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Consecutive, prospective case series of a new method for ultrasound-guided supraclavicular approach to the brachiocephalic vein in children

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Editor's key points

- A supraclavicular approach to ultrasound-guided brachiocephalic vein cannulation in children is described.
- First-time puncture rate was good and catheters were placed successfully in all cases.
- Cannulation was more difficult in lower weight, younger children.
- Further studies are needed to compare this with other approaches.

Background. During ultrasound (US)-guided cannulation of the subclavian vein (SCV) via an infraclavicular route, the view of the needle behind the clavicle may be obscured. This study describes the US-guided supraclavicular cannulation of the brachiocephalic vein (BCV).

Methods. The 25 mm broadband linear array US probe was placed in the supraclavicular region to obtain a longitudinal view of the BCV beginning at the junction of the internal jugular vein and SCV. Using the in-plane technique, the needle was directed under US guidance into the BCV.

Results. Forty-two cannulations in 35 patients (aged 26 months−8 yr, weight range 0.96–21 kg) were included. Central venous catheter placement was successful in all children. In 31 patients (73.8%), the BCV was successfully punctured on the first attempt, in six patients (14.2%) after two attempts, and in five patients (11.9%) after three attempts. Significantly more puncture attempts were needed in the smaller weight and younger children, whereas the time course of the study had no significant impact on the success rate.

Conclusions. This US-guided method offers a new possibility for central venous line placement in small children. It provides good needle guidance without any disturbing US shadow caused by bony structures.

Keywords: children; ultrasound; vein, subclavian, brachiocephalic

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Central venous catheters can be of vital importance during surgery and the postoperative care of neonates, infants, and young children. However, percutaneous catheter insertion in infants is a challenge even for the experienced anaesthetist. Ultrasound (US)-guidance techniques have become the gold standard for catheterization of the internal jugular vein (IJV) in children.[1–7] However, the subclavian vein (SCV) may be the preferred site for long-term central venous catheterization owing to the lower incidence of catheter-associated infection.[8] Recently, Pirotte and Veyckemans[9] described a US-guided infraclavicular approach to the SCV, but with this method, the advancement of the needle below the clavicle cannot be seen using US. When using US scanning for the IJV and SCV, we found that an excellent longitudinal view of the junction of the IJV and the SCV and of the brachiocephalic vein (BCV) can be obtained easily using a US probe placed in the supraclavicular region and without any US shadow caused by bony structures. Therefore, we performed a pilot study to evaluate a new approach for US-guided supraclavicular BCV catheterization in children. The results of our first consecutive 42 cannulations are described.

Methods

After approval by the Ethics authority of Land Kaernten (Ref: A09/10) and after obtaining written informed consent from the parents, we used this US-guided approach subsequently for all central venous lines required by children <10 yr of age undergoing a major surgical procedure over a period of 6 months. The only exclusion criterion was inadequate US visualization of the BCV.

Equipment

We used a US device with a 13-6 MHz and 25 mm broadband linear array transducer (Micromaxx, Sonosite, Inc., Botholl,

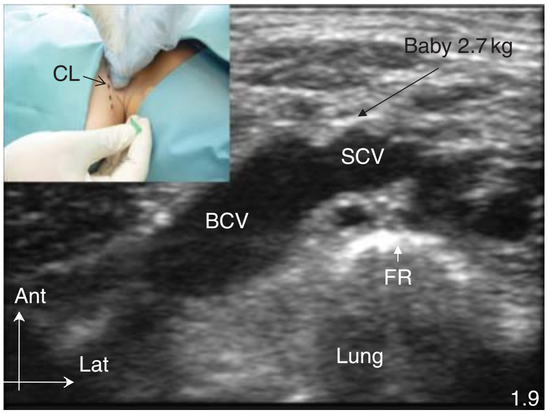

Fig 1 Ultrasonographic longitudinal view of the left BCV in a 2.7 kg infant. US probe placed in the supraclavicular region to obtain a longitudinal view of the left BCV. (Inset) Right-handed operator holding the needle without attached syringe in the right hand. CL, clavicle. US image: SCV, subclavian vein; BCV, brachiocephalic vein; FR, first rib; black arrow indicating the direction of the needle entry.

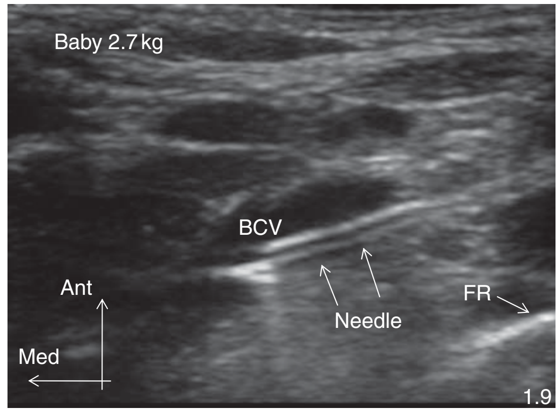

Fig 2 Tip of the 4 cm 21 gauge needle (arrow) within the left BCV of a 2.7 kg infant. BCV, brachiocephalic vein; FR, first rib.

WA, USA) (Fig. 1). The US unit was set on a resolution with a depth of 1.9 cm for infants and 2.2 cm for children. Colour flow was not applied routinely.

Principles of the technique

The US probe was placed in the supraclavicular region to obtain a longitudinal view of the BCV beginning at the junction of the IJV and the SCV (Fig. 1). Using the in-plane (IP) technique, the needle was directed under US control into the BCV.[10]

Protocol for positioning and US scanning of the BCV

All catheterizations were performed in the operating theatre under general anaesthesia including neuromuscular block and tracheal intubation. Children were placed in a head-down position. A standard-sized towel roll was placed under the shoulders. The patient's head was turned 45° to the side opposite to the cannulation. The operator (both right-handed) positioned himself next to the left side of the child's body while facing the head of the patient when attempting to cannulate the left BCV. For the cannulation of the right BCV, the operator was positioned at the child's head while facing the body of the patient. The US image was positioned as such to enable the operator to see both the US picture and patient's landmarks. By placing the US probe perpendicular to the skin at the level of the cricoid cartilage, a cross-sectional view of the IJV was obtained. The probe was then moved caudally after the IJV until the junction of the SCV and IJV was reached. After that the probe was turned slightly medially and caudally until a good longitudinal view of the BCV beginning at the junction of the IJV and SCV was obtained (Fig. 1). All catheterizations were carried out by two right-handed anaesthetists experienced in central venous line placement in children.

Protocol for sterile cannulation

Aseptic technique was used during the insertions. This included the use of sterile gloves, drapes, and facemasks. The patients' skin was disinfected by rubbing the site of insertion with sterile gauze soaked in a solution of 2% chlorhexidine in 70% alcohol and was allowed to dry. The US probe together with some unsterile gel was inserted into a sterile glove. Sterile gel (Gerosonic-S; Gerot Pharmazeutika, Vienna, Austria) was applied between the probe cover and the skin. A 4 cm 21 gauge needle (Arrow; Arrow International, Inc., Reading, PA, USA) was used for infants and children weighing more than 4.5 kg and initially a 2 cm 22 gauge needle (Seldiflex; Plastimed, Saint-Leu-la-Forêt, France) for neonates weighing <4.5 kg. For the last five neonates, a 4 cm 21 gauge needle (Arrow) was used as well. During the puncture of the vein, light pressure on the liver was applied in neonates. The US probe was then placed as described previously until a good longitudinal view of the BCV was obtained (Fig. 1). While holding the probe in the left hand, the needle without attached syringe was positioned using the right hand (Fig. 1). The needle pierced the skin close to the US probe.

Using the IP approach, the needle was then advanced strictly under the long axis of the US probe until visualized on the US screen. The tip of the needle was then guided under direct US vision into the BCV (Fig. 2). If there was a good spontaneous return of blood flow via the needle, the US probe was withdrawn and a J-shaped 0.018 in. (0.46 mm) guidewire (Arrow or Cook Inc., Bloomington, IN, USA) was introduced into the vein. If according to the US image the tip of the needle was believed to be inside the vein without a spontaneous return of blood flow, a syringe was attached in order to try to aspirate blood while slowly withdrawing the needle. After successful blood aspiration, the guidewire was introduced into the vein. If blood could not be aspirated, the US probe was again placed in the supraclavicular region so as to obtain a good longitudinal view of the

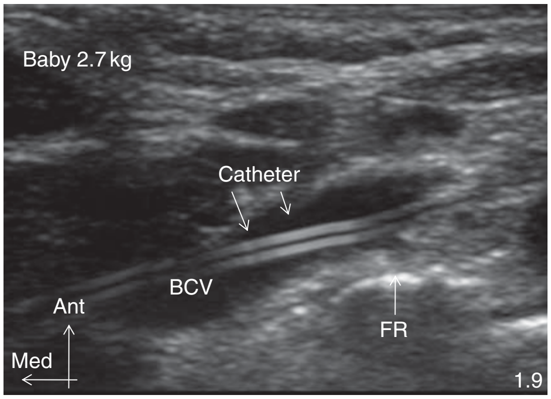

Fig 3 Two French single-lumen catheter (Seldiflex) placed in the left BCV of a 2.7 kg infant. BCV, brachiocephalic vein; FR, first rib.

BCV and the tip of the needle was redirected into the vein under direct US vision.

If the guidewire could not be advanced successfully, the needle and the guidewire were removed and the procedure was repeated as described previously. After the successful guidewire advancement, the correct position was confirmed by US. A 2 Fr single-lumen catheter (Seldiflex) was threaded over the guidewire into the vein in neonates and a 4 Fr double-lumen catheter (Arrow) in infants and children (Fig. 3). Aspiration of blood and X-ray were used to confirm the correct position of the catheter.

Data collection

The following data were recorded by a written and computerized protocol at the time of cannulation: patient's weight and post-conceptual age (PCA), that is, weeks=gestational+post-natal age; side (left or right); number of puncture attempts (one attempt=each piercing of the skin by the needle) until successful placement of the tip of the needle within the vein, that is, until a spontaneous return of blood flow or positive blood aspiration via a syringe was achieved; difficulties encountered in advancing the guidewire; complications, such as arterial puncture, pneumothorax, and haematoma; central venous catheter material and length of the needle; name of the physician attempting cannulation.

Statistical methods

The Kolmogorov–Smirnov test was used to test the normal distribution of data.

Correlations between variables (body weight *vs* number of puncture attempts; age *vs* number of puncture attempts) were tested by the χ^2 analysis and Fisher's exact test. The influence of relevant variables on binary data (success at first puncture attempt) was investigated by the logistic regression model. *P*-values <0.05 were considered as statistically significant. Data were analysed using R (Version 2.7.0, 2008; The R Foundation for Statistical Computing, ISBN 3-900051-07-0, http://cran.r-project.org), respectively (elementary statistics and figures) in HP-RPL (Ver. 2.08, 2006; Hewlett-Packard Company, San Diego, CA, USA).

Results

During a 6 month period, 42 BCVs were cannulated in 35 children and infants. The patients' PCA ranged from 26 to 420 weeks [median 52 weeks, inter-quartile range (IQR) 38–144 weeks] and the weight ranged from 0.96 to 21 kg (median 6.75 kg, IQR 2.8–13 kg) (Table 1). Weight and age were not normally distributed (Kolmogorov–Smirnov test: $P<0.01$). The primarily targeted BCV and junction of the IJV and SCV could be identified via US in all children, so data from all patients were included. The left BCV was cannulated in 35 cases and the right BCV in seven.

Ultimate success, that is, successful placement of the central venous catheter in the primarily targeted vein, was 100%. In 31 patients (73.8%), the BCV was successfully punctured on the first attempt, in six patients (14.2%) after two attempts, and in five patients (11.9%) after three attempts (Tables 1 and 2). No complications, such as arterial puncture, were noted.

Significantly more puncture attempts were required with smaller weight and younger children ($P<0.05$) (Tables 1 and 2). The logistic regression model also showed that success at first puncture varied significantly according to weight ($P<0.01$) (Fig. 4) and also according to age ($P<0.05$). The success rate improved over the time course of the study; however, this improvement was not statistically significant (logistic regression model adjusted for weight: $P=0.4$). The length of the needle in neonates did not have a significant impact on the success rate (Fisher's exact test: $P=0.12$).

Discussion

In this series, using US-guided puncture of the BCV in children via the supraclavicular approach, cannulation was successful in all, the majority at the first attempt and no serious complications occurred. This longitudinal in-line approach offers a good view of both the needle and the vein. It cannot always be clearly distinguished whether it is the BCV or in fact the SCV which is being punctured but this is not important in clinical practice as the puncture of any of these veins at this site provides a direct line to the superior vena cava where the tip of the catheter is eventually to be placed. The left BCV was the first choice for the two right-handed operators because their positioning beside the patient's body was more practical and convenient for them. The right BCV was the primary target only when specific indications were present, for example, right-sided thoracotomy. Not surprisingly, the most significant cause for a failed puncture attempt in our children was the small size of the vein in the very young infants[11] particularly in infants weighing <2.5 kg (Tables 1 and 2).

More than two attempts (regarded as a criterion for an increased incidence of complications) were needed in five infants.[12] Two of these infants weighing 2.5 and 3.3 kg, were Numbers 2 and 3, respectively, of this case series

Table 1 Collected data of all study patients. Significantly more puncture attempts were required the smaller the weight and the younger the age of the child (χ^2 analysis: $P<0.05$)

Patient number	PCA (weeks)	Weight (kg)	BCV (left/right)	Number of punctures	Complications at punctures	Complications of guidewire advancement
1	272	11	Left	1		
2	36	2.5	Right	3		
3	44	3.3	Right	3		
4	46	4.5	Left	1		
5	168	13	Left	1		
6	41	2.2	Left	1		
7	37	2.8	Left	1		
8	40	3	Left	2		2 attempts
9	136	11	Left	1		
10	96	8.8	Left	2		
11	38	3.3	Left	1		
12	34	1.8	Left	2		
13	26	0.9	Left	3	Puncture of cystic structure	
14	96	8	Left	1		Into left IJV
15	80	10	Left	1		
16	420	17	Left	1		
17	320	19	Left	1		
18	300	14	Left	1		
19	112	13	Left	2		
20	31	1.1	Left	3	Poor view of BCV	
21	124	18	Left	1		
22	32	1.3	Right	2	Poor view of BCV	2 attempts
23	144	11	Left	1		
24	116	9	Left	1		
25	49	5.5	Left	1		
26	232	16	Left	1		
27	216	17	Right	1		
28	38	3.2	Left	2		
29	196	15	Left	1		
30	32	1.2	Left	3		
31	48	4	Left	1		
32	64	8	Left	1		
33	38	3.1	Left	1		
34	112	9	Left	1		
35	32	1.3	Left	1		
36	328	21	Left	1		
37	46	5.5	Left	1		
38	60	8	Right	1		
39	168	14	Left	1		
40	36	1.9	Right	1		
41	36	1.9	Right	1		
42	39	3	Left	1		

(Table 1). The vein of the 2.5 kg baby was also severely distorted due to an underlying congenital diaphragmatic hernia with a severe mediastinal shift. We attribute these failed attempts to the lack of experience with this new method, which is in keeping with the trend towards a lower number of required puncture attempts over the time course of this study. The third patient requiring more than two attempts was a 960 g baby in whom we initially inadvertently punctured a cystic structure. However, when following the IJV leading into the BCV as proposed by our protocol, the left BCV was correctly identified as such and the puncture of the BCV was successful immediately. Thus, these failures

Table 2 Relation between the weight and number of puncture attempts. χ^2 analysis: $P<0.05$

Number of puncture attempts	1	2	3	Total
Weight (kg)				
0–2.5	4	2	4	10
2.6–4.5	6	2	1	9
4.6–10	8	1	0	9
10.1–21	13	1	0	14
Total	31	6	5	42

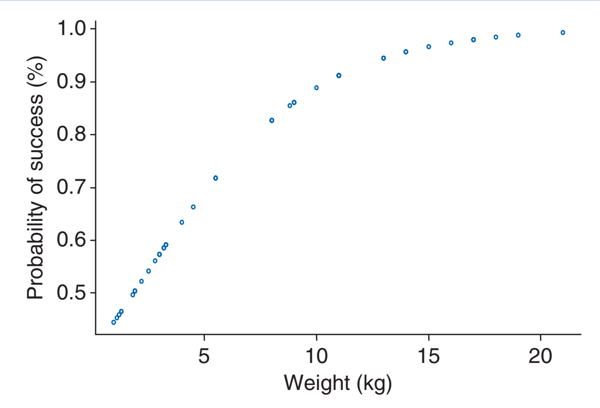

Fig 4 Probability of success at first venous puncture plotted against patient weight. This relationship was statistically significant ($P<0.01$) by logistic regression modelling.

could be explained by deviations from the procedure protocol. The left SCV and BCV of the fourth and fifth baby, weighing 1.1 and 1.3 kg, respectively, could not be as clearly viewed via US as usual, probably due to a partial thrombotic occlusion caused by previously peripherally inserted central venous lines.[13] This could eventually have been the reason for the failed attempts. Therefore, we consider that the low weight of all five patients contributed to the higher failure rate.

In addition to increasing experience with the technique, another explanation for the reduction in number of puncture attempts over the time course of our study could also be a slight change of the length of the needle in neonates. We used a 2 cm needle for infants <4.5 kg initially. This required the puncture of the skin very close to the US probe, leading to the compression of the skin and neighbouring tissue below the probe and a distorted view of the BCV on the US image. In order to avoid this, we changed the protocol by using a 4 cm needle (Arrow) for the last five neonates who weighed 3.2, 1.3, 1.9, 1.9, and 3 kg, respectively. Thus, the puncture of the skin was possible further laterally to the US probe without significant distortion of the tissue under the US view enabling the successful puncture on the first attempt in these five infants. However, the low number of neonates (n=19) in this study precludes a definitive recommendation in favour of the longer needle in neonates.

The advancement of the guidewire proved to be difficult in third children. In two babies (weighing 3 and 1.3 kg), the J-shaped guidewire could only be successfully advanced on the second attempt after recannulation of the vessel. In a third 8 kg child, the guidewire first passed into the ipsilateral left IJV which meant that the tip of the needle was initially positioned in the SCV. The median size of the SCV in infants from 1.4 to 4.5 kg is around 3.2 mm.[11] Therefore, the advancement of the smallest available J-shaped guidewire (diameter 2 mm) can be a major problem. Conversely, straight-tipped guidewires can easily get caught by the various angles of the small veins upon advancement.

In our opinion, the great advantage of this supraclavicular approach compared with the infraclavicular approach described by Pirotte and Veyckemans is the absence of a bony structure such as the clavicle preventing visualization of the needle during advancement.[9] Although the total number of attempts using this method was slightly greater, the success rate in children >2.2 kg weight was similar to that described by Pirotte and Veyckemans. Before this study, our two authors performing cannulations had 12 month experience using US-guided vascular and regional techniques. Together they used to perform about 70 IJV and SCV punctures in children per year using the landmark technique.

The greatest challenge with our method is the hand–eye coordination required when using the IP technique, which is a particular problem in very premature infants. Only a slight lateral movement of the US probe which can easily occur while piercing the skin with the needle leads to the loss of the view of the targeted vessel and sometimes the needle can also not be visualized. Good support of the hand holding the US probe may help to reduce this problem. In non-neonates, this problem is far less evident.

It is notable that the pleural fascia can be visualized via US very well when using this approach; therefore, we believe that a pneumothorax is very unlikely to occur. Unfortunately, the brachiocephalic artery can usually not be visualized. The use of US also enables catheter placement control and exclusion of a pneumothorax.[14] However, a chest X-ray remains the gold standard for the exact determination of the position of the catheter tip.

There was a non-significant improvement of the puncture success over the time course of the study. Including our post-study experience and assuming the operator has had experience with central venous line placement in children, we believe that around 15 cannulations in infants weighing <4.5 kg are needed in order to be comfortable with this method in neonates.

In the future, the inclusion of more patients may result in an improved success rate; however, it may also result in more complications. Furthermore, randomized trials are required to determine whether the US-guided infra- or supraclavicular approach to the SCV/BCV is superior.

In conclusion, this supraclavicular US-guided method offers a new option for central venous line placement in small children, neonates, and even premature infants. It shows a good view of the underlying anatomy without disturbing the US shadow. The most significant cause for failure was small infant weight; as with any new method, performance tended to improve with increased experience of this approach.

Conflict of interest

None declared.

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