIVAD,* totally implantable venous access device.
[a]Additional procedures needed to vein catheterization: guidewire use, radiocontrast injection, Trendelenburg position, and shoulder mobilization.

method for selecting patients suitable for open surgical dissection. Such an approach has previously been studied for pacemaker lead implantation providing a useful tool for prediction of feasibility.[12] In our hands, TIVAD insertion by cephalic vein cutdown was successful in 88% of patients when the vein was visible on ultrasound imaging. Absence of visibility of the vein was predictor of TIVAD insertion failure (OR, 4.39). This estimate is higher than the average success rates of open TIVAD implantation without prior ultrasound examination (from 71% to 85%[13-15]). Overall, the data suggest that the open cephalic technique should not be attempted in patients with no visible cephalic vein (success rate, 43%; OR for failure, 4.39). Alternative approaches, such as the puncture of the subclavian or jugular vein, or the open cutdown of the external jugular vein should be preferred.

Table II. Identification of predictive factors for totally implantable venous access device (TIVAD) insertion failure

	OR (95% CI)	*P* value
Age, years	1.00 (0.97-1.03)	.904
Male sex	1.41 (0.59-3.37)	.439
BMI	1.00 (0.92-1.08)	.940
Vein not visible ultrasound	4.39 (1.57-12.30)	.005
Diameter, mm	0.68 (0.43-1.06)	.091
Length, mm	0.98 (0.94-1.03)	.393
Depth, mm	1.07 (1.00-1.15)	.042
Junction of the vein not visible on ultrasound	1.97 (0.49-7.93)	.341
Tortuous vein	2.81 (1.00-7.93)	.051
Surgery performed by the resident	0.43 (0.18-1.03)	.059

BMI, Body mass index; *CI,* confidence interval; *OR,* odds ratio.

The failure of cephalic vein cutdown resulted in longer operative time and impaired patient's comfort. Conversely, operative time was short (<25 minutes) and patient comfort satisfactory (low need for local anesthetic) in patients with visible cephalic vein. In addition, the time for vein identification, catheterization and successful catheter positioning, was short (mean, 8.9 minutes) in these patients.

This study demonstrates that preoperative ultrasound imaging may allow choosing an alternative approach in selected cases where the cephalic vein approach might result in a high failure rate for centers performing cephalic vein cutdown for TIVAD placement. Therefore, it might help avoiding longer operative times and impairment in patient's comfort. The primary limitation of the study relates to the study design, as the operating surgeon was not blinded to the ultrasound result and this factor may have influenced surgeon persistence with the cephalic vein cutdown approach.

CONCLUSIONS

TIVAD implantation using the cephalic vein cutdown technique should only be considered as the primary approach for TIVAD when the vein is visible and its parameters are optimal in preoperative ultrasound. A patient-tailored approach with a switch to alternative approaches in patients with no visible vein should be adopted. The access to an ultrasound machine in the operating room and appropriate ultrasound skills of surgeon seem to be mandatory.

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AUTHOR CONTRIBUTIONS

Conception and design: WS
Analysis and interpretation: WS, SN, AM, JM, MR, PM, CT
Data collection: WS, AM
Writing the article: WS, SN, AM, JM
Critical revision of the article: WS, SN, AM, JM, MR, PM, CT
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WS and SN contributed equally to this article and share co-first authorship.

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Supplementary Table I (online only). Duration of procedure and total volume of anesthesia fluid used according to patient and ultrasound characteristics

	Duration of procedure, minutes	*P* value	Volume of anesthesia fluid, mL	*P* value
Gender (n = 160)				
Female	35.3 ± 16.0	.772	20.4 ± 9.1	.117
Male	34.6 ± 15.4		18.4 ± 6.9	
Vein visible on ultrasound imaging (n = 160)				
Visible	33.3 ± 15.3	.001	18.8 ± 8.2	.005
Nonvisible	45.8 ± 14.3		24.3 ± 7.8	
Veins junction[a] (n = 137)				
Yes	32.6 ± 14.5	.256	18.5 ± 7.7	.393
No	38.4 ± 19.8		20.9 ± 11.2	
Vein path (n = 137)				
Straight	32.7 ± 15.3	.510	19.3 ± 8.6	.288
Tortuous	34.6 ± 15.5		17.7 ± 7.2	

Values are presented as mean ± standard deviation unless otherwise noted.
[a]Junction of cephalic and subclavian vein visible on ultrasound imaging.

Supplementary Table II (online only). Comparison of short and long totally implantable venous access device (TIVAD) implantation in the overall population (N = 160) and according to vein ultrasound features

	≤25 minutes	>25 minutes or failure	*P* value
Sex[a]			
Female	30 (58)	67 (62)	.609
Male	22 (42)	41 (38)	
Vein visible on ultrasound[a]			
Visible	50 (96)	87 (81)	.008
Nonvisible	2 (4)	21 (19)	
Additional procedures[a]			
Yes	1 (2)	31 (29)	<.001
No	51 (98)	77 (71)	
Surgeon skills[a]			
Registrar	16 (31)	36 (34)	.857
Resident	36 (69)	71 (66)	
Missing	0	1	
Age, years[a]	61.8 ± 14.1	59.7 ± 13.6	.377
BMI[a]	22.6 ± 3.8	25.6 ± 5.6	<.001
Time to x-ray, minutes[a,b]	8.9 ± 2.7	24.4 ± 11.9	<.001
Anaesthesia fluid volume, mL[a]	14.3 ± 4.2	22.1 ± 8.7	<.001
Diameter[c,d]	3.3 ± 1.5	3.2 ± 1.3	.758
Depth[c,d]	17.5 ± 6.5	20.7 ± 7.4	.008
Length[c,d]	23.6 ± 10.6	24.1 ± 11.8	.794
Veins junction[d]			
Yes	45 (90)	75 (86)	.599
No	5 (10)	12 (14)	
Vein path[d]			
Regular	34 (68)	62 (71)	.702
Tortuous	16 (32)	25 (29)	

BMI, Body mass index.
Values are presented as number (%) or mean ± standard deviation unless otherwise noted.
[a]n = 160.
[b]Time in minutes measured from skin incision to the fluoroscopy confirmation of proper catheter tip position.
[c]In millimeters.
[d]n = 137.