Suction devices

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Abstract

Suction devices have widespread uses in the clinical environment. The process of suction is the removal of fluid or other debris using a vacuum, and the properties of suction devices are governed by the physics of the flow of fluid through a tube. The rate of flow is dependent on the radius, length and pressure difference across the ends of the tube. A pump is used to create the vacuum, the efficiency of which depends on the maximum displacement and degree of sub-atmospheric pressure that is generated. A high-efficiency, high-pressure system is used for the removal of vomit and secretions from the airway; a low-pressure system is used for intercostal drains. A central electrically driven pump is utilized in most clinical areas, but portable systems are available. The main components of a suction device are the pump, control box, reservoir, transfer tubing and suction catheter. Safety features prevent contamination of the pump and atmosphere by waste particles. Adverse effects of airway suction by rigid or flexible catheters include soft tissue trauma and airway obstruction as well as hypoxaemia, atelectasis and cardiovascular instability.

Keywords Bernoulli principle; liquid flow; suction; suction devices; vacuum; Venturi effect

Royal College of Anaesthetists CPD Matrix: 1A03, 1C02, 2A01

Learning objectives

After reading this article, you should be able to:

- understand the physical principles of the flow of a liquid
- outline the generation of a vacuum and how its characteristics affect its efficiency
- identify the essential components of a suction device

Suction devices are used throughout the anaesthetic and intensive care environment. They are regarded as essential equipment, necessary for the delivery of safe patient care. The Association of Anaesthetists of Great Britain and Ireland (AAGBI) has set out standards for suction, stating that it must be present, clean and working prior to delivering an anaesthetic.[1]

The use of suction is varied. High-pressure systems are used for removal of blood, vomit, and saliva from an airway. Lower pressure systems are used for nasogastric tubes, chest drains and vac-dressings. Suction is also used to maintain a surgical field, evacuate surgical plume and clean spills from the theatre floor.

The physics of suction

- Suction devices use a pump to create a vacuum. The vacuum creates a pressure gradient which allows fluid or other matter to be removed from the patient end and the liquid or matter to be collected in a reservoir.
- Suction apparatus can be considered as a series of tubes of varying diameters. The principles of flow through a tube can be applied and the characteristics of the system determine if the flow is laminar or turbulent.
- The rate of flow (Q) is the amount of a substance passing a certain point per unit time. This is related to the tube length, radius and the pressure gradient between each end. Fluid viscosity affects laminar flow and fluid density affects turbulent flow.
- Laminar flow exists where all particles of the liquid move in the same direction. In this manner, a series of concentric tubes within the tube are created. Liquid at the centre moves more quickly than liquid at the edge due to the effect of resistance from the tubing itself.
- Turbulent flow occurs when particulate matter is suctioned, or uneven surfaces are encountered. During turbulent flow, fluid particles move in different directions and form eddies.
- The Bernoulli principle states that when fluid flow increases there is a corresponding decrease in its potential energy and therefore the pressure it exerts. When a fluid passes through a constriction in a tube, the flow increases and pressure decreases (Figure 1).
- The decrease in pressure is the Venturi effect (Figure 1). If a second tube is attached at the point of the constriction the decrease in pressure can be employed to draw a fluid down through the second tube into the first tube (entrainment).

Creating a vacuum

The pump may be electrical, pneumatic or manual (Figure 2), and is integrated into the suction device or remote from it. The type of pump used will depend on the characteristics the suction device requires.

The efficiency of a suction system is described in terms of two main characteristics of the pump.

- Displacement – the amount of air – at atmospheric pressure, that the pump is able to move (litres/minute)
- Degree of vacuum – the amount of negative pressure (subatmospheric) that the pump generates and the time taken to achieve it.

Centrally piped vacuum system

These systems are those typically found in wall-mounted suction in a hospital environment. A powerful pump with a nearby large reservoir creates a vacuum that is transmitted, via pipeline to clinical areas.

Three or more pumps are required as standard to mitigate the risk of pump failure and enable maintenance. Each pump works

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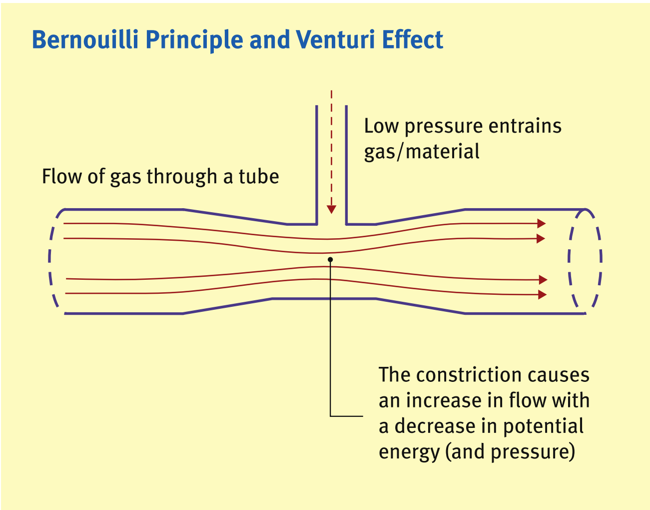

Figure 1

independently, thus, in the case of pump failure, the desired sub-atmospheric pressure can be maintained in the reservoir. Such systems are capable of a large displacement and high degree of vacuum. International standards[2] specify that a device used for pharyngeal suction should evacuate 200 ml of simulated vomitus within 10 seconds, develop a vacuum of 40 kPa below atmospheric pressure within 10 seconds, and produce a minimum free airflow rate of 20 litres/minute.

Outlets for the vacuum are wall mounted and self-closing. An indexing system prevents cross-connection with other gases. In the UK a yellow flexible hose connects to the outlet via a Schrader probe and non-interchangeable indexing collar. Current standards state that each ICU bed space has between two and four suction outlets, one per anaesthetic room, two per theatre and two per recovery bed space.[3]

Suction devices

There are five main components of a suction device: a pump, control box, reservoir, transfer tubing and catheter (Figure 3).

Figure 2 A Laerdal portable suction device.

Their safety, production and maintenance are governed by a series of international standards. Different types of suction are useful in different situations.

Pump

Electrical

- Mains or battery operated. Rotary pumps are used in centrally operated systems and produce high displacement and vacuum. Piston pumps produce high vacuum but low displacement.

Pneumatic

- These utilize the Bernoulli principle and Venturi effect. The driving gas creating the vacuum effect can be compressed air, oxygen, steam or water (Figure 1). Suctioned material is entrained into the driving gas. They do not require electricity and, depending on the design, can achieve high displacement or a high vacuum.

Manual

- Typically these pumps operate via a bellows system, driven by hand or foot. The degree of vacuum and displacement is dependent on the size of the bellows and effort of the operator.

Control box (Figure 4)

This consists of a number of components for function and safety.

- On-off switch
- Vacuum control valve – the amount of vacuum at the patient end can be adjusted according to need. To reduce the vacuum air is allowed to bleed into the system
- Vacuum gauge – measures vacuum pressure and allows testing. Typically a dial design where the dial rotates anti-clockwise as negative pressure increases
- Filter and float – these are protective mechanisms within the device. They act independently to stop material passing from the reservoir into the control box, central piping and pump. Thus protecting maintenance workers, avoiding contamination of the whole system, and preventing release of infective droplets into the atmosphere. Their design should not impede airflow or affect efficiency
- Cut-off valve – a final safety mechanism to prevent contamination of the pump in the event of float or filter malfunction.

Reservoir

The reservoir is the vessel that collects suctioned material. The nature of these containers is varied, but they will often be graded for measuring the contents. A sufficiently sized reservoir is required for the expected contents, but this must be balanced by the increased time to create the required vacuum within a larger container. Most reservoirs will have a disposable liner for ease of cleaning and removing suctioned material. As the reservoir fills, the float rises on the surface to occlude the outflow from the reservoir, preventing pump contamination.

Multiple reservoirs can be used, either in series, whereby fluid suctioned into the first reservoir is then sucked through to the second; or in parallel, so when switching the pump from one reservoir to the next, there is only brief loss in suction.