How Many “Milliliters” of Air Will Lead to an Air Embolism?

*Air in infusion lines is a major hazard to patients. How many milliliters of air will lead to an air embolism? Are minimal air bubbles acceptable, and what is “minimal?”*

**Answer:**

Unfortunately, there is no “X mL” answer to this question because the development of an air embolism is the combined result of many factors. Fortunately, air embolism is a rather rare complication.

**Multiple Causes of Air Embolism**

An air embolism may have many different causes, and most are iatrogenic in nature. Examples include:

- Unvented infusion lines (approximately 6 mL) can lead to an air embolism which in adults may be relatively unsymptomatic, though (1, 2, 3). In children, especially in preterm infants and neonates, even minute amounts of air may lead to an air embolism with catastrophic consequences (4).
- Parallel infusions (pump, gravity infusion), development of [beading] (fluid-air-fluid etc.) when a gravity infusion runs empty (5).
- Intraoperative air embolism in surgical procedures performed above heart level, e.g., with the patient in a sitting position (neurosurgery) (6).
- In spontaneously breathing patients, disconnection of a central venous catheter causes a suction effect with each breath and this facilitates the ingress of larger amounts of air (7, 8).
- Pressure infusions with plastic bottles containing residual air (9).
- Other factors, such as laparoscopic procedures (10), suicides, etc.
Studies in dogs and sheep (2, 3) have shown that the hazardousness of air depends essentially on the volume per kilogram of body weight and unit time (mL/kg/unit time) as well as on the size of an individual bolus, its rate and route (peripheral or central venous) administration. Dogs did not survive an air volume of 0.69 mL/kg/min (3).

Other studies indicate similar air volume limits. Case reports in the literature also describe that even larger amounts of air in the venous system of adults have been survived without neurological complications (13, 14, 15).

In the arterial system, even microscopic air bubbles may suffice to cause myocardial “infarction” or a cerebrovascular “accident” (11).

About one-third of all people have a patent oval foramen (12). Under conditions of resuscitation in particular (pressure passive patent foramen), there is the possibility that air from the venous system may directly enter the arterial system, and this will most likely be lethal for the patient.

What does this mean for routine nursing care?

Always use utmost care with all infusions.
– Make sure there is no air in the sets, and take care when changing bottles and bags.
– Regularly inspect the (tubing-needle/catheter) connections as part of your nursing routine.
– Always configure infusion regimens so that a siphon (>20 cm) in the system protects against the ingress of air, especially when a container runs empty (Figure 1).
– Avoid parallel infusions where possible. If a parallel infusion is really necessary, use a check valve in the gravity line, and place the three-way valve of the bypass of the infusion pump in the ascending siphon tube (in the direction of the patient) (Figure 2).
– As well as particles and bacteria, modern infusion filters can separate 100% of air from infusion lines.
– Use of modern infusion sets featuring an air stop.
– Have the air sensor of volumetric pumps (Infusomats®) adapted to the patient population you care for (children/adults).

The following alarm levels can be set on Infusomats® (16):
– Cumulated air volume per hour: 0.5 mL to max. 3.5 mL (standard setting 1.5 mL/hr).
– Size of individual air bubbles: 0.01 mL to max. 0.3 mL (standard setting 0.3 mL).

If the above limits (as set) are exceeded, the pump will stop and trigger an air alarm. Always carefully read and comply with the pump manufacturer’s Operating Instructions.

**Conclusion**

The hazard associated with air in the infusion system depends on numerous factors. Air embolism preventive measures that can be taken by nursing staff include utmost care when administering and handling infusions, bubble-free filling of infusion sets, creation of a siphon, monitoring of luer [lock] connections, and the use of air stop infusion sets.

To avoid any misinterpretation, air should *per se* be considered unacceptable in infusion sets. The limits specified by the pump manufacturer may be helpful (as mentioned above), but the patient population and their medical condition must always be borne in mind as well.

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