

Venous Air Embolism During Home Infusion Therapy

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ABSTRACT. Venous air embolism (VAE) is a potential complication of surgical procedures as well as central venous access. There are several reports in the literature of VAE during the in-hospital use and placement of central venous access. However, we are unaware of previous cases of VAE in children who received home infusion therapy via central venous access.

We report the occurrence of a VAE in a 2-year-old with a Broviac catheter for home intravenous antibiotic therapy. VAE occurred when a bolus of air was unintentionally administered as the mother removed the cassette from the pump when it was alarming air in line. The cassette and tubing had been placed into the pump without a fluid flush. After the tubing and cassette were removed from the pump, the air in the line was allowed to flow by gravity into the patient, resulting in the immediate onset of respiratory and neurologic symptoms. The mother administered 2 rescue breaths, and the child's color and breathing returned to normal over the next 2 minutes. After the child arrived in the emergency department, the child's mental status returned to normal and the remainder of her physical examination was unremarkable. She had an uneventful recovery and was discharged from the hospital the following day. Additional antibiotic administration was accomplished in the emergency department of a local hospital.

VAE can occur spontaneously when there is an open venous structure 5 cm or more above the heart or if air is delivered under pressure into the venous system, such as during a laparoscopy or mishaps with infusion bags. The morbidity and mortality of VAE are related to the volume of air, rate of entrainment, the patient's underlying cardiorespiratory status, and the patient's position. Morbidity and mortality occur as a consequence of right ventricular outflow obstruction or end-organ dysfunction from left-sided obstruction of coronary or cerebral vasculature as air passes across a patent foramen ovale or through the pulmonary circulation.

Of all the literature pertaining to VAE with central lines, there are no previous reports of VAE occurring during home infusion therapy in children. With managed care requiring shorter hospitalizations and more children being discharged from the hospital on home infusion therapy, parents and lay caregivers are being asked to administer medications and perform routine maintenance on central venous devices. In our case, despite the fact that the mother had been educated regarding the appropriate technique for medication administration, she forgot to purge the air from the line before

connecting the tubing and administering the antibiotic. Although the infusion pump will alarm when there is air in the line, it detects air only in a small part of the line and this safety feature is not in play if the device is removed from the infusion pump and administered via gravity. If such safety precautions are not adhered to, then the volume of air that fills the intravenous tubing from the drip chamber to the patient (25–30 mL in the pediatric infusion pump tubing used in our patient) can be infused by gravity into the patient's venous system.

Because the consequences of VAE are so severe, the focus should be on prevention. Pumps used for home infusion therapy should have appropriate alarms to alert caregivers to the presence of air in the line. Obviously, this will not totally prevent this complication as this type of pump was used in our patient. It is crucial to educate caregivers of patients with central venous access regarding the hazards of VAE and safety measures to prevent it. With the increased use of home infusion therapy, ongoing evaluations of complications related to this form of therapy are mandatory so that there is continued evaluation of practices and appropriate changes made when necessary to increase further the safety of these techniques. *Pediatrics* 2002;109(1). URL: <http://www.pediatrics.org/cgi/content/full/109/1/e15>; *venous air embolism, home infusion therapy, central venous access*.

ABBREVIATIONS. ED, emergency department; VAE, venous air embolism.

Home infusion therapy has become increasingly popular during the past 25 years since Rucker and Harrison¹ reported using home antibiotics in a group of 62 patients with cystic fibrosis in 1974. The number of patients who receive home intravenous antibiotics currently exceeds 250 000 per year with home antimicrobial infusions representing a \$2 billion industry.² In an era of increasing emphasis on cost containment, home antibiotic services can provide savings for insurance companies, health maintenance organizations, and government agencies.

Successful home therapy requires a multidisciplinary approach with an emphasis on caregiver education to prevent potential adverse events. Any situation that requires access of a central venous device can be fraught with potential morbidity or even mortality. In addition to potential adverse effects related to the medication itself, previously reported catheter-related complications include thrombosis, occlusion, infection, kinking, and trauma with line-related bacteremia being the most common catheter-related complication.³ Although inadvertent air embolism is a widely known complication in the inpatient and

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operative settings, it has not been previously reported in the setting of home infusion therapy. We report a case of an air embolus during home antibiotic infusion in a pediatric patient as a reminder of the potentially fatal complications that can be associated with this therapy and the importance of thorough caregiver education before initiation of home therapy.

CASE REPORT

A 2-year-old girl was brought to the emergency department (ED) because she stopped breathing and turned blue during a home infusion of vancomycin. She had a Broviac catheter placed for intravenous administration of vancomycin to treat chronic otitis media with effusion secondary to a methicillin-resistant *Staphylococcus aureus*. Infusion therapy had started 3 days before admission using a single-channel IMED infusion pump (IMED Corp, San Diego, CA). During the initiation of an infusion, the mother noted that the child stiffened up, turned blue in the face, and was not breathing. The patient's arms and legs stiffened bilaterally. No clonic movements were noted. After 2 rescue breaths were administered, her breathing and color gradually returned to normal during the next 2 minutes. On arrival, the paramedics found the child to have stable vital signs and transported her to our ED without incident. In the ED, the mother reported that before the incident, the alarm on the pump had sounded and the warning on the infusion pump read air in line. She also reported that she had not flushed the tubing before starting the infusion. When the pump alarmed, the bag and line were removed from the pump, the safety clamp was disengaged, and fluid/air was allowed to drip into the patient with gravity flow. No fluid (vancomycin) had actually reached the child before she developed the previously described signs and symptoms. Previous infusions had been tolerated without incident. On arrival to the ED, her vital signs were as follows: temperature, 37.3°C; blood pressure, 85/59 mm Hg; heart rate, 123 beats/minute; respiratory rate, 22 breaths/minute with an oxygen saturation of 90% on room air that improved to 98% on 30% fraction of inspired oxygen by face mask. Initially, the child was awake but lethargic. Her mental status rapidly improved to interactive and appropriate with examiners. Her physical examination was unremarkable other than a left purulent otitis media with effusion and a bulging right tympanic membrane with loss of landmarks. The Broviac catheter was in place in the left chest and had no signs of irritation or infection. Her neurologic examination was unremarkable with normal tone, reflexes, strength, and sensation in all extremities. A chest radiograph was unremarkable. On the basis of the patient's history and rapid resolution of symptoms, a presumptive diagnosis of venous air embolism (VAE) was made. Echocardiography did not reveal any evidence of intracardiac air. Telemetry monitoring revealed no abnormalities, and observation overnight in the pediatric intensive care unit was unremarkable. On discharge, antibiotic infusions were administered in the ED of a local hospital twice a day until the completion of therapy. Future vancomycin infusions were tolerated without difficulty.

DISCUSSION

VAE can occur spontaneously when there is an open venous structure 5 cm or more above the heart or if air is delivered under pressure into the venous system, such as during a laparoscopy or with mishaps with infusion bags, as was the case with our patient. The morbidity and mortality of VAE are related to the volume of air, rate of entrainment, the patient's underlying cardiorespiratory status, and the patient's position. In animal studies, infusion rates of >1.8 mL/kg/minute are fatal.⁴ In humans, the actual volume of gas that can be tolerated is unknown; however, mortality has been reported with injection of as little as 100 to 300 mL.⁵ Morbidity and mortality can occur as a consequence of right ventricular outflow obstruction and/or pulmonary

vasospasm with right-sided air or end-organ dysfunction from left-sided obstruction of coronary or cerebral vasculature as air passes across a patent foramen ovale or through the pulmonary circulation.

The surgical literature contains several reports of both fatal and nonfatal intraoperative VAE during various types of surgical procedures. VAE was originally reported during neurosurgical procedures performed in the upright sitting position with an incidence as high as 80%.⁶ VAE has also more recently been reported in several other surgical procedures, including lumbar laminectomy and obstetrical procedures; 1 study reported an incidence of 40% during cesarean sections.^{7,8}

The highest incidence of VAE is found in association with central venous access. VAE can occur during cannulization or later during accessing and use of the catheter. Although there is an obvious risk during venous cannulization, the majority of cases occur during maintenance of the catheter.⁹ Disconnection of the line, fracture of the hub, and a break in the tubing itself all may lead to air entry into the venous system. Patients who are cachectic, hypovolemic, or seated upright or who have high negative intrathoracic pressure are at higher risk for air entrainment.⁹

The largest prospective study of patients with complications attributable to long-term central venous access, reported by Torramadé et al¹⁰ in 1993, followed 218 patients, 45% of whom were younger than 18 years. There were no episodes of VAE during placement, routine use, and maintenance. However, the authors noted that the number of complications that were a direct result of home care of the line could have been reduced had more comprehensive instructions been provided to the staff and family members who were caring for the line.

Of all of the literature pertaining to VAE as a result of central lines, there are no previous reports of VAE occurring during home infusion therapy in children. With managed care requiring shorter hospitalizations and more children being discharged from the hospital on home infusion therapy, parents and lay caregivers are being asked to administer medications and perform routine maintenance on central venous devices. In our case, despite that the mother had been educated regarding the appropriate technique for medication administration, she forgot to purge the air from the line before connecting the tubing and administering the antibiotic. Although the infusion pump will alarm when there is air in the line, it detects air only in a small part of the line and this safety feature is not in play if the device is removed from the infusion pump and administered via gravity. If such safety precautions are not adhered to, then the volume of air that fills the intravenous tubing from the drip chamber to the patient (25–30 mL in the pediatric infusion pump tubing used in our patient) can be infused by gravity into the patient's venous system.

The prompt recognition of VAE is crucial for successful treatment by allowing for the prompt prevention of additional air entry. In animals or humans, with spontaneous respiration, a respiratory gasp oc-

curs after the initial air infusion followed by apnea and cyanosis, as was evident in our patient. Patients may complain of dyspnea, tachypnea, shortness of breath, lightheadedness, and chest pain. Cardiovascular signs and symptoms include tachycardia and hypotension. Classically, with auscultation, a mill-wheel murmur can be heard when a large enough bolus of air is trapped in the right ventricle. Neurologic signs include seizures, focal deficits, confusion, neurologic collapse, and obtundation. Subsequent cardiorespiratory changes may occur, including ventilation/perfusion inequalities, adult respiratory distress syndrome, pulmonary hypertension, hypoxemia, and hypercarbia. If there is a communication between the arterial and venous systems, such as in patients with patent foramen ovale or atrial septal defects, then fatal complications may result when an air embolus occurs and enters the cerebral or coronary vasculature.

The diagnosis of VAE begins with recognition of the symptoms and the site of air entry. Although the diagnosis generally is based on the history and clinical signs and symptoms, additional documentation can be provided by demonstrating the presence of air within the vasculature or alterations in cardiorespiratory function from the VAE. When the volume of air is limited, it is rapidly reabsorbed or excreted by the lungs and therefore no demonstration of intravascular air is possible. In order of sensitivity, the options to detect air within the vasculature and document VAE include echocardiography (transthoracic or transesophageal), precordial Doppler, end-tidal nitrogen monitoring, and auscultation of the previously mentioned mill-wheel murmur.¹¹ Large volumes of air can be documented by chest radiograph if the volume is large enough and still present in the heart. If the patient already has a central line in place, then it is rarely possible to aspirate air from the catheter. The options to detect cardiorespiratory changes and document VAE include end-tidal carbon dioxide, transcutaneous oxygen/carbon dioxide, and central venous/pulmonary artery pressure monitoring.⁶

Initial treatment includes prompt recognition and prevention of additional air entry followed by support of the cardiorespiratory system. Once VAE is identified, the patient should be given 100% oxygen and placed in the left side down, Trendelenberg position (Durant's maneuver) to relieve the air lock in the right heart. This positioning allows the air to gather in the apex of the right ventricle and move away from the right ventricular outflow tract. Inotropic support may be necessary if there is cardiovascular compromise. If there is a central venous catheter in place, then aspiration of the VAE may be attempted with some degree of success. With massive air entrainment, the use of open thoracotomy with direct aspiration from the heart or cardiopulmonary bypass has been reported.^{12,13}

Because the consequences of VAE are so severe, the focus should be on prevention. Pumps used for home infusion therapy should have appropriate

alarms to alert caregivers to the presence of air in the line. Obviously, this will not totally prevent this complication as this type of pump was used in our patient. It is crucial to educate caregivers of patients with central venous access that infusion lines must be purged of air before administering intravenous fluids or medications and that even the apparently small amount of air present in the distal part of the line can be hazardous. Furthermore, it should be stressed that the central line should be clamped until the distal end has been connected and tightened sufficiently to prevent air entry. Taping the lines in such a manner to prevent tension being placed directly on the hub will prevent hub failures and catheter hub disconnections that can lead to air entrainment. It is also recommended that the distal hub be placed such that in an upright position, the level is below the heart. This would cause back bleeding in the event of a disconnection as opposed to air entry.^{14,15} Parents or other caregivers also need to be taught that close inspection of all connections and filters is crucial to recognizing possible sites of mechanical failure or loose connections. These precautions decrease the incidence of this potentially fatal complication.¹⁵ With the increased use of home infusion therapy, ongoing evaluations of complications related to this form of therapy are mandatory so that there is continued evaluation of practices and appropriate changes made when necessary to increase further the safety of these techniques.

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