Surgical intervention for complications caused by femoral artery catheterization in pediatric patients

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Purpose: **This study evaluated the risk factors and surgical management of complications caused by femoral artery catheterization in pediatric patients.**

Methods: **From January 1986 to March 2001, the hospital records of all children who underwent operative repairs for complications caused by femoral artery catheterization were reviewed. A prospective cardiac data bank containing 1674 catheterization procedures during the study period was used as a means of determining risk factors associated with iatrogenic femoral artery injury.**

Results: **Thirty-six operations were performed in 34 patients (age range, 1 week-17.4 years) in whom iatrogenic complications developed after either diagnostic or therapeutic femoral artery catheterizations during the study period. Non-ischemic complications included femoral artery pseudoaneurysms (n = 4), arteriovenous fistulae (n = 5), uncontrollable bleeding, and expanding hematoma (n = 4). Operative repairs were performed successfully in all patients with non-ischemic iatrogenic femoral artery injuries. In contrast, ischemic complications occurred in 21 patients. Among them, 14 patients had acute femoral ischemia and underwent surgical interventions including femoral artery thrombectomy with primary closure (n = 6), saphenous vein patch angioplasty (n = 6), and resection with primary anastomosis (n = 2). Chronic femoral artery occlusion (> 30 days) occurred in seven patients, with symptoms including either severe claudication (n = 4) or gait disturbance or limb growth impairment (n = 3). Operative treatments in these patients included ileofemoral bypass grafting (n = 5), femorofemoral bypass grafting (n = 1), and femoral artery patch angioplasty (n = 1). During a mean follow-up period of 38 months, no instances of limb loss occurred, and 84% of children with ischemic complications eventually gained normal circulation. Factors that correlated with an increased risk of iatrogenic groin complications that necessitated surgical intervention included age younger than 3 years, therapeutic intervention, number of catheterizations (≥ 3), and use of 6F or larger guiding catheter.**

Conclusion: **Although excellent operative results can be achieved in cases of non-ischemic complications, acute femoral occlusion in children younger than 2 years often leads to less satisfactory outcomes. Operative intervention can provide successful outcome in children with claudication caused by chronic limb ischemia. Variables that correlated with significant iatrogenic groin complications included a young age, therapeutic intervention, earlier catheterization, and the use of a large guiding catheter. (J Vasc Surg 2001;33:1071-8.)**

The femoral artery remains the most preferred access site for diagnostic or therapeutic catheterization procedures. Common examples of complications associated with femoral artery catheterization include occlusion, hemorrhage, dissection, and pseudoaneurysm formation. Although therapeutic principles in adult iatrogenic groin injury have been well characterized,[1] the principles of the management of pediatric groin complications caused by catheterization procedures remain less well defined. This is in part because of the limited experience with iatrogenic femoral arterial injuries in children. In contrast to the adults with iatrogenic groin injuries, pediatric patients often pose a special therapeutic challenge because of the small size of their vessels. Furthermore, serious sequelae such as limb growth discrepancy can occur because of arterial ischemia in infants and children.[2-4] In this report, we describe our 15-year experience with children who underwent operative repair for iatrogenic injury after femoral artery diagnostic or therapeutic catheterization. In addition, we examine the associate variables that correlate with the development of iatrogenic groin complications after catheterization.

PATIENTS AND METHODS

From January 1986 to March 2001, the hospital records of all children (n = 34) 17 years or younger who underwent operative repairs for complications caused by femoral artery catheterization at the Egleston's Children Hospital in Atlanta were reviewed. In addition to demographic information, data were obtained on the indication of catheterization, presenting symptoms, interval from catheterization to operation, angiographic findings, technique of operative repair, and number of earlier catheterizations. Long-term outcome was assessed by means of post-discharge clinic visit records and, when necessary,

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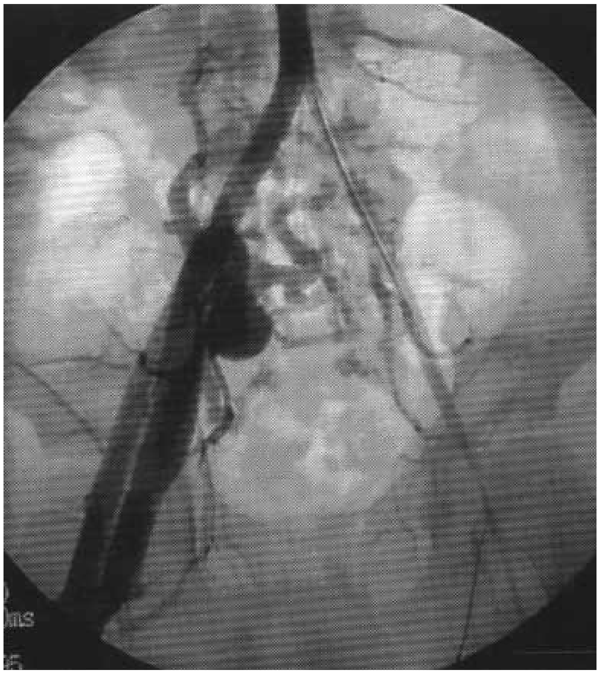

Fig 1. Preoperative angiogram in a 5-year-old child with an enlarging groin mass demonstrating a large femoral arteriovenous fistula caused by a recent diagnostic aortogram.

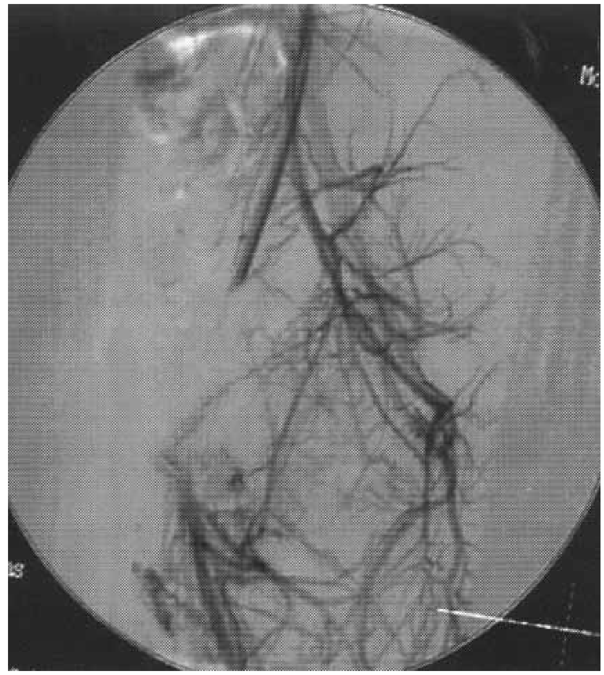

Fig 2. Preoperative femoral arteriogram in a 6-year-old child with severe right leg claudication demonstrating a chronically occluded right femoral artery with an abundant pelvic collateral formation.

telephone interviews. During the same interval, 1431 patients underwent 1674 diagnostic or therapeutic catheterization procedures via the femoral approach, as identified by means of a pediatric cardiac databank at the Egleston's Children Hospital. Patients in whom post-catheterization complications that necessitated operative repair did not develop formed the control group of this study. Various clinical variables that possibly influenced the development of post-catheterization complications were analyzed in the study and control groups. For statistical comparison, the study group only included patients who underwent operative intervention for iatrogenic complications directly attributable to the femoral artery catheterization (n = 34). Statistical analyses were performed by using the pooled Student *t* test and uncorrected Pearson chi-square test. A *P* value less than .05 was considered to be statistically significant. An SAS statistical software package (Version 5.0, Abacus Concepts, Berkeley, Calif) was used as a means of analysis.

RESULTS

During the 15-year period, 36 operations were performed in 34 patients (age range, 1 week-17.4 years) in whom iatrogenic groin complications developed after arterial catheterization procedures. The overall incidence of iatrogenic groin injuries that necessitated operative repair was 2%. General anesthesia was used in all patients undergoing operative repairs. One infant died of pulmonary hypertension 2 weeks after a successful thrombectomy of a thrombosed femoral artery. This resulted in an overall 30-day operative mortality rate of 3%. No patient required an extremity amputation in postoperative follow-up. Four postoperative complications occurred in four patients, resulting in a surgical morbidity rate of 12%. Postoperative complications included two groin wound infections, one retroperitoneal hematoma after iatrogenic arteriovenous fistula repair that necessitated re-exploration for hematoma evacuation, and rethrombosis of a femoral artery that required groin re-exploration followed by thrombectomy and saphenous vein patch angioplasty.

Among the 21 patients with either acute or chronic limb ischemia, 19 children were available for follow-up (range, 8-62 months; Tables II and III). Sixteen children (10 from the acute ischemic group and six from the chronic ischemic group, or 84%) regained normal circulation, which was defined by means of the presence of palpable pedal pulses, after operative repairs.

Non-ischemic complications. Non-ischemic complications that led to operative interventions included femoral pseudoaneurysm repair in four patients, arteriovenous fistula repair in five patients, and groin hematoma evacuation in four patients. Ischemic complications were divided into either acute or chronic, with the latter defined to be ischemia that occurred more than 30 days after the catheterization procedure. Table I summarizes the complication types, mean patient ages, and mean intervals

Table I. Types of complications and time interval between catheterization and surgical intervention

Complication	*Number of patients*	*Mean age (y)*	*Percentage*	*Mean intervals (days)*	*Range (days)*
Pseudoaneurysm	4	4.5	11.8%	32	1-62
Arteriovenous fistula	5	4.8	14.7%	35	3-95
Hematoma/hemorrhage	4	6.5	11.8%	2	1-4
Acute ischemia	14	4.1	41.2%	3	0-8
Chronic ischemia (>30 days)	7	5.7	20.6%	193	31-842

between the femoral artery catheterization and the operative treatment. The preferred operative treatment for femoral pseudoaneurysm was proximal and distal exposure of the common femoral artery. After direct vascular control was obtained, the pseudoaneurysm was opened, and the arterial defect was repaired with interrupted polydioxanone (PDS) or polypropylene (Prolene) suture. Similarly, arteriovenous fistulas were exposed to obtain proximal and distal control, followed by closure of the arteriotomy and either lateral venorrhaphy or venous ligation, depending on the size of the involved vein. A preoperative angiogram was necessary in two patients as a means of determining the location of the arteriovenous fistulas (Fig 1). Children with uncontrollable hemorrhage or a large hematoma also underwent operative treatment and repair of the arterial defect with either interrupted PDS or Prolene sutures.

Acute femoral ischemia. Acute arterial ischemia was the most common iatrogenic complication requiring operative intervention, and it occurred in 14 patients (41.2%) in our series. Table II lists the clinical information, types of operation performed, and outcomes of the patients with acute arterial ischemia. Although all patients had an absence of a femoral Doppler signal at the time of the diagnosis, nine patients (64%) underwent immediate operative repair without additional diagnostic studies. Ultrasound scanning was used as a means of confirming the diagnosis in three patients (21%), and an arteriogram was performed in two patients (14%) before the operative intervention. Thromboembolectomy via the femoral artery was performed with either a #2 or #3 Fogarty embolectomy catheter in all patients. In six patients (43%), primary closure with interrupted Prolene suture was possible, whereas six patients (43%) required a patch angioplasty with a saphenous vein graft. In two children (14%) with thrombosed femoral arteries, intimal flaps in the femoral artery after thrombectomy were revealed by means of a groin exploration. A short segment of the common femoral arteries was resected, and primary anastomoses were performed with interrupted 7-0 PDS sutures. Palpable pedal pulses were reestablished in six patients (43%) at the time of discharge. During the follow-up period, 10 children (71%) regained palpable pedal pulses. Eight patients (57%) only had Doppler pedal signals after the femoral thrombectomy procedures. Among them, a 2-year-old boy (patient 2) died of multisystem organ failure 2 months later, and a 6-month-old infant (patient 7) died of pulmonary hypertension 2 weeks later (Table II). These two patients underwent operative repair on the 7th and 8th days after their respective catheterization procedures, in part because of their initial hemodynamic instability that precluded early intervention. If these two patients are excluded from the analysis, the mean interval between catheterization and operative repair is reduced to 1 day, rather than 3 days (Table I), in the acute ischemic group. Among the remaining six patients who were discharged home with Doppler pedal signals, four eventually regained palpable pedal pulses. The remaining two children, who were 8 months and 1 year old (patients 5 and 13), never regained palpable pedal pulses, whereas their ankle-brachial indices remained relatively unchanged in follow-up visits 10 months and 14 months later, respectively (Table II). In the group of 14 children with acute limb ischemia who underwent operative interventions, postoperative complications developed in two patients (14%), including a groin infection in a 2-year-old child who eventually died (patient 2) and femoral artery reocclusion in a 1-year-old child (patient 5) who subsequently underwent femoral artery re-thrombectomy with saphenous vein patch angioplasty. Adverse events and postoperative mortality all occurred in children younger than 2 years ($P < .05$). In contrast, the remaining children older than 2 years all regained palpable pedal pulses in the follow-up period.

Chronic femoral ischemia. Table III lists the clinical summary and treatment outcomes of the seven patients with chronic arterial ischemia. An arteriogram was performed in all patients via a contralateral femoral approach before surgical interventions (Fig 2). Ileofemoral bypass grafting with a reversed saphenous vein graft, which was performed in five patients (71%), was the most commonly used surgical technique. Femorofemoral bypass grafting with a reversed saphenous vein graft was performed in a 4-year-old child whose total occlusion of the right common and external iliac arteries precluded an ileofemoral bypass grafting procedure. All seven patients with chronic femoral occlusion had symptoms, including severe claudication (n = 4) or gait disturbance with unequal limb length (n = 3). In the latter group of patients, bone-length skeletal roentgenography was performed in all three patients as a means of documenting the limb-length discrepancy (LLD) before surgical interventions. In a 9-year-

Table II. Clinical summary of 14 patients with acute leg ischemia caused by femoral artery catheterization

Patient	*Sex*	*Age (y)*	*Diagnostic study*	*Type of repair*	*Result at discharge*	*Outcome*	*Follow-up duration*
1	M	7	Clinical examination	Thrombectomy and primary closure	Palpable pedal pulses	Palpable pedal pulses	3 y
2	M	2	Clinical examination	Thrombectomy and resection	Doppler pedal signal	Died 2 months later of MSOF	N/A
3	F	3	Clinical examination	Thrombectomy and primary closure	Palpable pedal pulses	Palpable pedal pulses	4.5 y
4	M	5	Ultrasound scanning	Thrombectomy and SVPA	Palpable pedal pulses	Palpable pedal pulses	2.4 y
5	M	1	Arteriography	Thrombectomy and SVPA	Doppler pedal signal (ABI, 0.63)	Doppler pedal signal (ABI, 0.65)	0.9 y
6	F	4	Clinical examination	Thrombectomy and primary closure	Palpable pedal pulses	Palpable pedal pulses	7 y
7	F	0.5	Clinical examination	Thrombectomy and primary closure	Doppler pedal signal	Died 2 weeks later of PH	N/A
8	M	4	Ultrasound scanning	Thrombectomy and SVPA	Palpable pedal pulses	Palpable pedal pulses	4.9 y
9	F	8	Clinical examination	Thrombectomy and resection	Doppler pedal signal	Palpable pedal pulses	3.2 y*
10	M	9	Clinical examination	Thrombectomy and SVPA	Palpable pedal pulses	Palpable pedal pulses	2.9 y
11	F	3	Ultrasound scanning	Thrombectomy and primary closure	Doppler pedal signal	Palpable pedal pulses	1.9 y
12	F	5	Arteriography	Thrombectomy and primary closure	Doppler pedal signal	Palpable pedal pulses	4.3 y
13	M	0.7	Clinical examination	Thrombectomy and SVPA	Doppler pedal signal (ABI, 0.72)	Doppler pedal signal (ABI, 0.77)	1.2 y
14	F	4	Clinical examination	Thrombectomy and SVPA	Doppler pedal signal	Palpable pedal pulses	0.8 y

*Lost to follow-up in 1998.
SVPA, Saphenous vein patch angioplasty; *MSOF,* multisystem organ failure; *PH,* pulmonary hypertension; *N/A,* not applicable.

Table III. Clinical summary of seven patients with chronic leg ischemia caused by femoral artery catheterization

Sex	*Age (y)*	*Diagnosis*	*Diagnostic study*	*Symptom*	*Type of repair*	*Result*	*Follow-up duration*
M	8	Aortic stenosis	Arteriography	Claudication	Ileofemoral bypass grafting	Palpable pedal pulses	4.2 y*
M	5	VSD	Arteriography	Claudication	Ileofemoral bypass grafting	Palpable pedal pulses	2.9 y
F	6	Aortic stenosis	Arteriography	Claudication	Femoral patch angioplasty	Palpable pedal pulses	3.2 y
M	9	Status post OP repair	Arteriography	Gait disturbance, LLD (>3 cm)	Ileofemoral bypass grafting	Palpable pedal pulses	5.1 y, LLD (>1 cm)
F	3	Aortic stenosis	Arteriography	Gait disturbance, LLD (>2 cm)	Ileofemoral bypass grafting	Palpable pedal pulses	2.2 y
M	4	Aortic stenosis	Arteriography	Gait disturbance, LLD (>3 cm)	Femorofemoral bypass grafting	Palpable pedal pulses	3.9 y†
F	5	VSD	Arteriography	Claudication	Ileofemoral bypass grafting	Doppler pedal signal (ABI, 0.78)	1.9 y

*Lost to follow-up in 1995.
†Lost to follow-up in 1996.
VSD, Ventricular septal defect; *OP,* ostium primum; *LLD,* limb length discrepancy.

old child with a 3.5-cm LLD who underwent ileofemoral artery bypass grafting (Fig 3), an improvement of 1 cm LLD was shown by means of the follow-up bone-length skeletal roentgenogram 5 years later. At the time of discharge, a palpable femoral pulse was reestablished in all patients except a 5-year-old child who underwent an ileofemoral bypass grafting procedure for severe claudication. Although his claudication symptoms had improved and his ankle-brachial index had increased from 0.56 to 0.78, he only had a Doppler signal in his femoral artery during a follow-up visit 22 months later. Although the absence of a palpable femoral pulse in this child may have been indicative of an occluded vein graft, no further studies or treatment were considered because the patient remained free of symptoms.

Risk factor analysis. Table IV demonstrates that four independent variables correlated with an increased risk of iatrogenic groin complications that necessitated surgical intervention, including an age younger than 3 years ($P <$ .05), therapeutic intervention ($P <$ .05), number of earlier catheterizations ($\geq$ 3; $P <$ .001), and the use of a 6F or larger guiding catheter ($P <$ .01). Lack of postprocedural anticoagulation with heparin showed a positive trend in leading to iatrogenic vascular injury requiring operative repair ($P =$ .06). The remaining variables, which included diagnostic catheterization and hemodynamic status at the time of the catheterization procedure, did not correlate positively with the development of a significant iatrogenic injury, as determined by means of Pearson chi-square analysis.

DISCUSSION

The concept of percutaneous arterial catheterization was first introduced by Seldinger in 1953[5] and was modified by Lurie nearly a decade later for use in children and infants.[6] The advancement in catheter-based technologies in the past two decades has significantly enhanced the physician's ability to perform both diagnostic and therapeutic procedures in children. Presently, arterial catheterization procedures remain the most common cause of pediatric vascular injury for which vascular surgeons are called. The focus of our series was on the iatrogenic femoral artery complications that led to operative intervention. On the basis of our experience in the last 15 years, the incidence of such complications was 2% at our institution.

Non-ischemic complications that necessitated operative repair occurred in 13 patients (38%) in our series, and these complications included femoral artery pseudoaneurysm, arteriovenous fistula, and acute hemorrhage. One patient who required two operative interventions was a 6-year-old boy with protein C deficiency in whom a groin arteriovenous fistula developed after a diagnostic aortogram, which was manifested by an enlarging groin mass, and he underwent an uneventful operative fistula ligation. Postoperatively, a retroperitoneal hematoma developed, presumably as a result of intravenous heparin anticoagulation, and another operation was required for hematoma evacuation. In a mean follow-up period of 3.8 years in patients with iatrogenic non-ischemic injuries, all 13 children had a good clinical outcome, and no patient sustained any untoward sequelae related to either the injury or the operative repair.

The operative approaches used in patients with acute femoral artery ischemia mainly consisted of thrombectomy with a simple balloon catheter. Primary closure of the femoral arteriotomy was possible in six patients (43%), and saphenous vein patch angioplasty was necessary in another six patients (43%). The choice of repair was determined by the vascular surgeon on the basis of operative findings. In general, when the injured artery could be repaired primarily without causing visible luminal narrowing, interrupted PDS or Prolene sutures were used for primary closure. However, when the catheter-induced artery injury involved more than 30% of the luminal diameter or when obvious luminal narrowing occurred after primary closure, the femoral artery was repaired by means of saphenous vein patch angioplasty with running PDS or Prolene sutures. Intraluminal intimal flaps were identified at the time of thrombectomy in two patients, and femoral artery resection followed by primary anastomosis was achieved in these patients. Operative intervention was performed only in patients with an absence of a femoral Doppler signal. Although operative thrombectomy was successful in restoring either palpable pedal pulses (6 patients, 43%) or Doppler pedal signal (8 patients, 57%), 10 children (71%) ultimately regained palpable pedal pulses in the follow-up period. The two postoperative deaths in our series occurred in a 2-year-old boy (patient 2, Table II) and a 6-month-old infant (patient 7, Table II) after operative repair of acute femoral ischemia, and both deaths were related to complications of cardiopulmonary organ failure. Two other infants, ages 1 year and 8 months (patients 5 and 13, Table II), who never regained palpable pedal pulses had only Doppler pedal signals in follow-up

Fig 3. Bone length radiograph in a 9-year-old child with gait disturbance caused by a chronically occluded right femoral artery demonstrating a 3.5-cm LLD. His symptom improved 2 years later after an ileofemoral artery bypass grafting procedure.

Table IV. Analysis of variable factors associated with iatrogenic femoral artery complications

	*Study group (n = 34)**	*Control group (n = 1674)*	*Statistically significant*	P *value*
Age (average)	4.8 y (range, 0.3-17 y)	6.2 y (range, 0.8-17 y)	No	
Sex	Male, 19	Male, 976	No	
	Female, 15	Female, 698		
	Ratio, 1.3:1	Ratio, 1.4:1		
Age <3 y	23 (68.3%)	552 (33.0%)	Yes	<.05
Number of earlier catheterization ≥3	15 (44.1%)	74 (4.1%)	Yes	<.001
Lack of postprocedural heparin	2 (6.8%)	150 (8.9%)	No	
Diagnostic procedure†	24 (70.1%)	1272 (76.0%)	No	
Therapeutic procedure†	20 (58.8%)	402 (24.0%)	Yes	<.05
Normotensive‡	28 (82.4%)	1506 (89.9%)	No	
Hypotensive‡	6 (17.6%)	168 (10.0%)	No	
Use of ≥6F guiding catheter	9 (26.4%)	40 (2.4%)	Yes	<.01

*Reflect the most recent catheterization procedure resulting in iatrogenic complications.
†Indication for the femoral artery catheterization.
‡Hemodynamic status of the patient at the time of femoral artery catheterization.

visits 11 and 14 months later, respectively. Postoperative complications that occurred in this group of patients with acute limb ischemia, including groin infection and postoperative femoral reocclusion, occurred in two infants who were 1 year and 2 years old (patients 2 and 5, Table II). All postoperative morbidity and mortality and all cases of patients who never regained palpable pedal pulses occurred in children younger than 2 years. The operative results of acute femoral ischemia in our study confirmed findings from earlier reports that children younger than 2 years had more discouraging outcomes after thrombectomy for acute limb ischemia.[4,7,8]

Because the mainstay operative treatment for acute femoral occlusion is thrombectomy, preoperative arteriography is not essential in planning the operative intervention; it was performed in only two patients (14%) with acute ischemia in our series. In contrast, preoperative arteriography is critical in evaluating chronic disease patterns of ileofemoral occlusion. All seven patients (100%) with chronic femoral occlusion underwent preoperative arteriography as a means of determining the optimal operative treatment plan. Knowledge of the exact degree of femoral artery occlusion is essential in planning the vascular reconstructive procedures.

The proper timing and surgical management of chronic femoral artery occlusion in children has been debated extensively, particularly as it relates to the phenomenon of LLDs. All seven patients in our series who underwent operative bypass grafting for chronic femoral occlusion experienced clinical symptoms of arterial ischemia, including severe claudication in four patients and gait disturbance with limb-length inequality in three patients. In the latter group of patients, an LLD greater than 2 cm was documented by means of bone-length skeletal radiography before surgical intervention. Our finding agreed with clinical observations made by other researchers that an LLD greater than 2 cm was closely associated with gait disturbance.[9,10] Although all four patients with claudication improved clinically after surgical intervention in a mean follow-up period of 2.7 years, the clinical improvement in response to operative intervention in children with limb-length abnormalities is less clear. Only one of these three children showed a clear improvement in limb-length inequality, with a reduction from 3 cm to 1 cm in the 5 years after the ileofemoral bypass grafting procedure.

The significance of limb-length inequality as a result of chronic femoral artery occlusion was examined by Smith and colleagues, who studied 15 children younger than 2 years by means of both angiographic evaluation and operative intervention.[4] They noted significant LLDs, presumably related to growth retardation as a result of chronic femoral artery occlusion, occurred in all of these children. Our data concurred with recommendations made by other authors that the presence of chronic femoral artery occlusion in a child without any symptoms should be monitored on a regular basis.[2] However, the presence of symptoms caused by femoral artery occlusion warrants operative intervention.

In analyzing variable factors that may contribute to the development of significant iatrogenic vascular injuries, therapeutic intervention, in contrast to diagnostic procedure, was a significant factor. This presumably was related to the larger introducer sheath generally required for the therapeutic interventions. Not surprisingly, the use of a 6F or larger guiding catheter was also found to be a contributing factor in the development of significant pediatric iatrogenic injuries in our analysis. In fact, four of the seven children with chronic ischemia (57%) and five of the 14 children (36%) underwent catheterization with 6F or larger guiding catheters. The positive correlation of guiding catheter size with iatrogenic pediatric injuries in this study contrasted with an earlier study that analyzed catheter-related iatrogenic injuries in the adult population at our institution, which noted that the use of a large guiding catheter (9F or larger) did not appear to increase the risk of an iatrogenic vascular complication.[11] Repeated groin catheterizations (≥ 3) and an age younger than 3 years also correlated positively with the development of a significant iatrogenic vascular complication in this review, particularly with resultant acute or chronic femoral occlusion.

The positive correlation of catheter size-related and age-related iatrogenic vascular complications in our study supports the concept postulated by many researchers that the magnitude of arterial occlusion is related to catheter size occurring in small-diameter vessels.[12,13] A positive age-related correlation in young children with intraluminal radiographic abnormalities or arterial occlusion was demonstrated by means of earlier radiographic and clinical studies.[3,8] Mortesson and colleagues performed second arteriograms in 44 children at a mean interval of 3.1 years after initial arterial catheterization; nearly one third of the 28 children younger than 8 years had angiographic abnormalities at the catheterization site.[14] This was in sharp contrast to only one case of radiographic abnormality among the 16 children older than 8 years in the same study.[14] Similar findings were noted in a clinical study by Freed and colleagues, who examined the relationship between age and catheter-related complications in 161 children.[15] In that study, no catheter-related complications occurred in 84 children older than 10 years, whereas children younger than 10 years had a complication rate of 40%. Moreover, nearly one third of the 77 children younger than 10 years lost femoral pulses shortly after the arterial catheterization, and half required operative interventions.[15]

Several potential mechanisms have been proposed to possibly contribute to the thrombotic occlusion after arterial catheterization. Prominently among them is the development of intimal flaps as a result of direct arterial puncture.[16,17] This mechanism was confirmed in the cases of two patients with acute femoral occlusion in our series, in which intimal flaps were identified at the time of thrombectomy. Other researchers have postulated that arterial spasms are an important factor leading to thrombotic occlusion after arterial catheterization.[14,18] Clinical observation by Fraken and colleagues confirmed that the size of the catheter in relation to the vessel diameter is a major contributor to arterial spasm in infants.[12] Moreover, femoral artery spasm was more likely to occur when either the catheter diameter was 50% or more of the arterial diameter or the difference between the arterial catheter and vessel diameter was less than 1.9 mm.[12,19] The diameter of the normal femoral artery in a 3-year-old child is about 4 mm, and the outer diameter of a 6F catheter is about 2.5 mm.[20] The use of a large guiding catheter in young children can undoubtedly lead to reduction of vessel lumen because of vasoconstriction in the presence of hypovolemia, which effectively reduces the vessel-catheter ratio to the point at which arterial spasm with subsequent occlusion can occur. Other researchers postulated that the presence of fibrin sleeves on angiographic catheters might be a potential cause of femoral artery occlusion.[20] In this scenario, stripping of the fibrin sleeve during catheter removal may in part lead to intraluminal occlusion at the femoral artery puncture site.[20,21] Several other mechanisms that may contribute to thrombotic femoral artery occlusion after catheterization in children include polycythemia, poor cardiac function, and extracellular fluid deficits.[7,14]

In conclusion, iatrogenic femoral artery complications in children that necessitate operative interventions remain relatively uncommon. Although excellent operative results can be achieved in non-ischemic complications, acute femoral occlusion in children younger than 2 years often leads to less satisfactory outcomes. Operative intervention for chronic femoral occlusion should be considered only when children manifest symptoms of arterial insufficiency. Variables that correlated with an increased risk of iatrogenic groin complications that required operative intervention included an age younger than 3 years, therapeutic intervention, number of catheterizations (≥ 3), and the use of a 6F or larger guiding catheter.

REFERENCES

1. Youkey JR, Clagett GP, Rich NM, et al. Vascular trauma secondary to diagnostic and therapeutic procedures: 1974 through 1982. A comparative review. Am J Surg 1983;146:788-91.
2. Taylor LM Jr, Troutman R, Feliciano P, Menashe V, Sunderland C, Porter JM. Late complications after femoral artery catheterization in children less than five years of age. J Vasc Surg 1990;11:297-306.
3. Flanigan DP, Keifer TJ, Schuler JJ, Ryan TJ, Castronuovo JJ. Experience with iatrogenic pediatric vascular injuries. Incidence, etiology, management, and results. Ann Surg 1983;198:430-42.
4. Smith C, Green RM. Pediatric vascular injuries. Surgery 1981;90:20-31.
5. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography. Acta Radiol 1953;39:368-71.
6. Lurie P, Armer R, Klatte E. Percutaneous guide wire catheterization: diagnosis and therapy. Am J Dis Child 1963;106:189-95.
7. Perry MO. Iatrogenic injuries of arteries in infants. Surg Gynecol Obstet 1983;157:415-8.
8. Leblanc J, Wood AE, O'Shea MA, Williams WG, Trusler GA, Rowe RD. Peripheral arterial trauma in children. A fifteen year review. J Cardiovasc Surg (Torino) 1985;26:325-31.
9. Moseley CF. A straight line graph for leg length discrepancies. Clin Orthop 1978:33-40.
10. Moseley CF. Assessment and prediction in leg-length discrepancy. Instr Course Lect 1989;38:325-30.
11. Oweida SW, Roubin GS, Smith RB III, Salam AA. Postcatheterization vascular complications associated with percutaneous transluminal coronary angioplasty. J Vasc Surg 1990;12:310-5.
12. Franken EA Jr, Girod D, Sequeira FW, Smith WL, Hurwitz R, Smith JA. Femoral artery spasm in children: catheter size is the principal cause. AJR Am J Roentgenol 1982;138:295-8.
13. Hurwitz RA, Franken EA Jr, Girod DA, Smith JA, Smith WL. Angiographic determination of arterial patency after percutaneous catheterization in infants and small children. Circulation 1977;56:102-5.
14. Mortensson W. Angiography of the femoral artery following percutaneous catheterization in infants and children. Acta Radiol 1976;17:581-93.
15. Freed MD, Keane JF, Rosenthal A. The use of heparinization to prevent arterial thrombosis after percutaneous cardiac catheterization in children. Circulation 1974;50:565-9.
16. Kocandrle V, Kittle CF, Petasnick J. Percutaneous retrograde abdominal aortography complication. Intimal dissection. Arch Surg 1970;100:611-3.
17. Paul JJ, Desai H, Baumgart S, Wolfson P, Russo P, Tighe DA. Aortic dissection in a neonate associated with arterial cannulation for extracorporeal life support. ASAIO J 1997;43:92-4.
18. Frezza EE, Mezghebe H. Indications and complications of arterial

catheter use in surgical or medical intensive care units: analysis of 4932 patients. Am Surg 1998;64:127-31.

19. Sahn DJ, Goldberg SJ, Allen HD, et al. A new technique for noninvasive evaluation of femoral arterial and venous anatomy before and after percutaneous cardiac catheterization in children and infants. Am J Cardiol 1982;49:349-55.
20. Steinberg C, Weinstock DJ, Gold JP, Notterman DA. Measurements of central blood vessels in infants and children: normal values. Cathet Cardiovasc Diagn 1992;27:197-201.
21. Williams EC. Catheter-related thrombosis. Clin Cardiol 1990;13: VI34-6.

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