Original Article

Supraclavicular ultrasound-guided catheterization of the brachiocephalic vein in infants and children: A retrospective analysis

ABSTRACT

Objective/Background: Ultrasound (US) facilitates central venous catheter (CVC) placement in children. A new supraclavicular approach using the brachiocephalic vein (BCV) for US-guided CVC placement in very small children has been recently described. In 2012, we changed our departmental standard and used the left BCV as preferred puncture site during CVC placement. In our retrospective analysis, we compared US-guided cannulation of the BCV with other puncture sites (control).

Design/Materials and Methods: We performed a retrospective analysis of all CVC cannulations from October 2012 to October 2013 in our department. For cannulation of the BCV, the in-plane technique was used to guide the needle into the target vein.

Results: We performed CVC cannulations in 106 children (age 1-day to 18 years). In 29 patients, the weight was <4.5 kg. CVC placement was successful in all patients. The left BCV could be used in 81.1% of all cases. In a Poisson regression model of punctures regressed by age, weight or group (left BCV vs. control), age, weight or the cannulation site did not influence the number of punctures. In a logistic regression model of complications (yes vs. no) regressed by the group (left brachiocephalic vs. control) an odds ratio of 0.15 was observed (95% confidence interval 0.03-0.72, *P* likelihood ratio test = 0.007).

Conclusion: US-guided puncture of the left BCV is a safe method of CVC placement in children. The use of the left BCV was associated with a high success rate in our retrospective analysis.

Key words: Brachiocephalic vein; central venous catheter; children; infant; ultrasonography; ultrasound

Introduction

Central venous catheters (CVCs) are often a necessity for surgery and the care of critically ill patients. The placement of a CVC in children, however, is technically difficult and remains challenging even for very experienced pediatric anesthesiologists. The use of ultrasound (US)-guided techniques facilitates the cannulation of central veins in children, and their use is becoming more and more the gold standard in the catheterization of central veins in children.[1-3]

In randomized trials, the use of US guided techniques reduced the number of cannulation attempts and decreased complications like the carotid artery puncture.[2,4] The internal jugular vein (IJV) is probably the most preferred

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anesthesiologists puncture site for central venous access. CVC placement in the IJV can be challenging for very small children because the size of the target vessel and advancement of the guidewire is often troublesome. The subclavian vein (SCV) access is generally associated with a higher rate of early mechanical complications,[1,5,6] the lower incidence of catheter-associated infections makes it the preferred site for long-term CVC placement, especially in very small patients.[7]

In 2007, Pirotte and Veyckemans described a method using US to cannulate the SCV from infraclavicular, whereas the US probe is placed at supraclavicular level.[8] Although, this method provides good needle guidance, and one is able to check the vessel patency, a disadvantage is the operator's inability to monitor the needle's advancement below the clavicle. Recently, Breschan *et al*. described an alternative method to cannulate the SCV in children using the brachiocephalic vein (BCV).[9] Here, the US-probe is placed in the supraclavicular region, and a longitudinal view of the junction of the IJV, the SCV, and the BCV is obtained. This allows the operator to monitor continuously the needle during the procedure while using the in-plane technique. In a retrospective analysis of their cases, Breschan *et al*. reported facilitated puncture of the left BCV as compared to right side.[10]

In 2012, after encouraging results in using this technique in preterm infants, we changed our departmental standard and used the left BCV, as the preferential puncture site for CVC cannulation. The aim of this analysis was to describe and analyze immediate outcomes of 106 CVC insertions during the first 12 months. In particular, we compared US guided cannulation of the BCV with other puncture sites (success rates, complications). In addition, we compared whether there is a difference between the left or right BCV puncture site.

Materials and Methods

Study population

A temporal cohort of patients, who received a CVC in our department from October 2012 to October 2013, where included in this analysis. After approval by the Local Ethical Review Committee, the catheterization protocols of 106 patients were retrospectively analyzed. The patients' demographics, as well as CVC indications, are described in Table 1.

Anesthesia management

After application of standard monitoring (electrocardiography, noninvasive blood pressure, SpO_2), the CVC cannulation was performed either under general anesthesia with surgery (n = 34), general anesthesia (n = 58) or sedation (n = 14) without surgery, and cannulation only. General anesthesia for cannulation was induced with fentanyl 2 μg/kg intravenous (i.v.) and propofol 2 mg/kg i.v. in 90 patients. After insertion of a laryngeal mask, anesthesia was maintained with sevoflurane. In 16 children, the CVC cannulation was performed using sedation with propofol up to 5 mg/kg i.v.

Puncture of the left brachiocephalic vein

Puncture of the left BCV has been performed under direct US-guidance using a transportable US system (SonoSite M-Turbo, SonoSite Inc., Bothell, WA) with a L25 (6-13 MHz) or a 12 L-RS (7-13 MHz) linear US transducer. The BCV was visualized at the level of the sternoclavicular joint, and the puncture was performed using a strict in-plane technique as described recently.[9]

Statistical analysis

The complication was estimated in a logistic regression model, regressed by the group (left brachiocephalic vs. control). The control was defined as all others. The significance of the factor (i.e., the group) was tested in a likelihood ratio test comparing to the null model (i.e., constant factor only). The effect was reported as odds ratio (OR) and 95% confidence interval (CI). The significance of the effect was additionally tested using the Wald's test (H0: OR = 1, H1: OR ≠ 1). The number of punctures was tested in a Poisson, regression model. The significance of the group was again tested in a likelihood ratio test comparing the model (number of punctures- group) to the null model (number of punctures — constant). The effect was reported as incidence density ratio and its 95% CI. Since reduced body size may hamper cannulation and the vessel size is smaller at younger ages, the complication and number of punctures were analyzed using weight and age as factors in a similar way (logistic regression model and Poisson regression model).

Results

General results

A total of 124 punctures has been carried out in 106 patients during the study period. The left BCV was chosen in 86 patients (81.1%), the right BCV in 10 patients (9.4%), the right IJV in six patients (5.6%), the left IJV in one patient (0.9%), and a femoral vein in three patients (2.8%). The reasons for not choosing the left BCV are demonstrated in Table 2. US was used during all CVC cannulations. Typical US images are illustrated in Figure 1. Furthermore we compared patients, who received a CVC in the left BCV (left brachiocephalic, n = 86), with patients, who have been cannulated elsewhere (control, n = 20).

Success rates

Correct intravascular placement of the catheters was possible in 100%. In all patients (n = 106), CVC cannulation was

Table 1: Patient demographics

Weight classification	<2500 g	2600 g-4.5 kg	4.6 kg-10 kg	11 kg-20 kg	>20 kg	Total
Number of patients	7	22	21	21	35	106
Median age						
Years	0.01	0.13	0.83	3.6	10.4	2.74
Months	0.1	1.7	9.9	43.6	126.4	34.7
Days	3	50	296.5	1307	3793	1058.5
Median weight (kg)	2.3	3.5	8	17.8	35	12.95
Reason for cannulation						
Parenteral nutrition	3	8	2	1	2	16
Dialysis/plasma seperation	0	0	0	3	6	9
Prolonged intravenous therapy	4	13	17	11	21	66
Trauma/surgery	0	1	2	6	6	15
Anesthesia during procedure						
General anesthesia (ITN, LMA)	7	22	20	18	23	91
Sedation	0	0	1	3	12	15
Central venous catheter (size) (cm)						
5	6	17	3	0	0	26
8	1	5	18	14	0	38
12	0	0	0	2	1	3
13	0	0	0	5	16	21
16	0	0	0	0	17	17
18	0	0	0	0	1	1
Success	7	22	21	21	35	106
Complications						
Artery puncture	0	1	0	0	0	1
Catheter malposition	0	0	1	0	1	2
Inability to advance wire	1	1	0	0	0	2
Target vessel not detectable	0	0	0	2	0	2
Thoracic duct injury	0	0	0	0	0	0
Pneumothorax	0	0	0	0	0	0
Total punctures	7	25	27	23	42	124

LMA: Laryngeal mask airway; ITN: Intubation

successful in 94 patients (88.7%) on the first attempt, in 8 patients (7.5%) on the second attempt, in 2 patients (1.9%) on the third attempt, and in 2 patients (1.9%) on fourth attempt. In the left brachiocephalic group ($n = 86$), CVC cannulation was successful in 76 patients (89.5%) on the first attempt, in 7 patients (8.1%) on the second attempt, in 1 patient (1.2%) on the third attempt, and in 1 patient (1.2%) on fourth attempt. In the control group ($n = 20$), CVC cannulation was a successful in 17 patients (85%) on the first attempt, in 1 patient (5%) on the second attempt, in 1 patient (5%) on the third attempt, and in 1 patient (5%) on the fourth attempt. In a Poisson regression model of punctures regressed by age, weight or group (left brachiocephalic vs. control), age, weight or the cannulation site did not influence the number of punctures [Table 3].

Complications

As depicted in Table 1, we observed 7 (6.6%) early complications during the study period. In a logistic regression model of complications (yes vs. no) regressed by the group (left brachiocephalic vs. control) an OR of 0.15 was observed (95% CI 0.03-0.72, P likelihood ratio test = 0.007). Age or weight did not predict complications in a logistic regression model [Table 4]. Figure 2 depicts the distribution of complications regarding age and weight in a scatterplot.

Discussion

In our series, US-guided CVC placement was possible in 100% and the vast majority of the CVC could be placed with one attempt. The cannulation of the left BCV proved to be an eligible alternative in comparison to other puncture sites. Use of the left BCV was associated with fewer side effects. Age or weight did not predict complications or the number of punctures.

As already mentioned, US can alleviate puncture of central venous veins in children.[2,5] The routine use of US at our department can be credited, at least in some part, with the 100% success rate seen in our patients. We do, however, admit, the use the landmark technique also can also lead to impressive results, as recently demonstrated by Malbezin *et al*.[11]

Percutaneous central venous vein access is aggravated by multiple causes in pediatric patients, which cannot be overcome entirely by the use of US. The access to the IJV is limited due to the special anatomic circumstances in infants, like the shortness of the neck. The size of the IJV in very small children makes it difficult to advance the J-shaped guide wire. Moreover, the IJV easily collapses under the pressure of a US probe. It is possible to avoid some of these problems, using the SCV for catheter placement, because of the anterior wall fixation of the vessel on the clavicle. However, hemothorax and pneumothorax are more commonly associated with catheterization of the SCV.[6] As demonstrated in 2007, US can be used meaningful during infraclavicular SCV catheterization.[8] Disadvantages of this approach include the operator's inability to visualize the needle with US while it is under the clavicle. Moreover, the infraclavicular SCV approach is not recommended for long-term catheters in children.[12] A novel supraclavicular approach has been described by the groups of Breschan *et al*. as well as Rhondali *et al*.[9,13] in 2011. As already mentioned, the supraclavicular longitudinal in-line approach offers an excellent visibility of both needle and the vessel. Moreover, the pleural fascia can be easily visualized using this access, which makes the occurrence of a pneumothorax rather unlikely. It is not always possible to discriminate between the BCV and SCV during cannulation using this approach; clinically, however, this is of lesser relevance since both veins provide a direct access to the superior vena cava. In contrast, to Rhondali *et al*., who opted for the right BCV, Breschan *et al*. used primarily the left BCV for CVC cannulation, which they deemed easier for right-handed operators. Interestingly, Rhondali *et al*. feel exactly the opposite regarding this matter and routinely use the right side for cannulation.[9,13] In a follow-up study Breschan *et al.* reported greater success rates using the left BCV instead of the right side.[10] This probably results from the different anatomic conditions. The BCV is formed by the union of the SCV and IJV at the level of the sternoclavicular joint. The left BCV is thicker, and its length is approximately twice that of the right BCV. Facilitated CVC cannulation via the left BCV, especially in very small infants, therefore, seems comprehensible. If choosing the left BCV, one runs the risk to injure the thoracic duct.[14] However, CVC cannulation related chylothoraces as well as a lesion of the thoracic duct also have been reported after puncture of the right IJV as well as the SCV.[15,16] In our series, we did not encounter a chylothorax or lesion of the thoracic duct. One chylothorax, we did encounter in our patients, was related to a surgical procedure.

Table 2: Reasons for alternate puncture site

Reason	Percentage
Operator's discretion	9 (45)
Pneumonia on the left side	5 (25)
Inability to visualize the target vessel	2 (10)
Infection on puncture site	2 (10)
Catheter *in situ*	1 (5)
Chylothorax on the left side	1 (5)
Total	20 (100)

The left BCV proved to be an easily accessible vessel for CVC cannulation in our series, only in two cases, visualization failed, and an alternative vein had to be chosen. Apart from obvious medical reasons, like pneumonia or catheter infections on the corresponding side, operator's discretion was the number one reason for not choosing the left BCV. The majority of these cases result from spatial limitations in our X-ray examination unit, where CVC have been placed while the children were in general anesthesia during an exam. In this room, due to space constraints through equipment and theater nurses the right side was preferentially chosen.

Our success rates after the first attempt were slightly superior to the numbers given by Breschan *et al*., Rhondali

Table 3: Poisson regression predicting puncture

Variable	Crude IDR (95% CI)	Adjusted IDR (95% CI)	*P* (Wald's test)	*P* (LR-test)
Age days (control variable)	1 (0.9997, 1.0002)	1.0002 (0.9994, 1.0009)	0.653	0.657
Kg (control variable)	0.99 (0.96, 1.03)	0.97 (0.88, 1.07)	0.547	0.543
Groups: Left brachiocephalic versus control	0.47 (0.18, 1.25)	0.44 (0.16, 1.19)	0.105	0.123

Log-likelihood = −53.4126; Number of observations = 106; AIC value = 114.8252; CI: Confidence interval; IDR: Incidence density ratio; LR: Likelihood ratio

Table 4: Logistic regression predicting complication

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	*P* (Wald's test)	*P* (LR-test)
Age days (control variable)	0.9996 (0.9989, 1.0002)	0.9982 (0.9954, 1.0011)	0.222	0.186
Kg (control variable)	0.96 (0.89, 1.03)	1.14 (0.86, 1.51)	0.376	0.393
Groups: Left brachiocephalic versus control	0.15 (0.03, 0.72)	0.09 (0.02, 0.53)	0.008	0.007

Log-likelihood = −20.389; Number of observations = 106; AIC value = 48.7779; OR: Odds ratio; CI: Confidence interval; IDR: Incidence density ratio; LR: Likelihood ratio

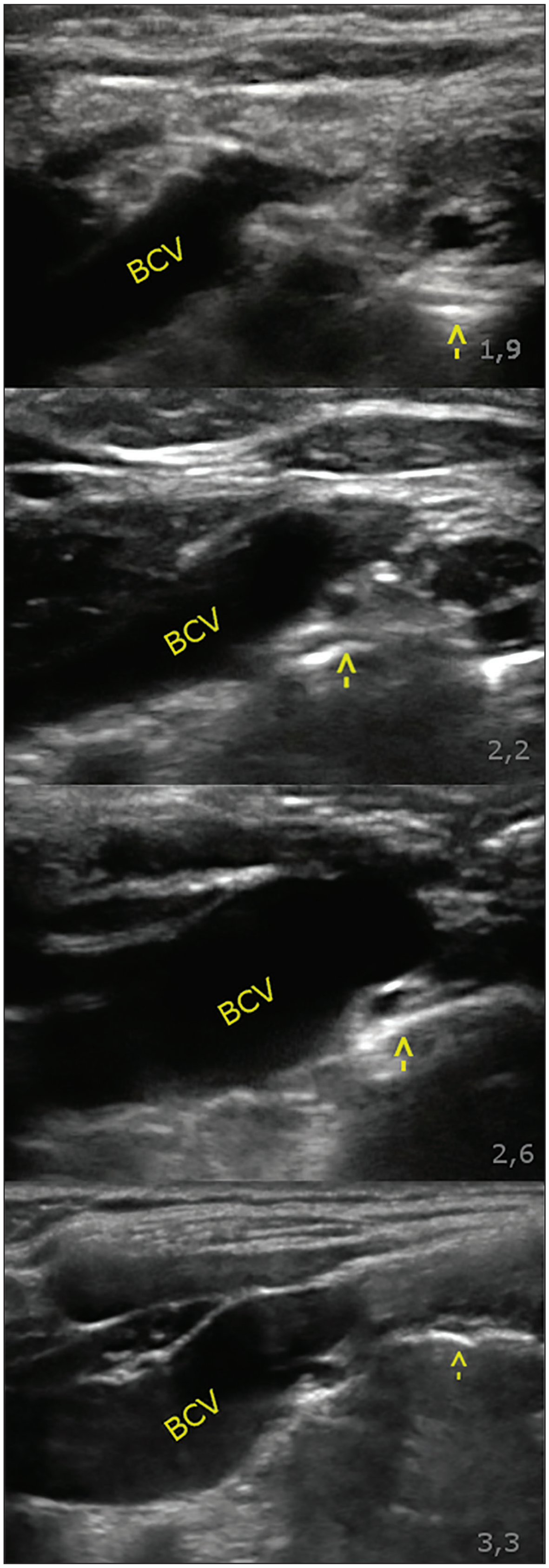

Figure 1: Ultrasound images of the anatomy respectively, the brachiocephalic vein of a 1 kg body weight (BW) infant, 5 kg BW, 10 kg BW child, and a 48 kg BW teen. Regardless of age and weight, always the same anatomical image can be identified. The arrows (↑) mark the pleura of the lungs being visible

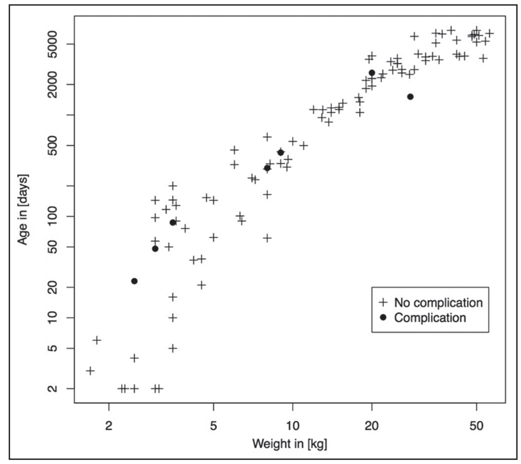

Figure 2: The distribution of complications regarding age and weight

et al. as well as Pirotte and Veyckemans.[8,9,12] The operators in our series, however, are all well versed in the technique of US-guided CVC cannulation, and moreover the method described by Breschan *et al*. and Rhondali *et al*. was already used in selected patients at our department. The existence of learning curves during percutaneous CVC cannulations has been described before.[17] Much to our surprise age or weight did not influence the number of punctures or complications in our patients. This is, however, in-line with the observations made by Di Nardo *et al*., while using the left BCV for CVC insertion.[18]

Our complication rate compares less favorably with the figures given by others,[11,19] but the definition of a complication varies greatly in different publications.[5] We did not encounter any pneumo- or hemothorax during our series; the most severe complication was one arterial puncture. If catheter malpositions are added to the complication definition, like in other publications,[5] the left BCV is associated with fewer complications as compared to the alternate cannulation sites. This originates are most likely again from the different anatomic conditions at right and the left side. The right BCV is shorter and takes a sharp angled caudal turn, whereas the left BCV runs more horizontally.

Limitations of our study are the retrospective nature as well as the preference of the left BCV as the premier cannulation site. Only randomized prospective trials will be able to clarify a possible superiority of one cannulation site over the other.

Conclusion

Ultrasound-guided puncture of the left BCV is a safe alternative to CVC placement in children. The use of the left BCV was associated with fewer complications in our retrospective analysis.

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Conflicts of interest

There are no conflicts of interest.

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