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ORIGINAL ARTICLE

Femoral Arterial Thrombosis After Cardiac Catheterization In Infancy: Impact of Doppler Ultrasound for Diagnosis

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Abstract Femoral arterial thrombosis (FAT) is a non-negligible complication after cardiac catheterization (CC) in infancy. The aim of this study was to evaluate the impact of Doppler ultrasound (US) for diagnostic work-up after catheterization. We compared *standard follow-up* (FU) without Doppler US by relying on clinical signs of FAT with *advanced FU* using Doppler US of the femoral vessels. Between January and December 2009, we evaluated the rate of FAT in infants <12 months of age using a multicenter, prospective observational survey. We analysed 171 patients [mean age 4.1 ± 3.3 (SD) months; mean body weight 5.3 ± 1.8 kg] from 6 participating centres. The mean duration of catheter studies was 57.7 ± 38.0 min. The overall rate of FAT based on clinical diagnosis was 4.7 % and was comparable in both groups [3.4 % undergoing standard FU vs. 7.4 % undergoing *advanced FU* ($p = 0.15$)]. However, the overall rate of thrombosis as screened by Doppler US was greater at 7.1 %, especially in patients after advanced FU [18.5 % advanced vs. standard FU 1.7 % ($p < 0.01$)]. In conclusion, FAT remains a relevant and underestimated complication after catheterization in young infants when relying only on clinical signs of FAT. Therefore, to start effective treatment as soon as possible, we recommend Doppler US to be performed the day after CC.

Keywords Pediatric catheter intervention · Complication · Arterial thrombosis

Introduction

The most frequent and relevant complications after cardiac catheterization (CC) using femoral vascular access in early childhood are arterial and venous thrombosis [11, 12, 20]. Femoral artery thrombosis (FAT) has been reported to occur

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in 8–39 % of young infants [7, 8, 19]. Premature babies with birth weight <1,500 g, term newborns, and young infants <1 year of age are at particular risk of thrombosis among the pediatric population [2, 16]. Cardiac disease has been reported to be a risk factor for thrombosis in childhood [1]. Patency of vascular access is mandatory in children undergoing subsequent procedures during their lifetime.

The estimated number of unknown cases of asymptomatic forms of FAT in pediatric patients is probably high, and these cases are often missed due to the immediate recruitment of the collateral femoral artery vessels. Nevertheless, during long-term FU, FAT may lead to compromised arterial supply of the distal leg with claudicatio intermittens and significant leg length discrepancies at later age. Postthrombotic syndrome may occur in cases of femoral venous thrombosis [18]. FAT can be diagnosed clinically with apparent different findings at the lower extremities, including skin colour and temperature, capillary refilling time, blood pressure, and palpable pulse. Nevertheless, the clinical presentation of FAT in infancy may be subtle, and therefore the diagnosis of FAT can be missed. Doppler ultrasound (US) of the femoral artery, including Doppler flow pattern and colour Doppler modality, may detect partial or complete obstruction of the femoral artery even in clinically inconspicuous cases. The aim of the study was to determine the impact of Doppler US as an additional diagnostic tool in making the diagnosis of FAT after CC in infants.

Methods

Study Design

The study was planned and designed as a prospective, multicenter, clinical observational survey to evaluate the rate of FAT in infants <1 year of age after CC. The survey was performed on behalf of the Working Group Interventional Cardiology of the German Association of Pediatric Cardiology. During 1 year, all consecutive patients were included undergoing CC for diagnostic purposes or therapeutic interventions.

The primary end point of the trial was the rate of FAT on the day after CC as documented by clinical diagnosis. Criteria of clinical diagnosis of FAT were defined as cold and pale lower extremities with decreased or absent palpable pedal pulses and low blood pressure (systolic blood pressure difference >20 mmHg between both legs). The second end point was the rate of FAT as determined by Doppler US, which was primarily based on obstructed pulsatile flow pattern on Doppler US and colour Doppler using a linear 12-MHz transducer on high-end US equipment. Furthermore, we analysed risk factors contributing to FAT.

To analyse the impact of Doppler US on the diagnosis of FAT, we defined two study groups: (1) the group called *standard FU* included all patients whose diagnosis of FAT was made clinically and secondarily confirmed by Doppler US; and (2) the called *advanced FU* included those patients who underwent Doppler US as a routine procedure the day after CC independent of clinical signs of FAT.

All data were collected by a questionnaire, which was sent to participating centres performing pediatric CC, including therapeutic interventions, in Switzerland and Germany. The following data were analysed: age; sex; weight; length; cardiac diagnosis; cyanosis [defined as transcutaneous oxygen saturation ($tcSo_2$) with moderate (80–90 %) and severe cyanosis (<80 %)]; anticoagulation before and after CC; congestive heart failure (defined as need for inotropics, such as adrenaline); haemoglobin; hematocrit; and femoral artery puncture before CC. Additional periprocedural data including cumulative frequency of vessel puncture, type and size of sheath used, need for sheath exchange during CC, procedure time, pedal pulses palpable before leaving CC laboratory, and mode of anticoagulation during CC were analysed. Postprocedural data included clinical signs of FAT during the first 24 h after CC according to our previously described criteria. FAT determined by Doppler US was defined as an abnormal obstructed flow pattern with partial or complete arterial obstruction on Doppler and colour Doppler.

Doppler US was performed the day after CC after pressure dressings were removed. Doppler US was performed by an experienced pediatric radiologist using a 12-MHz linear US probe in vascular mode and included two-dimensional colour and pulsed-wave Doppler flow. Ethical approval for the study and data collection was obtained according to the guidelines of the local ethics committees.

Statistics

For descriptive statistics, values are shown as mean ± SD. Statistical comparison between the patients of the two defined study groups, *standard FU* and *advanced FU*, was performed using Mann–Whitney test for comparison of metric data, and Chi-square test was used for comparison of frequencies; $p < 0.05$ was considered statistically significant.

Results

Patients

Between January and December 2009, the survey identified 249 consecutive patients from 6 participating centres in Germany and Switzerland. Data sets of femoral arterial access were available for 171 patients (92 female) for

statistical analysis. CC was performed at (mean ± SD) a patient age of 4.1 ± 3.3 months and a body weight of 5.3 ± 1.8 kg; the procedure time was 57.7 ± 38.0 min. Cardiac diagnoses were acyanotic congenital heart disease ($tcSo_2 > 90$ %) in 61.8 % and cyanotic congenital heart disease ($tcSo_2 \leq 90$ %) in 39.2 % of patients, with 23.4 % of patients having moderate ($tcSo_2$ 80–90 %) and 15.8 % having severe cyanosis ($tcSo_2 \leq 80$ %). A minority of patients (11.9 %) undergoing CC were treated for congestive heart failure.

Complications

On the day after CC, 18 of 171 patients (10.5 %) had clinical complications or pathologic findings on Doppler US. Clinical complications included signs of arterial thrombosis in 8 (4.7 %) and groin hematoma in 5 (2.9 %) patients. Pathologic findings on Doppler US occurred in 12 patients (7.1 %), including complete in 9 and partial arterial thrombosis in 3 patients.

Femoral Artery Thrombosis

Therefore, the overall rate of FAT made by clinical diagnosis was 4.7 %. Rates of FAT were comparable ($p = 0.15$) in both study groups: 3.4 % of patients with *standard FU* (clinical diagnosis) compared with 7.4 % in patients with *advanced FU* (including additional Doppler US).

The overall rate of FAT detected by Doppler US screening was greater at 7.1 % [18.5 % in patients with advanced FU vs. 1.7 % in patients with clinical FU ($p < 0.01$)]. Table 1 lists different parameters of the two FU modalities. Table 2 lists the patients with a complicated course after CC and gives a detailed overview and relationship to different risk factors for FAT.

Vascular Access

Regarding the modalities of femoral artery puncture, the majority of patients (71.4 %) had not been punctured before CC. However, femoral artery access had been established before CC at least one time in 23.1 % of patients and more than one time in 5.5 % of patients, including preceding CC or arterial lines placed during intensive care treatment.

The right femoral artery was preferred (82.5 %) for vascular access compared with the left femoral artery (10.5 %) and both arteries (7 %). Only one successful puncture was needed in 62.2 % of patients; two to five attempts were needed in 34.5 % of patients; and more than five attempts were needed in 3.3 % of patients. Exchange of the arterial sheath during CC was necessary in 7 % of patients.

Anticoagulation

Anticoagulation before CC [including acetylsalicylic acid (18.9 %) and heparin (7.5 %)] was given in 26.4 % of all patients, but no patient was placed under phenprocoumon medication (0 %). Anticoagulation during CC was performed in 83.6 % of patients using heparin (intravenous dose 100 IU/kg after puncture) and after CC at least for the first 24 h in 86 % of patients using heparin or low molecular weight heparin in therapeutic dosages. One patient was treated with thrombolytic therapy after CC and was excluded from further analysis.

Table 1 Comparison of infants (<12 months) undergoing CC with standard FU (clinical signs, differences of pulse, blood pressure by Doppler US) with those undergoing advanced FU (including additional Doppler US) screening for FAT

Characteristics	All ($n = 171$)	Standard FU ($n = 117$)	Advanced FU ($n = 54$)	p
Age (months)	4.1 ± 3.3	4.0 ± 3.3	4.4 ± 3.4	0.42
Body weight (kg)	5.3 ± 1.8	5.3 ± 1.9	5.2 ± 1.6	0.72
Body length (cm)	59.3 ± 8.4	59.5 ± 8.3	58.8 ± 8.5	0.53
Arterial sheath size (F)	4.01 ± 0.25	4.05 ± 0.26	3.94 ± 0.23	0.14
Study time (min)	57.7 ± 38.0	55.6 ± 40.9	60.2 ± 34.6	0.20
Hemoglobin (g/dl)	13.4 ± 2.4	13.5 ± 2.8	13.3 ± 2.4	0.52
Hematocrit	40.4 ± 8.0	40.5 ± 7.8	40.3 ± 8.3	0.67
Cyanosis ($tcSo_2$ <90 %) (%)	39.2	35.9	46.3	0.34
Anticoagulation during CC (%)	83.6	83.8	92.6	0.62
Anticoagulation after CC (%)	86.0	84.6	88.8	0.53
No. (%) with clinical signs of thrombosis	8 (4.7)	4 (3.4)	4 (7.4)	0.15
No. (%) with thrombosis by Doppler US	12 (7.1)	2 (1.7)	10 (18.5)	0.01

Data are given as mean ± SD. For statistical analysis, Mann–Whitney test was used for comparison of metric data, and χ^2 test was used for comparison of frequencies

Table 2 Overview of 18 infants (<12 months) with complications undergoing CC after standard FU (patients no. 14–18) and advanced FU (patients no. 1–13) using Doppler US screening for FAT

Patient no.	Body weight (kg)	Age (months)	Diagnosis	Cyanosis[a]	CHF[b]	Previous puncture	No. of punctures	Sheath size (F)	Sheath change	Anticoagulation during/after catheterization		Clinical outcome	Doppler US
1	4.0	2	ReCoA	No	**Yes**	**Yes**	1	4	No	Yes	Yes	Normal	Complete thrombosis
2	7.8	4.1	AP window	No	No	No	1	4	No	Yes	Yes	NIBP difference	Complete thrombosis
3	3.9	0	Aortic valve stenosis	No	**Yes**	No	1	4	No	Yes	Yes	Normal	Complete thrombosis
4	4.0	2.3	ReCoA	No	No	**Yes**	2–5	4	No	Yes	Yes	Normal	Complete thrombosis
5	4.5	0.9	ReCoA	No	No	No	1	4	No	Yes	Yes	Normal	Complete thrombosis
6	3.0	1.0	Tricuspid atresia	**Severe**	**Yes**	No	2–5	4	**Yes**	Yes	Yes	Normal	Complete thrombosis
7	6.2	4.8	ReCoA	No	**Yes**	No	1	4	No	Yes	Yes	Hematoma	Normal
8	2.2	2.4	Pulmonary valve stenosis	No	No	No	1	4	No	Yes	Yes	NIBP and pulse differences	Complete thrombosis
9	3.4	1.7	TGA after arterial switch	No	No	**Yes**	1	4	No	Yes	Yes	NIBP and pulse differences	Complete thrombosis
10	3.6	0.5	CoA	**Moderate**	**Yes**	No	2–5	4	No	Yes	Yes	Hematoma	Partial thrombosis
11	4.7	4.4	VSD	No	No	No	1	4	No	**No**	**No**	Hematoma	Normal
12	3.6	0.3	CoA	No	No	No	1	4	No	Yes	Yes	Pulse difference	Partial thrombosis
13	5.8	7.1	DORV, TGA	**Moderate**	No	No	2–5	4	No	Yes	Yes	Hematoma	Normal
14	3.3	0.2	TOF	No	No	**Yes**	2–5	4	No	Yes	Yes	Pulse difference	Normal
15	3.8	0.2	Double aortic arch	No	No	No	2–5	4	No	Yes	**No**	NIBP difference	Complete thrombosis
16	4.7	0.3	DCM	No	No	No	2–5	4	No	Yes	Yes	Pulse difference	Partial thrombosis
17	5.3	3.0	PA/VSD	**Moderate**	No	No	1	4	No	Yes	Yes	Pulse difference	Normal
18	6.9	4.6	Aortic valve stenosis	No	No	**Yes**	**>5**	4	No	Yes	Yes	Hematoma	Normal

Risk factors are given in bold text

AP aortopulmonary, *CHF* congestive heart failure, *CoA* coarctation of aortic arch, *DORV* double outlet right ventricle, *DCM* dilated cardiomyopathy, *NIBP* noninvasive blood pressure, *PA* pulmonary atresia, *TGA* transposition of great arteries, *TOF* tetralogy of Fallot, *VSD* ventricular septal defect

[a] Cyanosis was defined as moderate (80–90 %) or severe (<80 %) transcutaneous oxygen saturation

[b] CHF was defined as need for inotropics

Discussion

The etiology of arterial thrombosis in childhood in most cases is secondary to vessel trauma, e.g., arterial catheterization, vessel sheaths, or arterial monitoring lines, whereas primary noncatheter related arterial thrombosis is rare [14]. Therefore, the most frequent type of catheter-related arterial thrombosis after CC requires peripheral and umbilical artery catheterization [14]. The frequency of catheter-related arterial thrombosis has increased due to the substantial progress made in pediatric intensive care, thus enabling better survival rates of patients with life-threatening diseases [9].

The main findings of this survey were that the clinical diagnosis of FAT occurring after CC in infancy was made in 4.7 % of all cases (3.4–7.4 %), whereas the rate of diagnosis made by routine Doppler US was exceedingly greater at 18.5 % (Table 1).

The clinical diagnosis of FAT on the first day after CC was made using the previously mentioned criteria. Using oscillometric blood pressure measurement, even when optimized by additional hand-held Doppler pencil examination, the blood pressure difference between legs may be difficult to detect due to movement artefacts of small, restless infants. Therefore, colour Doppler US has become a useful noninvasive diagnostic tool for diagnosing FAT, although similar limitations of patient agitation during the examination must be taken into account. Performed by experienced hands, Doppler US allows a reliable diagnosis or exclusion of FAT even in small children.

The rate of FAT in our survey is comparable with the results of published studies of the last few decades [5–8, 15, 19]. Our data confirm the risk profile for FAT in small children regarding rheology, including cyanosis, polycythemia, and congestive heart failure with low cardiac output; technical aspects, such as previous vessel puncture, sheath size, and sheath change; and prophylactic factors, including anticoagulation during and after CC (Table 2). Specific thrombolytic medical therapy was believed to be necessary only in one patient, in whom it was successful and without adverse events, as described in the literature [3].

Although the overall incidence of thrombosis in childhood is very low (0.07/10.000) [2], risk populations include young infants (<12 months) with congenital heart disease undergoing CC and cardiac surgery requiring need for a femoral arterial line [1, 2, 10, 13].

The total number of asymptomatic forms of FAT seems to be underestimated. Although the predictive value of pediatric thrombosis diagnosis in a Danish National Patient Registry has been recently described as being rather low (53.7 %), more detailed FU, including routine Doppler US the day after CC, is recommended, [17]. Early diagnosis of FAT is mandatory to avoid impaired limb growth and to establish life-long patency of arterial vessel access.

Limitations of the study include primarily technical factors regarding the clinical diagnosis of FAT, such as difficulties in blood pressure measurements due to movement artefacts as well as appropriate settings for Doppler US in small, restless infants to reach optimal imaging quality. Furthermore, we could not standardise the puncture techniques, type of sheaths used, and characteristics of bleeding control after CC, including the amount and type of pressure dressing, due to the local differences among the participating centres.

Conclusion

In conclusion, the rate of FAT in young infants after CC may be underestimated due to missed clinical signs. Therefore, the use of Doppler US is recommended in those cases in which FAT may be suspected. Future studies must determine the medium-term outcome of FAT, which was not part of this survey. A recent study has shown impressive efficacy of enoxaparin for the management of FAT in children after CC: for indwelling catheters during medium-term FU, the vessel patency rate was 91 % after 1 month [4]. These results emphasize that a timely diagnosis of FAT is mandatory for the early initiation of anticoagulatory therapy, which can result in excellent vessel-reopening rates in this patient group.

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