Extended Abstract
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Cardiology 2019: The proof and reasons that Starling's Law for the capillary-interstitial fluid transfer is wrong: Advancing the hydrodynamics of a porous orifice(G) tube as the real mechanism

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Introduction and objective: In 1886, Starling proposed a hypothesis for the capillary–interstitial fluid (ISF) transfer in which the capillary was thought a tube of a uniform diameter that is impermeable to plasma proteins. The flow of fluid across its wall was thought dependent upon a balance between the hydrostatic pressure within its lumen, encouraging fluid to leave 'filtration', & the osmotic pressure of plasma proteins, tending to draw fluid back to the capillary lumen 'absorption', with similar opposing smaller forces in the ISF space. At the arterial end of the capillary, lumen pressure is greater than the oncotic pressure & fluid is pushed out. At the venous end, osmotic pressure is higher & fluid is withdrawn into capillary lumen.

The physical basis on which lumen pressure of a capillary was thought positive & responsible for filtration was Poiseuille's work (1799–1869) on long Brass tubes of uniform diameters. However, Burnoulli's effect of a fluid jet & Venturi's effect of a tube constriction are well known & must also be considered to be of significance even under laminal flow conditions. LP refers to the arterial pressure of a capillary.

We studied the hydrodynamics of a rubber inlet tube in order to demonstrate the negative side pressure gradient exerted on its wall as well as the flow pressure (FP) components of its lumen pressure (LP). We then studied the porous orifice (G) tube akin to capillary & later enclosed it in a chamber (C), akin to interstitial fluid space, making the G-C apparatus demonstrating the G-C circulation phenomenon.

The factors affecting the speed and efficiency of the G-C circulation were evaluated. These included the proximal (PP), the distal pressure (DP) & the inlet diameter (r) as a relation to the tube diameter (R). The G-C apparatus was enclosed in a circulatory model driven by electrical pump & connected to manometers for evaluating the hydrodynamics of the circulatory model.

The hydrodynamics of a rubber inlet tube that demonstrates the -ve side pressure gradient exerted on its wall as well as the flow pressure (FP) components of its lumen pressure (LP) is shown in Figure 1. A graph showing FP & SP gradients is shown in Figure 2. The hydrodynamics of the G tube is shown in Figure 3. The G-C phenomenon is shown in Figure 4. The relation of PP to SP & CP is shown in Figure 5. The relation of Orifice diameter to SP & CP is U shaped or inverted Bell shaped, & is shown in Figures 6 & 7. The relation of DP to SP & CP is shown in Figure 8. The pressure gradient observed & measured at various points in the G- C circulatory model is shown in Figure 9. Figure 10 shows a circulatory model incorporating the G-C apparatus with manometers measuring various pressures.

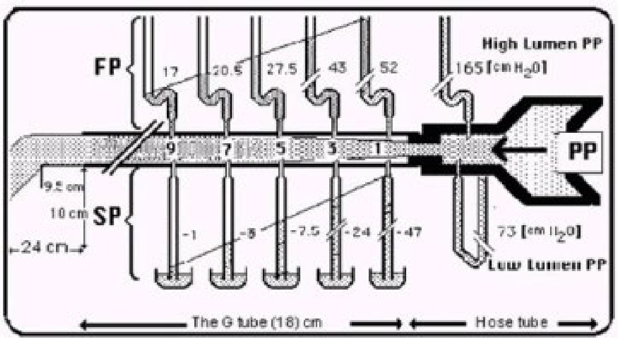

Figure 1. shows the lumen pressure (LP) components of flow pressure (FP) and side pressure (SP) of a rubber orifice tube as measured by manometers with needles inserted at various cm distances from the inlet. When the needle's bevel faces upstream it measures FP (Top manometers) and when acing downstream it measures SP (Bottom manometers).

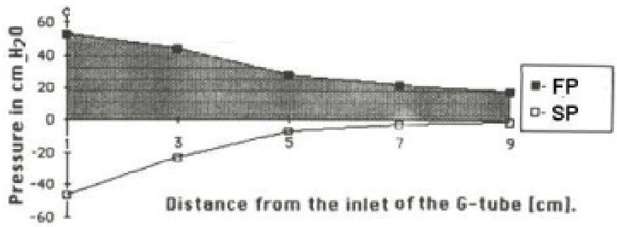

Figure 2. is a graph showing the FP and SP components of LP of the G Tube at CM distances rom the inlet.

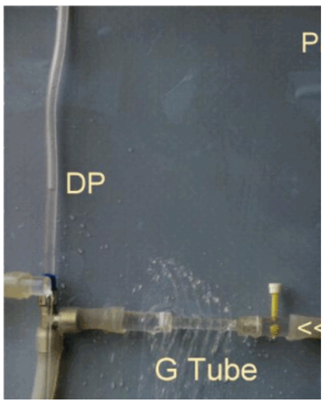

Figure 3. shows the hydrodynamic of a porous oriice (G) tube. The side pressure (SP) gradient exerted on its wall turns from negative near the inlet to positive near the exit. The magnetic field like G-C circulation is shown when the tube is placed in a surrounding chamber.

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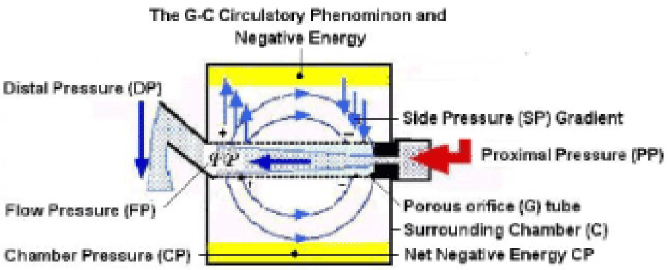

Figure 4. shows a diagram o the G-C circulation creating a net negative pressure in C (Highlighted in yellow).

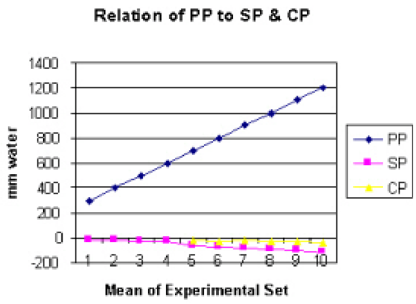

Figure 5 shows the relation of proximal pressure (PP) to side pressure (SP) and chamber pressure (CP). A high PP enhances suction negativity of SP and CP.

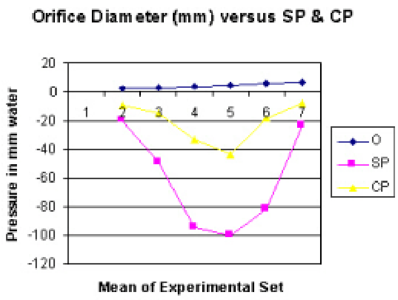

Figure 6. shows the relation of orifice diameter to side pressure (SP) and chamber pressure (CP).

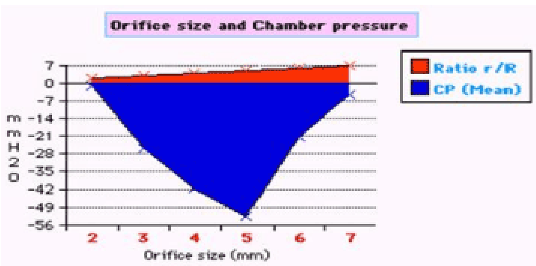

Figure 7. shows the relation of orifice ratio to tube diameter on CP.

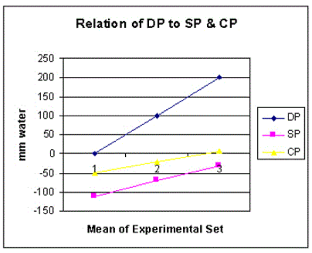

Figure 8. shows the relation of distal (venous) pressure (DP) to side pressure (SP) and chamber pressure (CP).

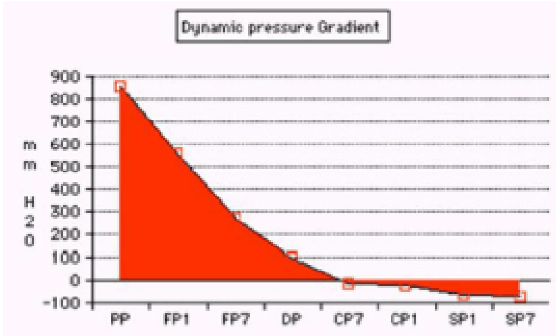

Figure 9. shows the pressure gradient from proximal pressure (PP) to flow pressure (FP) inside the G tube at points 1 and 7 to distal venous pressure (DP) then chamber pressure (CP) and side pressure (SP) at points 1 and 7.

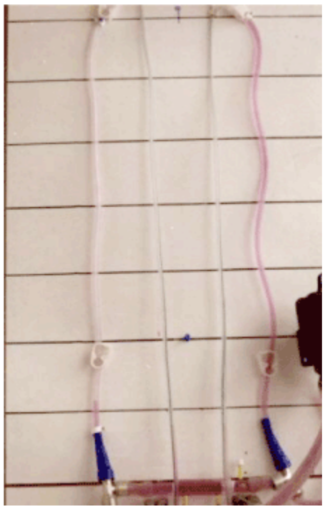

Figure 10. shows a circulatory model incorporating the G-C apparatus with manometers measuring PP, CP at points 1 and 7 and DP. Note that CP is lower than DP.

It is observed from the submitted results that the hydrodynamics of the G tube is totally different from Poiseuille's tube. The orifice of the G tube creates a -ve pressure gradient on its wall inducing a suction force which is transmitted to the surrounding chamber C creating a dynamic magnetic field like fluid G-C circulation that rapidly irrigates the C. The orifice thus transfers the PP from filtration force in Poiseuille's tube into a suction force in the G tube. Increasing the PP enhances the G-C circulation while reducing it slows it down as shown in Figure 5. Increasing the DP slows down the G-C circulation & turns the pressure in C into positive with increased volume. The effect of increasing the orifice diameter has U or inverted Bell shaped effect on SP & CP Figure. The G-C circulation thus offers a complete & correct replacement for Starling's law. The circulatory model has remarkable similarity to the circulatory vascular system.

Conclusion

Hydrodynamic studies on a porous orifice (G) tube, based on capillary ultrastructure, demonstrate results which differ from Poiseuille's in a strait tube & hence challenge the role attributed to arterial pressure as a filtration force in Starling's hypothesis. A perspective literature review shows that the oncotic pressure force has been previously cancelled & the hypothesis has failed to explain the capillary–ISF transfer in most parts of the body.

A concept based on a new hydrodynamic phenomenon is proposed for the capillary–ISF circulation hypothesis. It explains this vital circulation in every organ & tissue under both physiological & pathological conditions. An autonomous dynamic magnetic field-like G–C circulation occurs between fluid in the G tube's lumen & a surrounding fluid compartment C. Based on results of studies on a circulatory model incorporating the G–C apparatus, factors which initiate, regulate & affect the G–C circulation, its physiological & haemodynamic relevance & its clinical importance to the pathogenesis of oedema, shock & the MVOD/F syndrome are discussed.

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