Persistent Infections

Lecture 17
Biology 4310
Virology
Spring 2021

Paralyze resistance with persistence
—Woody Hayes
Acute vs persistent infections

- Acute infection - rapid and self-limiting
- Persistent infection - long term, life of host
- Stable, characteristic for each virus
- Most persistent infections probably begin as an acute infection
General patterns of infection

Acute
- Rhinovirus
- Rotavirus
- Influenza virus

Latent
- Herpes simplex virus types 1 and 2

Persistent: asymptomatic
- Lymphocytic choriomeningitis virus
- JC virus

Persistent: pathogenic
- Human immunodeficiency virus type 1
- Human T-lymphotropic virus
- Measles virus SSPE
Persistent infections

- Occur when primary infection is not cleared by immune response
- Virus particles, protein, genomes continue to be produced
- Viral genomes may remain after proteins are not detected
Persistent infections

- No single mechanism
- When cytopathic effects are absent and host defenses are reduced, persistent infection is likely
- Viral immune modulation
## Persistent human infections

<table>
<thead>
<tr>
<th>Virus</th>
<th>Site(s) of persistence</th>
<th>Consequence(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenovirus</td>
<td>Adenoids, tonsils, lymphocytes</td>
<td>None known</td>
</tr>
<tr>
<td>* Epstein-Barr virus</td>
<td>B cells, nasopharyngeal epithelia</td>
<td>Burkitt’s lymphoma, Hodgkin’s disease</td>
</tr>
<tr>
<td>* Human cytomegalovirus</td>
<td>Kidneys, salivary gland, lymphocytes, nervous system, stem cells, stromal cells^a</td>
<td>Pneumonia, retinitis</td>
</tr>
<tr>
<td>* Hepatitis B virus</td>
<td>Liver, lymphocytes</td>
<td>Cirrhosis, hepatocellular carcinoma</td>
</tr>
<tr>
<td>* Hepatitis C virus</td>
<td>Liver</td>
<td>Cirrhosis, hepatocellular carcinoma</td>
</tr>
<tr>
<td>Human immunodeficiency virus</td>
<td>CD4+ T cells, macrophages, microglia</td>
<td>AIDS</td>
</tr>
<tr>
<td>* Herpes simplex virus types 1 and 2</td>
<td>Sensory and autonomic ganglia</td>
<td>Cold sore, genital herpes</td>
</tr>
<tr>
<td>Human T lymphotropic virus types 1 and 2</td>
<td>T cells</td>
<td>Leukemia, brain infections</td>
</tr>
<tr>
<td>Papillomavirus</td>
<td>Skin, epithelial cells</td>
<td>Papillomas, carcinomas</td>
</tr>
<tr>
<td>* Polyomavirus BK</td>
<td>Kidneys</td>
<td>Hemorrhagic cystitis</td>
</tr>
<tr>
<td>* Polyomavirus JC</td>
<td>Kidneys, central nervous system</td>
<td>Progressive multifocal leukoencephalopathy</td>
</tr>
<tr>
<td>* Measles virus</td>
<td>Central nervous system</td>
<td>Subacute sclerosing panencephalitis, measles inclusion body encephalitis</td>
</tr>
<tr>
<td>Rubella virus</td>
<td>Central nervous system</td>
<td>Progressive rubella panencephalitis</td>
</tr>
<tr>
<td>* Varicella-zoster virus</td>
<td>Sensory ganglia</td>
<td>Zoster (shingles), postherpetic neuralgia</td>
</tr>
</tbody>
</table>

^aProposed but not certain.
The cytotoxic T lymphocyte response

- **IFN-α/β** binds to the IFN receptor (IFNR)
- **TCR** on the surface of the cytotoxic T lymphocyte (CTL)
- Peptide-MHC complex presented by the virus-infected cell
- **Perforin and granzyme B** released by the CTL
- **Apoptosis** of the virus-infected cell
Modulation of MHC I system

Cytotoxic T lymphocyte
CD8
T cell receptor
Infected cell

Viral and cellular peptides
Proteasome
Ubiquitin-dependent proteolysis

Cainexin
MHC class I heavy chain
Endoplasmic reticulum

Go lif apparatus

Lyso some

EBV EBNA-1
hCMV US6
hCMV US11, US2

mCMV gp48
HIV Nef

mCMV m152
Adenovirus E3 gp 19kDa
hCMV US3

hCMV ICP47

Degraded by proteasome

Group A adenoviruses

β2-microglobulin

Principles of Virology, ASM Press
CTL escape mutants

- Herpes simplex virus
- Hepatitis C virus

Changes may also affect proteasomal processing
Killing activated T cells

- When CTL engages an infected cell, the CTL may die instead of the target.
- An example of viral defense.
- A normal cell process to limit immunopathology.

HIV, CMV induce FasL on infected cell surface.
Reduced immune surveillance

- Cells and organs differ in degrees of immune defense
- CNS, vitreous humor of eye, skin, are devoid of initiators and effectors of immune response (eye, high FasL)
- Could be damaged by fluid accumulation, swelling, and ionic imbalances of inflammation
- Persistent infections of these tissues are common
Persistence of Ebola Virus in Ocular Fluid during Convalescence


SUMMARY
Among the survivors of Ebola virus disease (EVD), complications that include uveitis can develop during convalescence, although the incidence and pathogenesis of EVD-associated uveitis are unknown. We describe a patient who recovered from EVD and was subsequently found to have severe unilateral uveitis during convalescence. Viable Zaire ebolavirus (EBOV) was detected in aqueous humor 14 weeks after the onset of EVD and 9 weeks after the clearance of viremia.

Also: flare-up in 2016 in Guinea originating from a survivor with virus persistence in seminal fluid for more than 500 days
Ebola virus genomes from Guinea 2021 outbreak

https://virological.org/t/release-4-ebov-genomes-from-guinea-2021-outbreak/642
Infection of immune cells

- Many viruses infect cells of the immune system
- Measles virus infection of APCs
- HIV-1 infection of CD4 T cells, monocytes, macrophages, dendritic cells
Which of the following are features of persistent infections?

A. They last the lifetime of the host
B. Viral immune modulation is involved
C. Immune cells may be infected
D. They may occur in areas of reduced immune surveillance
E. All of the above
Measles virus

- **Paramyxoviridae**
- One of most contagious human viruses
- 207 000 deaths globally in 2019 - preventable
- Lifelong immunity after infection
- A classic acute virus infection
SSPE

- Subacute sclerosing panencephalitis, a progressive, degenerative encephalitis
- After measles, 1/million contract SSPE
- 6-8 yr incubation
- Viral nucleoprotein particles detected in brain, but no infectious virus produced
- Genomes spread between synaptically connected neurons
Polyomavirus persistence

- Infected for life, high seropositivity in human populations
- Variety of organs - kidney, intestine, respiratory tract
- 100,000 particles/ml in urine
- Unknown mechanisms of persistence
- Progressive Multifocal Leukoencephalopathy (PML)
- TWiV #250 - Wookie viruses microbe.tv/twiv/twiv-250-wookie-viruses/
Hepatitis B virus

- Transmitted by exposure to blood (childbirth, transfusion, sex, drug use, tattooing, nosocomial)
- Main target is hepatocyte
- 95% of adults, 5-10% newborns resolve acute infection
Hepatitis B virus pathogenesis

A  Acute Hepatitis B

B  Chronic Hepatitis B

ALT = alanine transaminase

5% of adults
Most children <1 yr
Chronic HBV

- Virus is not cytopathic (!) for hepatocytes
- CTL kill infected hepatocytes
- T cell exhaustion may lead to T cell dysfunction (persistence)
- During chronic infection, fibrosis leads to cirrhosis, liver failure
- Hepatocellular carcinoma develops after 20-30 yr of chronic (often asymptomatic) infection
Hepatitis C virus

- + strand RNA virus, *Flaviviridae*
- Transmitted by exposure to contaminated blood (sex, drug use, tattooing, during birth)
- 71 million infected globally
Persistence via multiple immune modulation mechanisms
Opioid crisis has led to an increase in HCV infections in the US.

Source: CDC
Which are shared features of persistent infections with polyomavirus, HBV, and HCV?

A. Genomes are present but not expressed
B. Liver damage
C. Kidney damage
D. Virus particles are produced
E. All of the above
Latent infections - general properties

- Viral gene products that promote productive replication are not made or found in low concentrations.
- Cells harboring the latent viral genome are poorly recognized by the immune system.
- Viral genome persists intact so that productive infection can be initiated to spread infection to new hosts.
State of the genome

- Non-replicating DNA in a non-dividing cell
  - HSV, VZV in neurons

- Autonomous self-replicating DNA in dividing cell
  - EBV, CMV, HPV, HBV, KSHV

- Integrated into host chromosome, replicates with host
  - HHV6
Herpes simplex virus infections

- US >80% seropositive with genomes in PNS
- Millions carry latent viral genomes in nervous system without symptoms
- 40 million experience recurrent herpes disease
- HSV-1, HSV-2
- A well-adapted pathogen
HSV primary infection of ganglia

- Often infected in utero or during birth (80% of babies)
- Incubation 2-12 days
- Primary infection usually inapparent, but can result in combinations of fever, sore throat, ulcerative and vesicular lesions, gingivostomatitis, edema, swollen lymph nodes, anorexia, malaise
Post-infection events in neurons

- Viral genome silenced, coated with nucleosomes
- Multiple copies of episomal viral DNA remain in nucleus
- No further replication needed to persist - neurons do not divide
- Herpes is forever - drugs and vaccines cannot cure a latent infection
Latency associated transcript

- Only LATs, miRNAs made in latently infected neurons
- No proteins translated from LATs
- RNA silencing to maintain viral genome in latent state
- Host contribution
- Small number of neurons in ganglion reactivate
- Virions appear in mucosal tissue innervated by latently infected ganglia, blisters ensue (not always)
- This is how infection is transmitted (intimate contact)
- Immune response is too slow (viral antagonism) to prevent shedding
- Some reactivate every 2-3 weeks; others never
Reactivation

- Sunburn (UV), physical or emotional stress, nerve damage, hormonal imbalance, steroids
- Stimulate production of viral proteins needed to activate viral transcription program
Neuronal stress
Kinase activation
Persistence of herpes simplex virus in nerve ganglia requires which of the following?

A. Continuous episomal DNA replication
B. Low level production of virus particles
C. Silencing of all gene expression except LAT and miRNA
D. UV light, stress, or steroids
E. All of the above
**Epstein-Barr virus**

- 95% of US adults are seropositive and carry EBV genome
- Genome resides in B lymphocytes
- Most are infected at an early age, are asymptomatic
- Causal agent of:
  - Infectious mononucleosis
  - Human cancers (Hodgkins lymphoma, nasopharyngeal carcinoma, Burkitt’s lymphoma)
EBV primary and latent infection

Infectious mononucleosis

B cells are essential for EBV latency

EBV primary infection:
- EBV enters through the oral mucosa
- Latency occurs in B cells
- EBNA and LMP proteins produced

EBV persistent infection:
- EBV infects B cells in the blood vessel
- B cells are essential for EBV latency
- EBV replication in B cells
- EBNA and LMP proteins produced

Saliva
Stratified squamous epithelium
Basement membrane
Lamina propria
Blood vessel
EBV latency

- Viral DNA is self-replicating episome, associates with nucleosomes in B cells
- Produces limited repertoire of viral genes
- B cells home to bone marrow and lymphoid organs
- Not killed by CTLs or antibody unless reactivation occurs (modulation of MHC)
Varicella-zoster virus (VZV)

- Infection via conjunctiva and upper respiratory tract
- Reproduction in primary lymph nodes
- Days 4–6: Primary viremia
- Reproduction in liver, spleen, and other organs
- Secondary viremia
- Day -14: Infection of skin and appearance of rash
- Reactivation
- Infection of sensory ganglia and establishment of latent infection
- To central nervous system

Varicella (chickenpox)

Herpes zoster (shingles)
VZV

- 99% adults infected pre-vaccine, 30% develop zoster, 2/3 >50 years of age
- Latency: Episomal viral DNA, 2-9 genomes in 1-7% of neurons (non-replicating)
- Viral gene expression is restricted, IE, E, L genes
- Factors that trigger reactivation from neurons are unknown
Cytomegalovirus (HCMV)

- High seroprevalence (50-99%) globally
- Transmitted by respiratory routes (virus in saliva), urine, sex
- Replicates in peripheral blood leukocytes, endothelial cells
HCMV

- Primary infection in immunocompetent host usually asymptomatic or febrile, mono-like illness
- Persistent shedding of virus in saliva and urine for months to years
- Resolved by cellular immune response, but latently infected myeloid cells remain in bone marrow (precursors of monocytes, macrophages, dendritic cells)
HCMV

- Major problem in organ transplantation
- Virus crosses placenta, can cause severe multi-organ congenital defects, death

http://www.cdc.gov/cmv/
What do persistent infections with EBV, VZV, and CMV have in common?

A. B cells are essential for latent infection
B. May cause congenital birth defects
C. Viral DNA persists as an episome
D. The factors governing reactivation are well known
E. All of the above

Go to:

b.socrative.com/login/student
room number: virus
HHV-6, HHV-7

- Agents of exanthem subitum, mild childhood rash (sixth disease)
- >85% of adults have antibody to both viruses
- Horizontal infection through respiratory secretions, parent to child
- Infect lymphoid, endothelial, liver, CNS, salivary cells
- Latency: HHV-6 monocytes, macrophages, CD34+ progenitors; HHV-7 CD4+ lymphocytes
HHV-6 integration

- In some cell types viral DNA integrates into telomeres
- About 1% of transmission acquires HHV-6 via germline
- Plausible strategy for latency and transmission
Everyone

We each harbor 8-12 chronic infections
Next time: Transformation and oncogenesis