Can J Anesth/J Can Anesth (2015) 62:427–428
DOI 10.1007/s12630-014-0258-y

CORRESPONDENCE

Understanding the physics and fluid dynamics governing ultrasound gel behaviour facilitates its use: the ketchup analogy!

Vincent Lecluyse, MD

Received: 1 October 2014 / Accepted: 20 October 2014 / Published online: 29 October 2014

To the Editor,

Ultrasonography has now become ubiquitous in modern anesthesia practice. It can be used to guide peripheral nerve blocks, to assist with vascular access, and even to provide point-of-care patient evaluation during resuscitation.

A layer of gel is generally applied between the transducer and the patient's skin to improve transmission of ultrasound waves. This gel is commonly stored in cylindrical 250 mL containers. Due to the gel's high viscosity, it can be difficult to access the contents of the container whenever it is less than fully filled, and an inability to remove the gel and completely empty the container may lead to loss of time, waste of gel, and increased frustration. A good case in point is the similar challenge encountered with a ketchup bottle! The following overview of the principles of physics governing fluid motion should help to clarify the concepts at issue when manipulating ultrasound gel (and ketchup).

First, the physical properties of this material must be well understood. The viscosity of a fluid is a measure of the resistance to deformation when force is applied; this property may be referred to as fluid "thickness". Many liquids of moderate viscosity, like ultrasound gel (or ketchup), can behave as either liquids or solids depending on the underlying conditions. For example, some authors actually consider glass, a material largely considered a solid, to have the properties of a liquid with very high viscosity. This idea is based on the observation that the dependent portion of a glass window will become progressively thicker over time at the expense of the non-dependent portion.[1]

With our knowledge of the mixed properties of ultrasound gel, we can predict how it will move. In order for movement to occur between two solid objects, an applied force must overcome the static friction existing between the objects.[2] In our case, the goal is to generate enough force to break the static friction between the container walls and the gel (which we consider behaves partially as a solid). If a bottle is placed upside down, the force of gravity is insufficient to break the static resistance and displace the gel. Very slow motion will occur because of the liquid qualities of the gel, but since it is rarely convenient to wait for hours, many clinicians will eventually vigorously shake the container. Although some movement of gel is generated by this method, lack of control over the direction of motion gives disappointing results at best and comes at the unnecessary expenditure of energy. Herein, I propose a different method that provides consistent results with minimal effort.

Fundamental physics stipulates that a rotating object will always create a force vector oriented towards the centre of rotation. As force is the product of mass and acceleration, with a constant mass of ultrasound gel one need only consider the factors determining acceleration. Acceleration toward the centre of rotation, centripetal acceleration (a), is a function of an object's speed of rotation (v) and the radius of its circular trajectory (r), and it is governed by the equation $a = \frac{v^2}{r}$.[3] Newton's third law of motion stipulates that, for any force in one direction, there is a force of equal magnitude in the opposite direction.[4] This apparent force that draws a rotating body away from the centre of rotation is referred to as the reactive centrifugal force. At constant mass, the reactive centrifugal acceleration (a') may be calculated using the

V. Lecluyse, MD (✉)
Département d'anesthésie, Université de Sherbrooke, CHUS, Sherbrooke, QC, Canada
e-mail: vincent.lecluyse@gmail.com

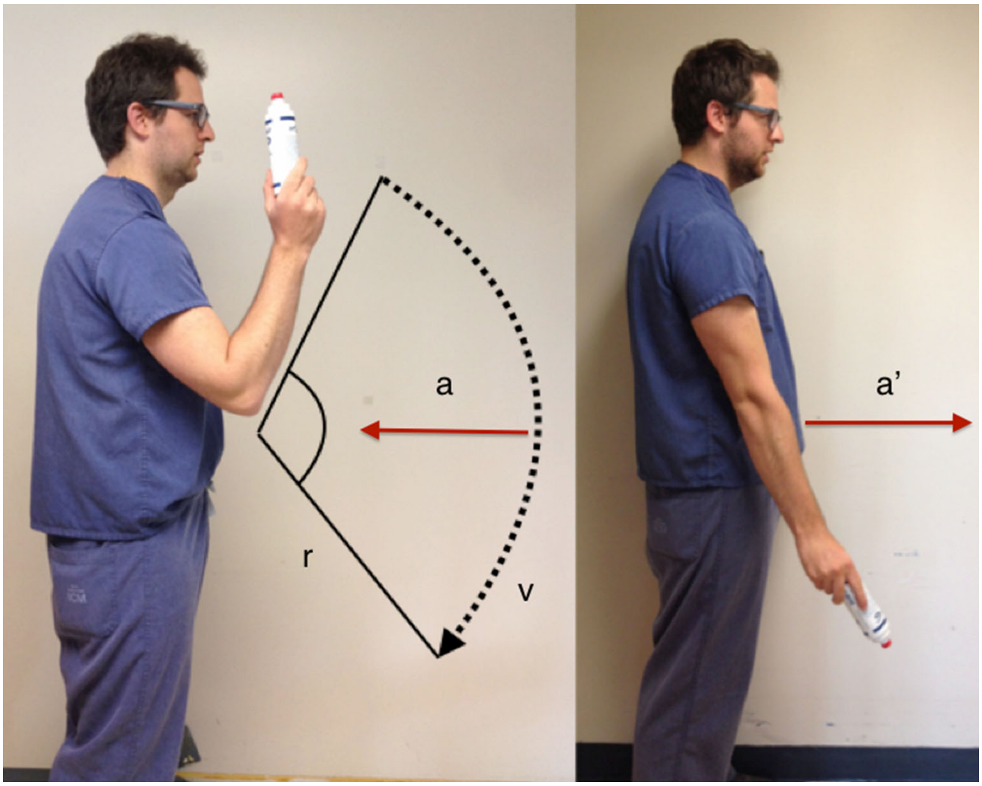

Figure Components of centrifugal force. Rapid acceleration of a bottle over a circulatory trajectory will create an outward driving force (centrifugal force) and easily displace the ultrasound gel. a = centripetal acceleration; r = rotation radius; v = rotation velocity; a' = reactive centrifugal acceleration

formula above where the magnitude of $a' = -a$. If the object in question is the gel container moving at high speed (v) in an arc created by a person's arm (r), the resulting reactive centrifugal force (a') directed away from the centre of rotation will be strong enough to overcome static friction and displace the gel towards the inner wall of the bottle during rotation (Figure).

After this maneuver, the gel should be lined up with the lid of the container, and gentle pressure should easily provide the necessary quantity of gel. Before trying to impress your co-workers with this move, it may be best to test this technique on another high-viscosity liquid - ketchup!

Disclosure No funding was received to support this work. No commercial or non-commercial affiliations.

Conflicts of interest None declared.

References

1. *Elert G*. Viscosity. The Physics Hypertextbook. ©1998-2014. Available from URL: http://www.physics.info/viscosity/ (accessed October 2014).
2. *Bhavikatti SS*, *Rajashekarappa KG*. Engineering mechanics: New Age international Ltd.; 1994.
3. *Scott GD*. Centrifugal forces and Newton's laws of motion. Am J Phys 1957; 25: 325.
4. *Isaac N*. The Principia – Mathematical Principles of Natural Philosophy – A New Translation (by Cohen IB, Whitman A). University of California Press; 1999.