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Mini Review

Twenty-one Reasons Affirming Starling's Law on the Capillary-interstitial Fluid Transfer Wrong and the Correct Replacement is the Hydrodynamic of the Porous Orifice (G) Tube

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ABSTRACT

Many reasons why Starling's law wrong and the correct replacement is the hydrodynamic of porous orifice (G) tube exist. Starling's hypothesis is based on Poiseuille's work in which the hydrostatic pressure causes filtration. The oncotic pressure force of plasma proteins causes re-absorption. Starling's law is wrong on both forces.

The capillary has a pre-capillary sphincter and pores that allow the passage of plasma proteins. This makes the capillary a porous orifice (G) tube with different hydrodynamic; side pressure causes suction not filtration. The pores nullify the oncotic force in vivo. There is evidence to show that the osmotic chemical composition of various body fluids is identical to plasma proteins. The interstitial fluid (ISF) space has a negative pressure of -7 cm water. Evidence on Albumin versus Saline for fluid resuscitation shows no significant difference. This affirms that the oncotic force does not exist in vivo that partly prove Starling's law wrong. Inadequacy in explaining the capillary–ISF transfer, has previously called for reconsideration of Starling's hypothesis.

Physics and physiological research demonstrate that pressure does not cause filtration across the wall of G tube, it causes suction. In G tube negative side pressure gradient causing suction maximum near the inlet and turns positive maximum near the exit causing filtration. Physiological study completed the evidence that Starling's law is wrong as the capillary works as G tube not Poiseuille's tube. Both absorption and filtration are autonomous functions of G tube thus fit to replace Starling's law. The clinical significance is discussed.

Keywords: *Capillary-interstitial fluid; Hydrodynamic; Osmotic chemical composition; Plasma; Starling's law.*

MINI REVIEW

The complete evidence that Starling's law is wrong and the correct replacement is the hydrodynamic of the porous orifice tube has been reported as summarized here[1]: Dr. Starling[2] proposed his hypothesis >80 years prior to the discovery of the capillary ultrastructure and correct capillary physiology as shown here. He based his hypothesis on Poiseuille's[2] work on strait uniform brass tube in which the hydrostatic pressure is a positive force of the arterial pressure causing filtration.[3] The oncotic pressure force of plasma albumin causes re-absorption. Starling's law is wrong on both forces because of the following reasons.[3]

1. In the pulmonary circulation arterial pressure is less than the plasma oncotic πc pressure. In the liver, muscles and lung interstitial fluid (ISF) has high protein content.Thus fluid filtration in the lungs and reabsorption in the liver and muscles lacks explanation.[3]

2. The capillary has a pre-capillary sphincter as reported by Rhodin in 1967[4,5] which makes it different from Poiseuille's tube of uniform diameter as modern research mentioned below demonstrates.

3. The capillary has porous wall of intercellular slits that allow the passage of molecules larger than plasma proteins as shown by Karnoveski in 1967.[6] Hence plasma proteins cannot exert an oncotic pressure in vivo.

4. The osmotic chemical composition of various body fluids is iden-

tical to plasma proteins as demonstrated by Hendry in 1962,[7] Hence the oncotic pressure if it exists is too week and too slow force to cause absorption.

5. The oncotic pressure of plasma proteins does not work as absorption force neither in physiology as proved by Hendry in 1962[7] nor in clinical practice demonstrated by Cochrane Injuries Group and other authors in 1998[8,9] and 2006.[10]Also most recent study using hydroxyethyl Starch (HES) as plasma substitutes for fluid resuscitation in 2020 demonstrated, like albumin, that there is no significant difference from using Saline.[11]

6. Guyton and Coleman (1968)[12] demonstrated that the interstitial fluid (ISF) space has a negative pressure of -7 cm water and Calnan et al (1972)[13] showed that the lymph has the same negative pressure. The pressure under the skin is negative. That cannot be explained by Starling's law.

7. Inadequacy in explaining the capillary–ISF transfer in many parts of the body as reported by Keele et al in 1982,[4] particularly vital organs, has previously called for reconsideration of Starling's hypothesis by Renkin in 1986.[14]

8. Recently reported evidence on plasma protein[8-10] and HES[11] versus Saline for volume replacement therapy during major surgery shows no significant difference. This affirms that the oncotic force does not exist in vivo that partly prove Starling's law wrong.

9. Both physics[15,16] and physiological[17] research has demonstrated that the hydrostatic or rather dynamic flow pressure induced by the proximal akin to arterial pressure does not cause filtration, as proposed by Starling, across the wall of porous orifice (G) tube. It causes suction.[15,16]

10. The proximal or arterial pressure induces negative side pressure gradient along the G tube wall causing suction maximum near the inlet and turns positive maximum near the exit causing filtration as based on physics experiments[15,16] (Figure 1) and physiological research17. Venous pressure enhances filtration and causes oedema but arterial pressure does not- it causes absorption by suction. Both absorption and filtration are autonomous functions of G tube making it the correct replacement for the faulty law.[1]

11. The physiological study on the hind limb of sheep[17] has completed the evidence that Starling's law is wrong as the capillary works as G tube not Poiseuille's tube.[1]

12. The physiological study showed that plasma proteins versus Saline as circulation fluid has no significant difference. First set of experiments the fluid is run through the artery. This produced no oedema formation but irrigated the limb well. Second set of experiments the fluid is run through the vein; both plasma and saline induced oedema and accumulation of fluid under the cling membrane that replaced the skin.

13. Received thinking that elevating central venous pressure (CVP) is synonymous with elevating arterial pressure is prevailing in current clinical practice during fluid therapy for shock, the resuscitation of the acutely ill patients and prolonged major surgery. This may be correct during restoration therapy for hypovolemic and haemorrhagic shock, but vascular expansion or volumetric overload (VO) is a different issue as it induces volumetric overload shocks (VOS)[18-23] and causes the acute respiratory distress syndrome (ARDS)[23,24] that was originally reported by Ashbaugh et al,[24] in 1967.

14. Persistent attempts to elevate CVP up to levels of 18 to 22 cm water are common received practice, but wrong.[23] The normal CVP is around 0 and most textbooks report a range of –7 to +7 cm water[3,4,25] The question of: Does raising CVP up to level of 18-22 cm water cause VOS?. Has been positively answered.[26]

15. Clinical observations demonstrate that, in addition to the well-known effect of high venous pressure causing oedema, arterial hypertension has no such effect, if not exact opposite. In clinical practice, although arterial hypertension is common, ISF oedema is unknown among its complications.[23]

16. In the G–C model of the physics experiments,[15,16] a minor increase in distal pressure (DP), akin to venous pressure, increases fluid volume in chamber C around the G tube (Figure 1) reverting chamber pressure (CP) from negative to positive while slowing the G–C circulation. Increasing DP has similar effect to decreasing proximal pressure (PP) akin to arterial pressure on the G–C circulation and CP and volume.

17. Vascular expansion of volumetric overload with hypervolaemia causes VO shocks.[18-22] There is no doubt that the erroneous Starling's law is responsible for the many errors and misconceptions prevailing on fluid therapy[22] for shock, the acutely ill patients and during major surgery which mislead physicians into giving too much fluid that induce VOS and cause the multiple vital organ dysfunction syndrome (MODS) or ARDS.[23,24]

18. This wrong law dictates faulty rules on fluid therapy that underlies the treating physician's thought when embarking on the overzealous fluid infusion during the resuscitation of shock, acutely ill and prolonged major surgery.

19. A concept based on the new hydrodynamic phenomenon of G tube is proposed to replace Starling's law for the capillary–ISF circulation1. It explains this vital circulation in every organ and tissue.

20. A rapid autonomous dynamic magnetic field-like G–C circulation occurs between fluid in the G tube's lumen and a surrounding fluid compartment C akin to ISF around the capillaries (Figure 1).

21. The presented evidence does not only prove that Starling's law is wrong but also provides the correct replacement that is the hydrodynamic of the G tube explaining the capillary-ISF circulation in every tissue and organ of the body. This is the only way to resolve the puzzles of the transurethral resection of the prostate (TURP) syndrome, acute dilution hyponatraemia (HN) and ARDS.[23,26,27]

Figure 1

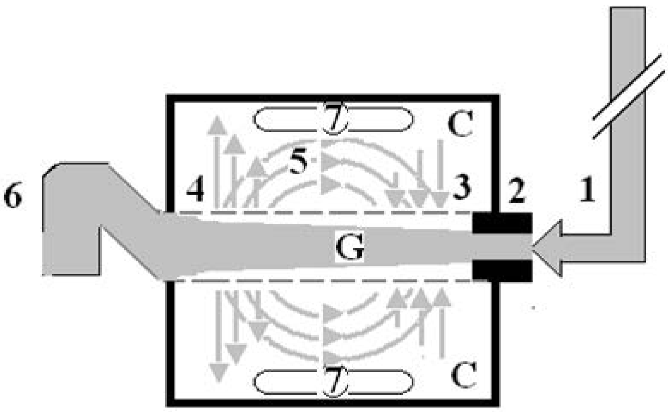

Figure 1 shows a diagrammatic representation of the hydrodynamic of G tube based on G tubes and chamber C seen in 5.

This 38-years old diagrammatic representation of the hydrodynamic of G tube in chamber C. The G tube is the plastic tube with narrow inlet and pores in its wall built on a scale to capillary ultrastructure of precapillary sphincter and wide inter cellular slit pores, and the chamber C around it is another bigger plastic tube to form the G-C apparatus. The chamber C represents the interstitial fluid space. The diagram represents a capillary-ISF unit, and the numbers should read as follows:

1. The inflow pressure pushes fluid through the orifice

2. Creating fluid jet in the lumen of the G tube**.

3. The fluid jet creates negative side pressure gradient causing suction maximal over the proximal part of the G tube near the inlet that sucks fluid into lumen.

4. The side pressure gradient turns positive pushing fluid out of lumen over the distal part maximally near the outlet.

5. Thus, the fluid around G tube inside C moves in magnetic field-like circulation (5) taking an opposite direction to lumen flow of G tube.

6. The inflow pressure 1 and orifice 2 induce the negative side pressure energy creating the dynamic G-C circulation phenomenon that is rapid, autonomous and efficient in moving fluid and particles out from the G tube lumen at 4, irrigating C at 5, then sucking it back again at 3,

7. Maintaining net negative energy pressure inside chamber C.

**Note the shape of the fluid jet inside the G tube (Cone shaped), having a diameter of the inlet on right hand side and the diameter of the exit at left hand side (G tube diameter). I lost the photo on which the fluid jet was drawn, using tea leaves of fine and coarse sizes that runs in the centre of G tube leaving the outer zone near the wall of G tube clear. This may explain the finding in real capillary of the protein-free (and erythrocyte-free) sub-endothelial zone in the Glycocalyx paradigm (Woodcock and Woodcock 2012).

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