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# A Prospective Evaluation of Femoral Artery Monitoring in Pediatric Patients

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Femoral artery cannulation is generally avoided in pediatric patients requiring arterial monitoring. This practice has stemmed in part from a suspected increased risk of infection due to the catheter's close proximity to the perineum, the risk of hip capsule puncture with subsequent septic arthritis, and the risk of thrombotic or embolic complications to the leg.[1] Radial artery cannulation is not without risk and can be difficult in small children, often necessitating an arterial cut-down. Furthermore, radial artery pressure frequently is not an accurate indicator of central arterial pressure when terminating cardiopulmonary bypass.[2,3] For these reasons, femoral artery catheters are routinely used at the Mayo Clinic in children undergoing open heart surgery. This study was undertaken to define the incidence of perfusion-related and infectious-related complications from femoral artery catheters in pediatric patients.

## METHODS

After approval of our Institutional Review Board, 151 pediatric cardiac surgical patients requiring 165 femoral arterial cannulations were prospectively evaluated. Femoral puncture was routinely performed percutaneously at least 2 cm below the inguinal ligament using the catheter-over-needle technique. Either an 18- or 20-gauge 4-in Teflon® catheter (Becton-Dickinson, Rutherford, NJ) was arbitrarily chosen by the anesthesiologist, depending on the patient's body size. A 20-gauge 2-in catheter was used in neonates and infants. Arterial lines were sutured in place and dressed in a sterile fashion. The dressing was changed every 24 h.

Patients were evaluated daily throughout their hospital course for: infection at the puncture site; loss of palpable distal pulse; clinical evidence of distal ischemia or embolization; catheter malfunction; duration of catheter placement; and postoperative sepsis. Perfusion-related complications were defined as signs or symptoms of distal ischemia or decreased perfusion that led to the removal of the catheter. Catheters were removed at the discretion of the attending physician. Catheter malfunction was defined as consistent dampening of the pressure waveform, inadvertent dislodgement, or catheter occlusion. Postoperative sepsis was defined as a positive bacterial blood culture obtained from a venipuncture and clinical features consistent with bacterial sepsis. Values are presented as means ± standard deviation.

## RESULTS

The patients' age and the duration of catheter placement data are found in table 1. All patients had a central venous catheter, at least one peripheral iv line, and a urinary catheter. The tracheas of most patients were intubated for at least 12 h.

Complications are found in table 2. Percutaneous femoral artery puncture failed in six of 168 (3.6%) attempts, resulting in a femoral artery cut-down in three patients and radial artery cannulation in the remaining three patients. Postoperative sepsis occurred in six cases, all in patients who were older than 1 yr of age. The femoral artery catheter was in place for more than 5 days in five of the six cases in which sepsis occurred.

Transient loss of distal pulse, mottling or coolness of the distal limb, or temporary signs of ischemia occurred in six cases, all in neonates or infants. The decreased perfusion was felt to be mild in degree, the catheters were

TABLE 1. Patient Population

| | Number of Patients |
|---|---|
| Age* | |
| Neonates | 12 |
| Infants | 25 |
| 1–4 yr of age | 52 |
| >4 yr of age | 76 |
| Duration of catheter placement† | |
| 12–48 h | 43 |
| 48–96 h | 76 |
| 96–168 h | 32 |
| >168 h | 14 |

* Mean 4.8 ± 4.4 yr.
† Mean 81 ± 64 h.

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TABLE 2. Complications Associated with Femoral Artery Catheters

| | Number | Per Cent |
|---|---|---|
| Catheter malfunction | 5/165 | 3.0 |
| Perfusion-related complications | 4/165 | 2.4 |
| Neonates | 3/12 | 25 |
| Infants | 0/25 | 0 |
| Children | 1/128 | 0.8 |
| Infection at puncture site | 0/165 | 0 |
| Postoperative sepsis | 6/165 | 3.6 |

not discontinued, and perfusion returned to normal within 6–24 h. In two infants the transient loss of distal pulses and decreased limb perfusion were secondary to a low cardiac output state and resolved when the cardiac output improved.

Perfusion-related complication occurred in three neonates and one child. The only perfusion-related complication in patients greater than 1 month of age occurred in a three-yr-old child who accidentally had two catheters placed in the same femoral artery during a femoral venous cannulation attempt. When both catheters were removed, the perfusion to the leg returned to normal. Perfusion-related complications always occurred within the first 48 h of catheter placement. There was no permanent ischemic injury encountered during the hospital course in any patient.

## DISCUSSION

The previous studies of radial artery catheters in pediatric patients are compared with the present study in table 3. Differences in the incidence of perfusion-related complications exist between studies and could be explained by the use of different catheter material and differing definition of "complication." It is also possible that the incidence of complications may vary between elective and acute patient populations. There were no cases of tissue loss secondary to ischemia in any of the studies. In the present study, the incidence of perfusion-related complications from femoral artery catheters in infants and children is less than the incidence of complications from radial artery catheters reported by Miyasaka *et al.*[4] and comparable to the incidence reported by Marshall *et al.*[5] and Smith-Wright *et al.*[6] Neonates had a higher incidence of perfusion-related complications from femoral artery catheters than previously reported by Adams *et al.*[7] for radial artery catheters. Adams *et al.* used a 22-gauge catheter, and it is possible that the 20-gauge catheter used in our study was relatively too large for a neonate and could have led to the increased incidence of complications.

Part of the reluctance to use femoral artery catheters in pediatric patients stems from the perceived risks of thrombosis, with growth retardation of the ipsilateral leg. While thrombosis of the femoral artery has developed following cardiac catheterization, significant vascular problems are rare due to the development of collateral circulation.[8,9] Hurwitz *et al.*[8] and Rosenthal *et al.*[9] found no significant leg length discrepancy following femoral artery cardiac catheterization in 368 pediatric patients. Mortensson[10] reported a 4% incidence of significant ipsilateral leg length discrepancy but did not have precatheterization leg length measurements. No clinical evidence of vascular problems was evident at discharge in any patient in our study. However, perhaps a complication could be asymptomatic, and further follow-up of these patients would define the incidence of long-term complications.

A comparison of infectious complications between femoral and radial artery catheters in pediatric patients is presented in table 3. Patients in our study and in the Smith-Wright *et al.*[6] study had other possible causes of sepsis, *i.e.*, peripheral intravenous catheters, central venous catheters, and surgical incisions. Therefore, the sepsis was not necessarily arterial catheter related. While the definition of sepsis and the patient populations do vary between the studies, we think the incidence of sepsis associated with femoral artery catheters in pediatric patients is not greater than the previously reported incidence of radial artery catheter-associated sepsis. As shown previously with radial artery catheters, sepsis associated with femoral artery catheters is more likely if the catheter remains in place more than 4–5 days.[11,12]

TABLE 3. Comparison of Complications from Radial and Femoral Artery Catheters in Pediatric Patients

| Study (reference) | Site | Perfusion-related Complications | | Infectious Complications | |
|---|---|---|---|---|---|
| | | Per Cent | Number | Per Cent | Number |
| Miyasaka K. 1976[4] | Radial | 11.0 | 6/53 | — | — |
| Smith-Wright DL. 1984[6] | Mixed* | 0.9 | 3/330 | 3.3 | 11/337 |
| Marshall AG. 1984[5] | Radial | 0 | 0/70 | — | — |
| Adams JM.† 1980[7] | Radial | 10.8 | 16/147 | 0.6 | 1/147 |
| Present study | Femoral | 2.4 | 4/165 | 3.6 | 6/165 |
| | age < 1 month | 25 | 3/12 | — | — |
| | age > 1 month | 0.6 | 1/153 | — | — |

* Most were radial artery catheters.

† Study confined to neonates.

Previous studies have suggested that arterial catheters placed by surgical cut-down carry significantly greater risks of complications than those arterial catheters placed percutaneously.[4,12,13] Band and Maki[12] found a nine-fold increase in bacteremia in adults when arterial catheters were inserted by cut-down rather than percutaneously. Miyasaka *et al.*[4] reported 48% of the pediatric patients with radial artery catheters placed by cut-down developed perfusion-related complications. The results of this study would suggest that in infants and children in whom percutaneous radial arterial catheter placement fails, percutaneous femoral artery insertion may be safer than radial artery cut-down.

In conclusion, the femoral artery is a comparably safe and acceptable site for arterial monitoring in infants and children. The incidence of sepsis and perfusion-related complications associated with femoral artery catheters in this age group is no greater than the incidence previously reported for radial artery catheters. In contrast, in neonates, the incidence of perfusion-related complications was considerably greater and may exceed the complication rate associated with radial artery catheterization.

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# A Comparison of Aperiodic Analysis of the EEG with Standard EEG and Cerebral Blood Flow for Detection of Ischemia

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The 16-lead electroencephalogram (EEG) is a frequently used method for direct monitoring of cerebral function during general anesthesia because it is sensitive to hypoxemia and ischemia under stable conditions of anesthetic depth, partial pressure of carbon dioxide ($Pa_{CO_2}$), and brain temperature.[1] Monitors that process the EEG signal have been developed to simplify recognition and interpretation of EEG changes. The purpose of this study is to assess the accuracy of one of these new devices, the Lifescan™ EEG Monitor (Neurometrics™, San Diego, CA) in detecting cerebral ischemia.

The Lifescan™ uses aperiodic analysis,[2,3] which maps each waveform in relation to its frequency, amplitude, and time of occurrence rather than averaging a large number of waveforms over a given epoch. The EEG signal is divided into three components: 1–8 Hz, 9–30 Hz, and a composite signal having the potential to contain spikes. Following conventional electroencephalographic practice, each component measures the period of each wave, which

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