Feeling wall tension in an interactive demonstration of Laplace’s law

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Submitted 15 February 2012; accepted in final form 9 April 2012

LAPLACE’S LAW plays a mayor role in explanations of the wall tension of structures like blood vessels, the bladder, the uterus in pregnancy, bronchioles, eyeballs, and the behavior of aneurisms or the enlarged heart.

The general relation of Laplace’s law, expressing that the product of the radius of curvature (r) and pressure (P) is equal to wall tension (T) (i.e., \( r \times P = T \)), is quite simple, but students often have difficulties grasping its significance when applied to the organism.

Various types of demonstrations (1, 4) and illustrations (3) are used to familiarize students with the concept.

Here, an interactive demonstration of Laplace’s law is described. During the lecture on blood flow and circulation, when pressure in different parts of the circulation is elaborated, red balloons, as shown in Fig. 1, are distributed. Students are asked to tell the difference they feel by palpation between the narrow and wide part of the balloon. They all say that the narrow part of the balloon is softer than the wide part. When asked why this is so, the answer given is “because of different pressures.” The fact that, for students, the only possible cause of different softness is a difference in pressure deserves elaboration.

Through everyday experience students know that, while inflating a bicycle tire or a ball, they can feel the augmentation of pressure by palpating the tire or the ball. As a result, the misconception forms that palpation directly gives information about pressure. However, the quantity that is directly estimated by palpation is not the pressure but the wall tension. According to the general relation expressing Laplace’s law (\( r \times P = T \)), wall tension is proportional to pressure only in the case where \( r \) is constant. Therefore, a change in pressure can be estimated by palpation only if the radius does not change. This fact is often neglected. Even in papers dealing with these issues, the terms “softness” and “pressure” are used interchangeably without underlying the fixed value of diameter (2).

When students holding the balloons are reminded of Pascal’s law, it becomes immediately clear to them that pressure is the same throughout the balloon. At this point, Laplace’s law is introduced. Now they easily conclude that the palpable difference is caused by different wall tensions. The difference in wall tension can undeniably be felt by palpation when the ratio of radii in the narrow and wide part of the balloon is \( \sim 1:10 \) (Fig. 1).

Two more examples from everyday experience are discussed to train students in the application of Laplace’s law: 1) bicycle tires, when palpated, feel softer than automobile tires, yet bicycle tires, being narrower (i.e., having smaller radii of curvature) are, as we know, inflated to higher pressures; and 2) tennis balls, compared with basketball balls, are softer, despite their higher pressure, just because they have a much smaller radius.

Finally, an example from physiology is presented. Students are asked to recall, from courses of histology and anatomy, their knowledge and experience concerning wall structures of blood vessels, in particular, large structural and mechanical differences between the wall of the aorta and the wall of a capillary. According to Laplace’s law, such large structural differences are not due to the higher pressure in the aorta because the ratio of blood pressures in these vessels is \( \sim 4:1 \) but are due to the enormously greater radius and wall tension of the aorta (the ratio of radii is \( \sim 4,000:1 \)).

Several generations of students appreciated this approach to the issue and understood the significance of Laplace’s law.

REFERENCES


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