

The effect of zero gravity on human deficiency virus (HIV) and white blood cells (WBC)

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Abstract

HIV enters macrophages and CD4+ T cells by the adsorption of glycoproteins on its surface to receptors on the target cell followed by fusion of the viral envelope with the cell membrane and the release of the HIV capsid into the cell for replication process. At zero gravity this adsorption of glycoproteins and fusion process are deactivated, that is unbind GP120 – CCR5 co receptor; it may be due to varying the concentration gradients (Marangoni flow) in between HIV and WBC. Another consideration the white blood cells are like a liquid drop it lets its surface tension hang out and it takes up the maximum volume, as a result unbinding DNA-DNA for HIV and WBC at inside the infected WBC. As a result the HIV separated from WBC and its activation is neutralized.

Keyword: Zero Gravity, HIV-WBC Interaction, Marangoni Flow, HIV-Replication.

1. Introduction

Beginning with its first transmission into humans from chimpanzees approximately 100 years ago, human immune deficiency virus (HIV) has had a devastating effect throughout the world. There is currently no vaccine to prevent HIV infection, and while efforts to develop such a prophylactic vaccine are beginning to show promise [1], it is a complex challenge which is unlikely to be achieved in the near future. HIV infects and kills cells of the immune system, including CD4+ T cells and macrophages. These cells are critical for mounting effective immune responses against invading pathogens. Over time, HIV replication causes depletion of these cells, leading to lower total CD4+ T cell numbers, damage to the architecture of lymph nodes and other lymphoid tissues, immune activation, and general dysregulation of immune function. After an average infection time of around 10 years, the immune system is damaged to the point that the infected individual progresses to AIDS. At this stage the individual becomes highly susceptible to both common and unusual infections and cancers, which ultimately result in death. In our present research the effect of zero gravity on WBC and HIV replication cycle.

2. Problems and solutions

2.1. HIV replication

HIV replication is required for the development of disease, antiretroviral drugs have been developed to prevent this replication and stop progression to AIDS. A retrovirus, the genetic material in HIV virions (virus particles) is RNA, but the virus replicates through a DNA intermediate that is integrated into the DNA of the host cell. During infection, the virus first binds to the CD4 protein and a coreceptor protein at the cell surface. The most commonly utilized coreceptors are the chemokine receptors CCR5 and CXCR4, with CCR5 usage generally predominating in early infection, and often maintained throughout infection. The viral and host cell membranes then fuse, and the virion-borne reverse transcriptase enzyme catalyzes conversion of the viral RNA into DNA. This DNA is transported into the nucleus as part of a pre-integration complex. The viral integrase enzyme then mediates the integration process, whereby the viral DNA is inserted into the host cell's chromosomes. At this point the resultant proviral DNA is permanently integrated and will be maintained for the lifespan of the host cell. HIV RNA is then transcribed from the integrated provirus, and is either translated into proteins (following RNA splicing for certain viral proteins), or directly incorporated into new virions. The virions assemble and bud from the

plasma membrane. Finally, the viral protease enzyme cleaves polyproteins within the virion to produce mature infectious virus particles that are ready to infect a new cell [2-4].

2.2. Zero gravity

Zero gravity is an alternative term for weightlessness and holds for instance in a freely falling lift. It is subtly different from the complete absence of gravity, something which is impossible due to the presence of gravity everywhere in the universe. Weightlessness, or an absence of 'weight', is in fact an absence of stress and strain resulting from externally applied mechanical contact-forces, typically normal forces from floors, seats, beds, scales, and the like. Counter intuitively, a uniform gravitational field does not by itself cause stress or strain, and a body in free fall in such an environment experiences no g-force acceleration and feels weightless. In our case the effect of zero gravity on HIV and WBC influence the HIV-WBC interaction.

2.3. Physics of the cell membrane

The cell membrane is dynamic. External and internal forces routinely challenge the integrity of the cell membrane, which behaves as an elastic solid. The external forces become high-frequency vibrations, Shear stress of fluid Osmotic and gravitational pressure gradient. The internal forces become hydrostatic pressure, Cytoskeletal forces that push forward to comply with needed movement, Morphological changes, Growth, Adhesion. Depending on how the force is applied the membrane may be stretched, compressed, bent or twisted.

2.4. Thermodynamic Approach to Particle-Particle Interaction

Consider the case where the virus, HIV conceived as particle approaches [5] the CD4 lymphocyte (also assumed to be a particle) and attaches itself on the surface of the lymphocyte dispersed in a serum, as shown in Fig.1.

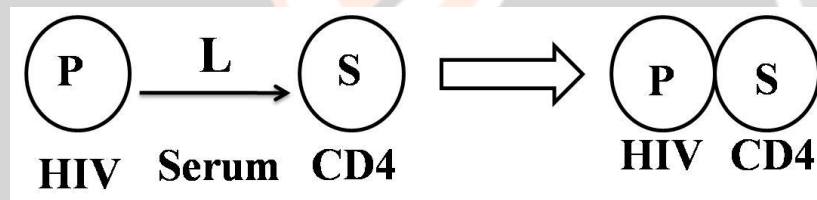


Fig- 1: Schematic of HIV-CD4 Lymphocyte Adhesion Process

The thermodynamic free energy of adhesion, ΔF^{adh} for the process shown in Fig-1 can be expressed as follows,

$$\Delta F^{adh} = \gamma_{ps} - \gamma_{pl} - \gamma_{sl} \tag{1}$$

Where the subscript P stands for the virus, S stands for the blood cell L the serum. ΔF^{adh} is the free energy of adhesion integrated from infinity to the equilibrium distance, d_0 . For the virus to succeed in penetrating the membrane of the blood cells, the net free energy of engulfing (of the virus by the blood cell) will be given by;

$$\Delta F_{NET} = \gamma_{ps} - \gamma_{pl} < 0 \tag{2}$$

At zero gravity ΔF_{NET} -is greater than zero, the WBC blood cell membrane will reject the HIV virus.

2.5. Zero-gravity and HIV-WBC interactions

This chapter deals with the interaction between WBC and HIV at zero gravity. Let us consider WBC and HIV are two different movable cells and they have different size and volume. It is explained by two phase flow motion at zero gravity. A typical example of a two-phase flow is a motion of a particle (bubble or droplet) in a stagnant fluid (liquid or gas). In many branches of engineering it is important to be able to describe the motion of gas bubbles in a liquid (Krishna & Baten, 1999) [6]. In multiphase flow, the simultaneous flow strongly depends on

the gravity force. However, in zero gravity conditions, buoyancy effects are negligible and as an alternative, three different methods were found to make the bubbles or drops move in zero gravity. They are electrocapillary, solutalcapillary and thermocapillary motion.

When a temperature/Concentration gradient exists on the interface, the surface tension varies along the interface, resulting in bulk fluid motion, called thermocapillary (Marangoni) [7] flow. In normal gravity this thermocapillary flow tends to be weighed down by buoyancy driven flow. However, for small geometry and/or zero gravity environments, this is not the case and thermocapillary is dominant and it could become an important driving force. In space, where buoyancy forces are negligible, thermocapillary forces can be dominant and can lead to both desirable and undesirable motion of fluid particles. Such a phenomenon is known as Marangoni flow or the thermocapillary migration. Marangoni flow is induced by surface tension gradients as a result of temperature and/or concentration gradients.

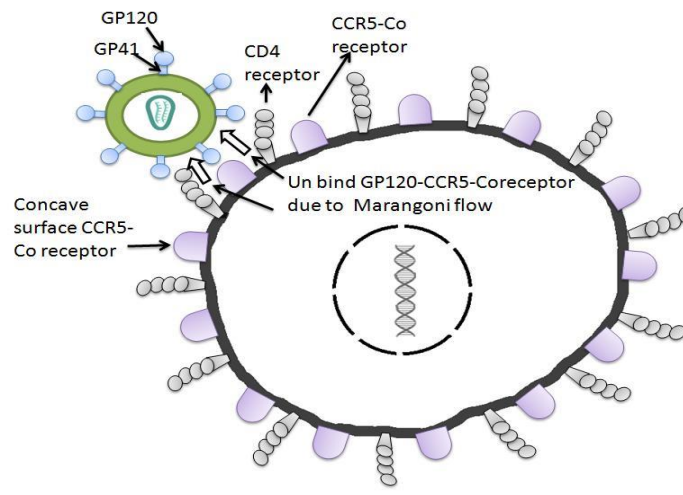


Fig-2: Un-binding of GP120 and CCR5-Coreceptor at zero gravity

Fig.2 shows that interaction between HIV and fresh WBC. At zero gravity condition the unaffected WBC CCR5-Co receptor changing its outer shape like convex shape and since it is difficult to bind GP120 of HIV on CCR5-Co receptor for WBC it may be due to absence of buoyancy forces. As a result the HIV and WBC are unbound and HIV replication become deactivate. According to thermodynamic Approach to Particle-Particle interaction was explained by eqn.2. At normal gravity environment the virus to succeed in penetrating the membrane of the blood cells because free energy of adhesion is lesser than zero, but net free energy of adhesion should greater than one since blood cell membrane will reject the virus.

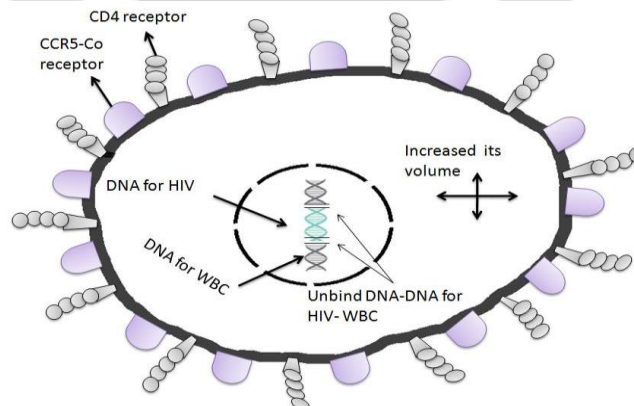


Fig-3: Un-binding of HIV and WBC DNA at zero gravity

Another consideration is WBC as a liquid drop at zero gravity it is nearly spherical shape and volume increases and other parameters also changes like internal pressure and surface tension. Finally the HIV DNA and WBC DNA becomes unbind, as a result undeveloped HIV DNA separated from WBC cell. The clear mechanism of unbinding process was explained as shown in Fig.3. Since the WBC volume increasing increases at zero gravity at the same time the bond between WBC and HIV DNA becomes break and HIV multiplication is deactivated.

3. Conclusion

HIV replication process was explained by three different approaches at zero gravity. From the Thermodynamic Approach to Particle-Particle Interaction the value of free energy of adhesion value becomes greater than zero the blood WBC cell membrane will reject the HIV virus. From Marangoni flow motion at zero gravity produce temperature/concentration gradient in between HIV and WBC as a result deactivate the HIV and WBC interaction. From liquid drop model the cell volume of the WBC were increases at zero gravity and the HIV DNA multiplication were neutralize.

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