Arterial cannulation is a common procedure in the care and management of critically ill patients. Blood pressure measurement, arterial blood sampling, cardiac output determinations, and a site for rapid blood withdrawal are the primary reasons for arterial cannulation. As is true with any invasive catheter placement, arterial catheters impose certain risks and clinical management problems.

The Thunder Project was undertaken by the American Association of Critical Care Nurses (AACN) to determine the effects of heparinized and nonheparinized flush solution on the patency of arterial lines for pressure monitoring. Data were received on 5037 patients in 198 hospital critical care units in the United States, Canada, and Australia.

Findings from that study are reported elsewhere. The data collection procedure involved checking the patency of the arterial lines by performing a square waveform test and determining arterial blood backflow every 4 hours for 72 hours after insertion of the line or until the line was removed. The presence or absence of an acceptable square waveform and arterial backflow were recorded on a data collection form. An acceptable square waveform test was defined as a rapid upstroke terminating in a flat line at the maximal indicator on the tracing paper, upon activation of the fast flush device, and a rapid and unimpeded downstroke approximating a 90-degree angle, with a negative deflection below the baseline and a return to the arterial waveform within 0.12 seconds (three small blocks on the tracing paper), upon release of the fast flush device. Free backflow of blood was defined as a flashback of blood in the tubing at the interface of the catheter and the pressure tubing within 1 second, when the stopcock was turned off to the transducer and opened to air.

Space for comments was provided for each data collection point. Site coordinators were instructed via an educational videotape to record discontinuation of arterial line, clotting, or other issues related to arterial
polyethylene catheter. Gardner et al found that the incidence associated with radial artery cannulation is limited. Early research suggested a lower incidence of arterial occlusion in comparison with the incidence associated with radial artery catheters. 

Catheter Location

Arterial catheters are most commonly placed in the radial and femoral arteries but also may be inserted in the brachial, axillary, and dorsalis pedis arteries. The most common complication in radial artery placement is asymptomatic temporary radial artery occlusion, which resolves spontaneously. **2, 3** In a study of radial artery function in 108 patients, Bedford and Hunt recommended using the smallest possible cannula gauge. The literature on patency rates for femoral artery catheters is limited. Early research suggested a lower incidence of catheter loss due to occlusion in comparison with the incidence associated with radial artery catheters. **26** The incidence of loss subsequent to catheterization, however, may be as high as 1% to 4% **.14** Kaye reviewed the literature on complications of femoral arterial cannulation and stated, "thrombosis of the femoral artery is especially common in the presence of peripheral vascular disease, following repeated attempts at insertion of catheters into the artery, and following prolonged, excessive pressure to control bleeding after catheter removal."

Monitoring Systems

In a classic article, Smith described the equipment and arrangement for a pressure monitoring system.
Since this publication, changes have occurred in transducer technology, resulting in smaller, disposable transducers. Smith identified system problems and strategies for troubleshooting this system. Some of the problems identified included bleedback (due to loose connections, a partially deflated pressure bag, or incorrect stopcock position), air bubbles (due to loose connections, cracked system components, or flush device inadequacies), and a dampened waveform (due to clotted catheter or inadequate flush solution). A review of the more recent literature indicated that many of these initial system problems still occur.  

Flush devices have been found to provide variable performance and to deliver higher flow rates than expected, \(^1\) to malfunction, and to cause falsely high pressure readings. \(^2\) In a case report, Passannante and Macik\(^1\) described a patient who was overheparinized due to repeated fast flushes of heparinized saline after blood withdrawal from hemodynamic lines. The amount of solution delivered by these fast flushes is variable and difficult to determine.

Air entrapment in hemodynamic lines has been reported and attributed to turbulence created by fastflushing and other unidentified system problems. \(^3\) Solutions to this problem include use of a macrodrip chamber for the flush solution and an in-line air filter.

Pressure infusor bags have also come under scrutiny. Hart\(^1\) found that as the amount of solution under pressure decreased, the delivered pressures were less than the applied pressures. In addition, the difference increased as the volume of saline within the bag decreased. The reason for the difference between the inflation and delivered pressures is unclear. Because of these inaccuracies, pressurized systems cannot be counted on for accurate drug or fluid volume delivery, cuff inflation pressures must be maintained at 300 mm Hg at all times, and the flush solution bag should not be allowed to be depleted. Few studies have addressed the recognition and treatment of patency problems once they have occurred. Gardner et also studied catheter complications in 492 patients in an intensive care unit. Only five catheters become nonfunctional, three from clotting and two from kinking. Hypotension, use of vasoconstrictive agents, and prolonged catheterization were associated with complete arterial occlusion in the three patients requiring thrombectomy.

Although most complications are related to the hematomic consequences of cannulation, infection is another category related to arterial cannulation. \(^5\) The incidence of infection associated with arterial catheters used for pressure monitoring and blood sampling is reported to range from 1.6% to 11.5%. \(^6\) Lines in place for longer than 4 days are associated with higher rates of infection. Studies of catheter insertion sites, however, do not consistently demonstrate an increased infection rate associated with insertion site. \(^7\)

**OBSERVATIONS FROM THE THUNDER PROJECT**

Although the site coordinators and site research associates collecting data for the Thunder Project were given limited instruction for recording comments, many observations were included on the data collection sheet. These statements raise questions concerning the problems associated with the management of arterial lines, both with and without heparin in the flush solution. Problems fall into six general categories: (1) equipment-related problems, (2) patient-related issues, (3) patency problems, (4) subjective reports by the patient, (5) objective reports from the nurse, and (6) hematologic events. The following discussion provides a description of the problems encountered with arterial lines. The observations were random comments, and the actual numbers of problems are not reported. Accordingly, the extent of these problems, in practice, is unknown.

**Equipment-Related Problems**

Equipment-related comments focused on the arterial catheter, the flush solution bag, the pressure monitoring system, and the pressure infusor bag. A bent or kinked catheter was a common observation. Similarly, a break or leak in the pressure infusor bag, a leak in the flush solution bag, a crack in the monitoring system tubing, loose connections in the monitoring system, and defective pressure tubing were mentioned. These equipment problems may contribute to other problems, such as patency and hematologic events. For example, a broken pressure bag will not allow the flush device to function properly and to deliver the flush solution necessary to maintain patency.

**Patient-Related Problems**

Use of a positional catheter was a patient-related problem. A positional line requires manipulation at the insertion site to provide an accurate waveform reading. Such an occurrence was determined to be a patient-related issue, because an adequate waveform reading depends on patient positioning of the extremity in which the insertion site is located. Other issues that affected the integrity of the waveform readings included patient agitation, bradycardia, and shock.
Patency

Several factors that appeared to precede the clotting or loss of patency of the arterial catheter were recorded and included a dampened or flat waveform, difficulty drawing blood from the line, and inability to aspirate blood from the line, sluggish or no backflow of blood from the arterial line, and difficulty flushing the arterial line. The exact sequence of these events and the time period before actual occlusion of the catheter require further analysis.

Subjective Reports

Patient complaints were recorded on the data collection sheet. They ranged from tingling, numbness, and pain to burning at the arterial catheter insertion site. The radial insertion site was the primary site of such complaints.

Objective Reports

Objective comments concerning the site of the arterial line revealed a variety of abnormal findings that may contribute to patient discomfort and morbidity. Comments included the following: (1) the site is red and inflamed; (2) the site is oozing and leaking; (3) the hand, wrist, and arm are edematous; and (4) the site is infiltrated and cool. At times, subjective reports correlated with objective data. For example, pain was associated with lower arm edema, and tingling and numbness with infiltration.

Hematological Events

Hematologic events included those related to either the extravasation of blood or the clotting of blood. Bleeding, hematoma, and bruising at the arterial catheter insertion site were mentioned, in addition to removal of a clot and a clotted or occluded catheter.

DISCUSSION

The link between the thrombotic complications and management problems associated with arterial cannulation is described in the literature as well as in comments provided on the Thunder Project data collection forms. Although the literature supports Teflon as the least thrombogenic material for the arterial catheter, other factors appear to be involved in thrombogenic risk. Results from the Thunder Project did not show rates of catheter patency to be significantly related to catheter material.

Also, speculation that the 20-gauge catheter is better than an 18-gauge catheter because of its increased surface area is not supported by Thunder Project data. Arterial line patency was monitored for 72 hours; during this time, patency was not affected by catheter gauge. Although the literature provides support for the radial artery as a primary site for maintaining patency, Thunder Project data identified the femoral site as having a significantly increased chance for patency when compared with other sites.

Evaluation of the troubleshooting guide presented by Smith in 1978 reveals no progress in addressing the management prob-
ARTERIAL CATHETER COMPLICATIONS AND MANAGEMENT PROBLEMS

Problems associated with arterial catheters, identified more than 14 years ago. Comments on bleed back due to loose connections, partially deflated pressure infusor bags, and dampened or flat waveforms due to a clotted catheter or inadequate flush solution are testimony to the lack of technologic progress in arterial cannulation and indwelling arterial catheter maintenance for the purposes of blood pressure measurement and arterial blood sampling.

The number and variety of comments indicate that a great deal of nursing time is spent maintaining line patency. Until the technologic issues associated with maintaining an indwelling arterial catheter are resolved, management issues surrounding arterial catheters will continue to be time-consuming. These problems put the patient at risk for thrombosis and related complications in addition to jeopardizing the quality of the data used to treat the patient.

CONCLUSIONS

If critical care nurses are to continue to measure blood pressure by direct measures and to use indwelling arterial lines to obtain arterial blood samples, low-maintenance systems must be researched and developed. This research should focus on the following criteria that are desirable in this type of system: (1) a pressure bag that remains inflated regardless of the volume of flush solution; (2) catheters that do not kink or bend when in the artery; (3) flush solution bags and monitoring systems that maintain their integrity and that do not crack, break, or leak during operation; and (4) comfortable ways of maintaining limb mobility. The patient who is agitated and uncomfortable may self-impose catheter problems. The extent to which current systems can tolerate movement needs to be determined. Systems designed to permit freedom of movement need to be developed.

Furthermore, research is needed regarding optimal catheter gauge to ensure accurate hemodynamic measures and vessel access while minimizing thrombosis and damage to the blood vessel wall. Optima) catheter length and its relationship to arterial insertion site necessitate additional investigation.

Management of arterial catheter problems and prevention of complications by the critical care nurse remain crucial in care of the critically ill patient. Management issues will continue until arterial lines are replaced by noninvasive methods of monitoring pressure and obtaining the data provided by arterial blood samples.

References


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