

# Use of ultrasound for vascular access during cardiac catheterisation in children with congenital heart disease: a Swiss multicentre cohort study

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## Summary

**AIM OF THE STUDY:** Our study aimed to assess the first-attempt success rate of ultrasound (US) and anatomical landmark (ALM) guidance for vascular cannulation in children with congenital heart disease in Switzerland.

**METHODS:** A prospective observational multicentre study was conducted from January 2022 to January 2023 in three university hospitals in Switzerland. We included patients with congenital heart disease aged 0 to 18 years who were scheduled for elective cardiac catheterisation. Periprocedural data were collected anonymously. The choice of vessel and guidance technique were at the operator's discretion.

**RESULTS:** 177 arterial and 240 venous cannulations in 253 patients were analysed. The median age and weight were 4.4 years (interquartile range [IQR] 1.2–8.8) and 15 kg (IQR 8–27), respectively. Nearly all operators, 97.5%, were deemed experienced. The femoral artery and femoral vein were the most preferred vessels. US guidance was used in 62% of procedures, predominantly with in populations who were younger, smaller and of lower weight. The success rate at the first attempt was notably higher with US guidance for arterial cannulation (US: 80%, ALM: 37%,  $p < 0.001$ ) and venous cannulation (US: 78% vs ALM: 47%,  $p < 0.001$ ). Overall success rates for venous and arterial cannulation were comparable between ultrasound and anatomical landmark guidance. A total of 45 complications (10.5%) occurred, with immediate uncomplicated haematoma being the most frequent.

**CONCLUSION:** US guidance is preferred for the localisation and cannulation of vessels during cardiac catheterisation within paediatric cardiology departments in Switzerland. Given its high success rate for first-attempt cannulation, US warrants additional research to evaluate its potential in reducing complications.

## Introduction

Central venous and arterial cannulation success is essential in patients with congenital heart disease because of the large number of punctures they undergo in their lifetime.

Improving the success rate and reducing complications help to preserve suitable veins and arteries for future vascular cannulation [1].

Vascular cannulation in children can be achieved either by anatomical landmark (ALM) or ultrasound (US) guidance. US is currently advocated in this population yet there is no clear evidence of its superiority or recommendation for its systematic use in cardiac catheterisation. Indeed, there are studies evaluating US guidance for femoral vein cannulation or radial artery cannulation in paediatrics, but the number of studies assessing femoral artery cannulation is limited. Most published data comparing fluoroscopy with US guidance come from adolescent and adult studies [2–4]. A few studies compared ultrasound with anatomical landmark guidance for venous and arterial cannulation in children and showed US guidance to be more effective, resulting in a reduced rate of cannulation failure and complications [5, 6].

However, there are no recommendations in the literature concerning the most effective method of gaining vascular access in children. Our study investigated the use of ultrasound and anatomical landmark techniques in different paediatric cardiology centres in Switzerland and evaluated the success rate and complications associated with each method while also considering the operator's level of expertise.

## Materials and methods

A prospective observational multicentre quality study was conducted at three university hospitals in Switzerland: CHUV in Lausanne, Inselspital in Bern and HUG in Geneva. From January 2022 to January 2023, the study recruited patients who met the following inclusion criteria: (1) age between 0 and 18 years, (2) patient with congenital heart disease, (3) scheduled for elective cardiac catheterisation. The elective procedure was performed independently of our study, and no action was planned to modify the course of the procedure, particularly the choice of technique used. As quality research, the regional state ethics commission waived the informed consent requirement.

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### Data collection

A case report form (CRF) was prepared and sent to the operators. Patients were referred to only by a unique participant number for the research protocol. The operator recorded the information in a secure database (REDCap<sup>®</sup>).

### The procedure

The three university hospitals each include a paediatric department that encompasses a paediatric cardiology service with interventional cardiology activities. The heads of the paediatric cardiology services were approached and provided with a case report form detailing the data to be completed. Additionally, in case of any queries, the principal investigator was available to provide assistance.

All patients were admitted in accordance with the protocol of the respective hospital, with a minimum of 24 hours of monitoring following the endovascular procedure. Regarding the data collected in the case report form, information related to weight, height, blood pressure and heart rate was recorded on the day of the procedure. During the procedure, a catheterisation lab nurse recorded the start and end times of the procedure as well as the type of equipment used in the intervention report, which was subsequently collected for calculation of the intervention duration. Operator experience in the two techniques was taken into consideration. We arbitrarily defined an experienced operator as one who had performed more than 100 punctures using each method. Only the Seldinger technique was used, which involves the insertion of a small gauge needle until blood is drawn out. A wire was then inserted in the vessel, and a sheath was placed in the vessel over the wire for catheter access.

### Outcomes

The primary objective of the present study was to assess the success rate at first attempt of arterial and venous cannulation procedures guided by anatomical landmark or ultrasound guidance. Secondary objectives were to examine the overall success rate of vascular cannulation and also at third attempt according to anatomical landmark and ultrasound guidance, as well as the assessment of the incidence of immediate and short-term complications associated with the procedure. Comparison groups between anatomical landmark and ultrasound guidance for venous and arterial cannulation were also assessed. Further subgroup analysis was conducted based on age and weight categories, with similar analyses performed for each subgroup.

#### Outcome definitions

For the purpose of this study, an attempt was defined as a needle that passed through the skin and was removed entirely. Successful cannulation was considered when the sheath was placed in the target vein or artery. We counted the number of attempts to cannulate the vessel without removing the needle. The total duration of the intervention from the first sheath placement to the last sheath removal was assessed. Complications related to the procedure during the first 24 hours were recorded. The overall success rate for cannulation did not account for any limitations on the number of attempts. As an example, consequently, the

success rate on the third attempt corresponds to the complete withdrawal of two needles and a successful puncture and cannulation on the third attempt.

Complications were classified as “immediate” if they occurred in the cardiac catheterisation room or “short-term” if they occurred outside the cardiac catheterisation room during the initial 24-hour follow-up period. A complicated puncture was defined as haematoma, thrombosis, accidental venous puncture or arterial spasms for arterial procedures and accidental arterial puncture for venous procedures. US examination to detect complications was performed only in cases of clinical suspicion of vessel injury or thrombosis. Other collected data included general information such as age, weight, heart rate, arterial pressure and prior or complication-related puncture.

### Statistical analysis

Data were summarised using descriptive statistics, with medians and interquartile ranges (IQR) for continuous variables and n (%) for categorical variables. Fisher’s exact test was used for categorical variables. The Mann-Whitney U test was used for non-normally distributed and numerical values. Statistical analyses were performed with Stata/SE version 17.0 (StataCorp<sup>®</sup>).

## Results

### Characteristics of the cohort

In total, 253 patients were enrolled in the study, comprising 177 arterial and 240 central venous catheterisations. The median age was 4.4 year (IQR 1.2–8.8), while the median weight and height were 15 kg (IQR 8–27) and 103 cm (IQR 74–131), respectively. The median blood pressure and heart rate were 84/45 mm Hg (IQR 75/40–92/52) and 100 bpm (IQR 82–120). A previous history of arteriovenous or complicated punctures was identified in 130 (52%) and 48 (19%) patients, respectively. Experienced paediatric cardiologists performed 346 punctures (83%), with trainees (17%) performing the rest of the punctures. A summary of the patients’ characteristics is provided in table 1.

The characteristics of the study population, such as weight, height and age, were compared at cannulation level and exhibited statistically significant differences when comparing ultrasound and anatomical landmark guidance methods ( $p < 0.001$ ). Additionally, the use of US was found to be more prevalent when a previous history of arteriovenous puncture (166 [64%] vs 59 [37%],  $p < 0.0001$ ) or a history of complicated puncture was found (56 [22%] vs 25 [16%],  $p = 0.03$ ). Table 1 presents a comparative analysis of patient characteristics between the ultrasound and anatomical landmark techniques.

### Characteristics of the arterial procedure

In total, 177 arterial procedures were performed. The most chosen technique for cannulations was US guidance in 114 (64%) cases overall and in 39 (89%) cases aged under one year. Overall, the femoral artery was the only site for arterial access. The median sheath size used was 4 Fr (IQR 4–4), and the median duration of the procedure was 60 min (IQR 45–80).

Successful cannulation at the first attempt was achieved in 91 (80%) patients with US guidance and in 23 (37%) patients with ALM guidance, with a significant difference in favour of US ( $p < 0.0001$ ). This difference was still present at the third attempt, with 113 (100%) patients with US guidance and 55 (87%) patients with ALM guidance ( $p < 0.0001$ ). However, the overall success rate did not show a statistically significant difference, with 114 (100%) vs 61 (97%),  $p = 0.12$ . The duration of the intervention was significantly longer for the US technique (68 [mean 50–105] min) than for the ALM technique (45 [mean 36–65] min).

Detailed analysis based on patient age or weight confirmed that the success rate on the first attempt was significantly higher with use of US guidance. This statistically significant difference in favour of US guidance was only observed up to the third attempt in patients weighing more than 10 kg and aged over 1 year. No significant difference was observed in overall success rates. Table 2 summarises characteristics by subgroups.

### Characteristics of the venous procedure

A total of 240 venous procedures were performed, with the preferred technique being US guidance in 144 (60%) cases overall and in 45 (87%) cases aged under one year. Out of all interventions, only 2 (0.8%) cases required a change of technique, in every case a switch from anatomical landmark to US guidance. The preferred localisation for venous access was the femoral vein in 216 (90%) procedures and the internal jugular vein in 24 (10%) procedures. The median sheath size used was 5 Fr (IQR 4–7), and the median duration of the procedure was 60 min (IQR 45–80).

Successful cannulation was achieved at the first attempt in 113 (78%) patients with US guidance and 45 (47%) patients with ALM guidance, with a significant difference in favour of US ( $p < 0.0001$ ). This difference in favour of US guidance was no longer maintained at the third attempt, with 140 (97%) patients with US guidance and 92 (95%) patients with ALM guidance ( $p = 0.51$ ). The overall cannulation success rate was 100% with US guidance and 100% with ALM guidance. The duration of the intervention was

significantly longer with the US technique than for the ALM technique (65 min [mean 50–100] vs 53 min [mean 40–65],  $p < 0.0001$ ).

Analysis based on patient age or weight showed that the success rate on the first attempt was significantly higher with the use of US. However, this significant difference was only present at the first attempt within the subgroups. Table 3 summarises characteristics by subgroups.

### Complications of the procedure

Complications were observed in 45 procedures without a significant difference in the complication rate between ultrasound and anatomical landmark guidance ( $p = 0.78$ ). Immediate complications were observed in 36 (9%) procedures, with uncomplicated haematoma being the most frequent complication: 12 (3%) for arterial procedures and 14 (3%) for venous procedures. Other immediate complications included one accidental venous puncture, seven arterial spasms for arterial procedures and one accidental arterial puncture for venous procedures. Short-term complications were rare, with 4 (1%) venous thromboses for venous procedures.

### Discussion

Our observations can be summarised as follows: (1) US guidance for localisation and vessel cannulation is the preferred technique in the majority of Swiss paediatric heart centres, particularly for patients aged under 1 year. (2) US guidance has a higher first-attempt successful cannulation rate than anatomical landmark guidance. (3) The overall success rate between US and ALM guidance remains unchanged.

### Studies comparing anatomical landmark and ultrasound guidance for veins

Our study presents a notably high success rate for venous procedures with no significant difference in overall cannulation rate between US and ALM guidance. Among studies comparing these two methods, a meta-analysis conducted

**Table 1:**

Baseline characteristics. Continuous variables are expressed as medians and interquartile ranges. Categorical variables are expressed as counts and percentages.

	Ultrasound-guided puncture		Anatomical landmark-guided puncture
	n = 253	n = 258	n = 159
	Patient level		
Age in years	4.4 (1.2–8.8)	2.6 (0.6–10.0)	5.6 (3.0–9.5)
Height in cm	103 (74–131)	90 (64–131)	111 (92–135)
Weight in kg	15 (8–27)	12.0 (6.2–28.0)	18.0 (12.0–29.0)
History of arteriovenous puncture	130 (51%)	166 (64%)	59 (37%)
History of complicated puncture	48 (19%)	56 (22%)	25 (16%)

**Table 2:**

Arterial and venous procedural information according to cannulation guidance technique. Variables are expressed as n (%).

	Arterial approach, n = 177			Venous approach, n = 240		
	Ultrasound guidance	Anatomical landmark guidance		Ultrasound guidance	Anatomical landmark guidance	
	n = 114	n = 63		n = 144	n = 96	
Patient-level			Patient-level			
Success rate at first attempt	91 (80%)	23 (37%)	<0.0001	113 (78%)	45 (47%)	<0.0001
Success rate at third attempt	113 (100%)	55 (87%)	<0.0001	140 (97%)	92 (95%)	0.51
Overall success rate	114 (100%)	61 (97%)	0.12	144 (100%)	96 (100%)	–

by Souza et al. concluded that using US guidance for venous cannulation, including use of the femoral and internal jugular veins, reduces the risk of overall cannulation failure compared to using ALM guidance [5]. However, there are only two published randomised studies comparing the two type of cannulation (ALM vs US guidance) for the femoral vein, yielding somewhat divergent results on the overall cannulation success rates.

One of them conducted by Aouad et al. compared ultrasound and anatomical landmark guidance for central vascular cannulation through the femoral vein in randomised paediatric patients undergoing major cardiac surgery [7]. The success rate at the first attempt was significantly higher for US guidance but without a significant difference in the overall success rate. Similarly Eldabaa et al. conducted a randomised study with paediatric patients undergoing major cardiac surgery, also comparing US and ALM guidance for central vascular cannulation through the femoral vein [8]. The success rate at the first attempt was also significantly higher for US guidance but also for the overall success rate. A potential reason for this lack of difference in the overall success rate is that the study populations were different (neonates for Eldabaa et al. vs infants for Aouad et al.) and the operators were only residents in training in the study by Aouad et al.

Our survey shows that US guidance is favoured, with 85% of all venous procedures in patients under one year of age. The reasons for the more significant use of US in this population were not investigated in this study; however, it may potentially indicate more challenges within this population.

### Studies comparing anatomical landmark and ultrasound guidance for arteries

The literature on arterial cannulation is scarce, and most randomised studies have been focused on radial artery cannulation, with US guidance being the standard of care [6]. Apart from this, we found only two randomised studies comparing US and ALM guidance for femoral artery cannulation. In these two investigations, Siddik-Sayyid et al. and Salik et al. carried out randomised studies comparing US and ALM guidance for central vascular cannulation via the femoral artery in infants undergoing elective cardiac surgery [9, 10]. Siddik-Sayyid et al. demonstrated that the success rate at first attempt was significantly higher with

the use of US guidance; however, the overall success rate revealed no significant differences. In contrast, Salik et al. observed substantial differences in both the first-attempt success rate and the overall success rate.

As for studies on venous cannulation, Salik et al. focused only on a neonatal population, while Siddik-Sayyid et al. enrolled patients under 12 years old. Moreover a subgroup analysis by Siddik-Sayyid et al. also suggested that US guidance for femoral artery cannulation may benefit children under six months of age [9]. In terms of expertise, in the former study, the operators were residents in anaesthesia, and in the latter study, the interventions were performed by senior anaesthetists with at least three years of practice and US guidance certification. These diverging data in overall success rate are potentially explained by differences in study populations and operator experience.

US guidance was preferred in 89% of arterial cannulations for patients under one year of age, similar to venous cannulations.

### The role of ultrasound guidance

The number of professionals certified for US-guided vascular access is as low as 24% [11, 12], with possible reasons for underuse being the lack of availability of the ultrasound device and the lack of training in its use. Training models have been developed and have demonstrated their usefulness in increasing the success rate of cannulation among inexperienced operators [13]. In our dataset, 97.5% of the procedures were conducted by experienced cardiologists, which precludes an assessment of the impact of experience on success.

Reported availability and use of the US technique for vascular puncture in children exhibit substantial variability across studies. Indeed, studies indicate that US availability is high and routine use can oscillate between 23% and 85% [12, 14]. In Switzerland, specifically at our three university centres, the US approach rate for vascular access was 60–65% for venous and arterial cannulation in the catheterisation room and this rate increased to 87–89% among patients aged under one year.

The ultimate aim of US guidance should be to reduce the risk of complications. Following venous cannulation, only one meta-analysis reported a significantly lower incidence of accidental arterial puncture with US guidance and found

**Table 3:** Procedural information according to age and weight. Variables are expressed as counts and percentages.

		Arterial approach, n = 177			Venous approach, n = 240		
		Ultrasound guidance	Anatomical landmark guidance		Ultrasound guidance	Anatomical landmark guidance	
		n = 114	n = 63		n = 144	n = 96	
Success rate at first attempt	≤1 year old	29/39 (74%)	0/5 (0%)	0.001	38/46 (84%)	2/7 (29%)	0.001
	>1 year old	62/75 (84%)	23/58 (40%)	<0.0001	75/98 (77%)	43/89 (48%)	<0.0001
Success rate at third attempt	≤1 year old	39/39 (100%)	5/5 (100%)	–	44/46 (98%)	7/7 (100%)	0.69
	>1 year old	75/75 (100%)	50/58 (87%)	0.001	96/98 (98%)	85/89 (96%)	0.34
Success rate at first attempt	≤10 kg	37/49 (76%)	0/8 (0%)	<0.0001	51/62 (82%)	3/11 (27%)	<0.0001
	>10 kg	55/49 (85%)	23/55 (40%)	<0.0001	63/82 (77%)	42/85 (49%)	<0.0001
Success rate at third attempt	≤10 kg	49/49 (100%)	7/8 (88%)	0.013	61/62 (98%)	11/11 (100%)	0.67
	>10 kg	65/65 (100%)	48/55 (87%)	0.003	80/82 (98%)	81/85 (95%)	0.43

variability in the haematoma frequency ranging from 0 to 28% [5]. As reported in the literature, the range of complications associated with arterial puncture varies (0–15%), with no significant differences observed between US and ALM guidance [9, 10]. In our study, regardless of the technique used, the primary complication observed was a haematoma. However, this did not lead to any reported adverse outcomes during the 24-hour monitoring period following venous or arterial procedures. We noted only four cases of haematoma reported within 24 hours because the patients showed clinical symptoms. Furthermore, we did not assess the methods of arterial and venous compression or the level of anticoagulation during the procedure, factors that could influence the occurrence of complications such as haematomas.

### Limitations

This observational, multicentre survey has some limitations. The study reflects the current use of US guidance for vascular access in cardiac catheterisation and was not designed to assess the superiority of one method of vascular access over the other. Furthermore, given the nature of this observational study, it is subject to potential biases, including selection bias, which may arise due to the presence of different populations associated with the operator's discretionary choice of technique. An information bias cannot be ruled out, considering the case report form was filled out by the operator, who, despite being briefed on the information required prior to the start of the study, may introduce inaccuracies. The outcomes of the two techniques should not be generalised beyond the populations studied in this paper, and their comparison should be interpreted in light of these limitations.

### Conclusion

Our findings align with existing literature indicating that the use of US guidance for the localisation and cannulation of vessels during cardiac catheterisation represents the primary methodology within paediatric catheterisation laboratories in Switzerland, particularly for patients under one year of age. Despite variations in study populations, US-guided vascular cannulation has proved to be more efficient and successful for first-attempt access. The impact of the operator's experience on puncture success was not assessed, as nearly all operators were deemed experienced. Nevertheless, the literature underscores the significance of implementing comprehensive training programmes to enhance success rates.

### Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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### Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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