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Valve Competence in Pulmonary Artery Catheter Introducers

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Pulmonary artery catheter introducer sheaths with self-sealing ports have been suggested as an aid for preventing air embolism associated with central venous and pulmonary artery catheterization. These sheaths typically have a sidearm through which fluid is infused and a valve proximal to the sidearm, preventing antegrade flow of air and retrograde flow of intravenous fluids. Doblar *et al.*[1] implied that two cases of air embolism after catheter removal would not have occurred if the introducers had been equipped with self-sealing valves.

Catheter introducer sheaths with self-sealing valves frequently are inserted into the central venous circulation to provide easy access if a pulmonary artery catheter is needed later. Others are allowed to remain for central venous infusions after removal of a pulmonary artery catheter. We began to question the safety of these practices when we noticed several instances of blood leaking retrograde through the valve after catheter removal.

METHODS

A two-phase study was designed to test the competence and break points of the self-sealing valves. The first phase studied new valves, while the second tested valves subjected to simulated *in vivo* conditions. The units tested included: Arrow§ Percutaneous Sheath Introducer (AK-09800); Cook¶ Check Flow® sheath set; Cordis** Catheter Sheath Introducer (501-608); and the USCI†† Hemaquet® Introducer. The study was limited to 8-French Introducers. Samples for testing were selected randomly from catheter introducers supplied by the manufacturers.

In the first phase, six unused catheter introducer sheaths from each manufacturer were tested, the side arms were clamped and the sheaths subjected to negative pressure at the distal (non-valve) end—simulating negative intrathoracic pressure. Pressures as great as -30 cmH_2O were applied, and air flow through the catheter introducer sheath was measured.

The second phase of the study simulated *in vivo* conditions with six randomly selected samples from each manufacturer. Unused catheter introducer sheaths were suspended in a water bath at 37° C. The sidearm and valve mechanisms remained above the water surface. Saline was used to fill the sidearm and the sheath. A 7-French pulmonary artery catheter was inserted through the valve and the sheath and allowed to remain in place for 48 hours. After the valve had been distorted by the catheter for 48 hours, the catheter was removed, the

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¶ Cook Incorporated, P.O. Box 489, Bloomington, Indiana 47402.

** Cordis Corporation, P.O. Box 370684, Miami, Florida 33137.

†† USCI Division, C. R. Bard, Inc., Box 566, Billerica, Massachusetts 01821.

TABLE 1. Air Leak Through Valved Catheter Introducers after Removal of Pulmonary Artery (PA) Catheter

Time after PA Catheter Removal (h)		Airflow (ml/s) at −30 cmH_2O			
		Arrow (AK-09800)	Cook® Check-Flo	Cordis 501-608	USCI Hemaquet®
0	Mean	0.110	0.057	0.090	0.295
	SD	0.043	0.028	0.084	0.525
	n	6	6	6	6
2	Mean	0.078	0.043	0.056	0.157
	SD	0.009	0.011	0.028	0.265
	n	6	6	6	6
6	Mean	0.096	0.038	0.044	0.105
	SD	0.067	0.028	0.021	0.145
	n	6	6	6	6
24	Mean	0.071	0.054	0.047	0.035
	SD	0.006	0.006	0.037	0.022
	n	6	4	4	4
48	Mean	0.076	0.028	0.030	0.027
	SD	0.006	0.016	0.023	0.015
	n	6	4	4	4
72	Mean	0.087	0.041	0.033	0.047
	SD	0.007	0.032	0.021	0.069
	n	6	6	6	6

sidearm was clamped, and negative pressure applied to the distal end of the sheath. Air flow through the sheath (if any) was measured. The valved catheter introducer sheath, without the pulmonary artery catheter, then was returned to the water bath and the sidearm and valve mechanism refilled with saline. This measurement procedure was repeated 2, 6, 24, 48, and 72 hours after removal of the pulmonary artery catheter from the valved sheath.

The central laboratory vacuum source was connected to the test apparatus through a T connector and a surge tank (2-liter vacuum flask). The third arm of the T connector opened to the atmosphere through a needle valve. Vacuum levels supplied to the test apparatus were regulated by adjusting the needle valve, thus controlling bleeding of atmospheric air into the vacuum line. The surge tank was utilized to minimize pressure/flow fluctuations from the central vacuum source.

Pressures in the test system were measured using a Statham® PM5ETC transducer calibrated against a water manometer. Gas flows were measured using a NEOS‡‡ linear resistor flowmeter. Pressure drop across the flowmeter was determined with a differential pressure transducer (PM5ETC, Statham). A precision flowmeter (with calibration traceable to the National Bureau of Standards) originally was used to calibrate the differential pressure transducer-linear resistance flowmeter system. Previous analysis of the test system disclosed an accuracy of ±0.250 ml/s for flow measurements. Outputs of both transducers were recorded on a recorder. The flow rates were corrected to eliminate the small but detectable sealed system leak rate.

‡‡ NEOS Inc., Lincoln, Nebraska.

RESULTS

No air leak was detected in an unused catheter introducer sheath subjected to vacuums of 30 cmH_2O. The results of the second phase of the study are summarized in table 1. With one transient exception, air leak through the valve remained at or below the limits of detection (0.25 ml/s), even when the valve mechanism had been subjected to 48 hours' distortion. In no case did airflow through a valve approach the level indicted as causing physiologic damage. In short, these valves generally function as they were intended.

DISCUSSION

Our system was designed to test for air leakage through the valve into the circulatory system. We felt this was a greater threat to the safety of the patient than the possibility of blood leaking from the vein through the valve (despite such an event occasioning the original observation of valve incompetence). The use of blood, rather than water, as the bathing medium would more closely mimic *in vivo* conditions. Anticoagulating blood for use in the bath would decrease the possibility of clots distorting the valve mechanism. Not anticoagulating a blood bath would render it uncirculatable. We therefore elected to use water as the bathing medium. We currently are collecting data on air leak in catheter introducer sheaths which have actually been used in patients. Initial studies corroborate the findings of this *in vitro* study.

Air leakage through the valves tested in this study was low. The largest average leak was less than 0.3 ml/s at −30 cmH_2O pressure. This approaches the limits of detectability in clinical practice,[2] and certainly falls below the flowrate implicated in most actual clinical complications. The situation of slow, continued leakage of air into the circulation has not been studied, so an "acceptable" leak rate cannot be defined. However, the experiences of Horrow and Laucks underscore the vulnerability to air-induced complications of any patient with a right-to-left intracardiac shunt.[3]

Certain valve designs appear capable of folding on themselves as the catheter is withdrawn, rendering the valve incompetent. Were this to occur, a situation similar to that described by Doblar *et al.*[1] would exist—a catheter introducer with one end in the venous system

and the other open to atmosphere. Careful inspection of the proximal end of the catheter introducer after removal of the pulmonary artery catheter could detect either absence or incompetence of the valve.

The relatively high average air flow through the USCI Hemaquet® valve immediately and two hours after removal of the PA catheter was the result of one valve leaflet in one sample folding upon itself as the catheter was withdrawn. Airflows of 1.36 ml/s were measured immediately after catheter removal. The defect in the valve was obvious to the naked eye, and the valve assumed its normal configuration spontaneously.

The valve mechanism of valved percutaneous catheter introducer sheaths has been accused of tearing the balloon on flow-directed catheters. We did not test balloon integrity and are unaware of any data supporting that contention. Even if it were true, the potential danger of air embolism from any misadventure with a nonvalved catheter introducer would seem to outweigh the occasional need to discard a damaged flow-directed catheter. We agree with Doblar *et al.*[1] in suggesting that if percutaneous catheter introducer sets with sidearms are to be used without catheters, only those introducers which have competent valve mechanisms should be inserted.

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Anesthetic Management and Gas Scavenging for Laser Surgery of Infant Subglottic Stenosis

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The CO_2 laser has been used recently to excise severe subglottic stenosis in infants, thus avoiding tracheotomy.[1] Anesthesia in these cases is difficult because the surgeon needs an unobstructed view and access to the subglottic larynx. In the last eight months, four infants with severe subglottic stenosis presented in our hospital and were treated with CO_2 laser as an alternative to tracheotomy. We describe the anesthetic management and scavenging of anesthetic gases and vapors that escape into the operating room.

Report of a Case

A 3.9-kg, 7-week-old girl, whose trachea had been intubated orally and was receiving continuous positive airway pressure (CPAP), was admitted to our intensive care unit. She had a history of "noisy breathing" since birth which had become progressively worse. Laryngoscopy at another hospital had yielded the diagnosis of congenital subglottic stenosis; within several hours of the endoscopic procedure, the infant had developed marked respiratory difficulty necessitating intubation of the trachea. A 2.5 endotracheal tube was inserted and she was transferred to our hospital. On admission, coarse rhonchi were present in both lung fields. On CPAP, with a $F_{I_{O_2}}$ of 0.4, pH_a was 7.37, Pa_{CO_2} 45 mmHg, and Pa_{O_2} 88 mmHg.

She was scheduled for endoscopic evaluation. Atropine, 0.1 mg, im, was given 30 min before inducing anesthesia with halothane and 50% nitrous oxide through the endotracheal tube. When adequate anesthetic depth was obtained, the trachea was extubated and the epiglottis, arytenoids, vocal cords, and trachea were sprayed with 1% lidocaine. A #8 catheter attached to the anesthetic machine was introduced into the nasopharynx through the right nostril. Direct observation confirmed placement immediately above the laryngeal opening. Anesthetic gases were insufflated with the infant breathing spontaneously.

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Key words: Anesthesia: pediatric. Anesthetic techniques: nasopharyngeal insufflation, non-rebreathing. Surgery: laryngoscopy, laser. Airway: subglottic stenosis. Equipment: exhaust systems.