Persistent Infections

Lecture 17
Biology 3310/4310
Virology
Spring 2018

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

- **Persistent: asymptomatic**
  - Lymphocytic choriomeningitis virus
  - JC virus

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

- Occur when primary infection is not cleared by immune response
- Virions, 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,* macrophages,* stem cells,* stromal cells*</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>

*Proposed but not certain.*
The cytotoxic T lymphocyte response
Modulation of MHC I system
CTL escape mutants

- Herpes simplex virus
- Hepatitis C virus

Changes may also affect proteasomal processing.

Fields Virology, Wolters Kluwer
Principles of Virology, ASM Press
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, areas of lymphoid drainage 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.
Many viruses infect cells of the immune system

- Measles virus infection of APCs
- HIV 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
- 114,900 deaths globally in 2014 - 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 infections virus produced
- Genomes spread between synaptically connected neurons
Polyomavirus

Wukipolyomavirus

Avipolyomavirus

KIPyV  WUPyV
HPyV6  HPyV7

GHPyV  CPyV  CaPyV
FPyV  APyV

BKPyV  SA12  JCPyV
SV40

SLPyV
BatPyV  MPIV  SqPyV  BPyV

MCPyV*
OraPyV2  MPyV  HaPyV
LPyV  TSPyV*
OraPyV1

Orthopolyomavirus
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
VIRAL HEPATITIS B IN THE WORLD

257m GLOBAL

21m EASTERN MEDITERRANEAN

15m EUROPE

39m SOUTH-EAST ASIA

115m WESTERN PACIFIC

60m AFRICA

7m AMERICAS
Hepatitis B virus

**A** Acute Hepatitis B

- Symptoms
- HBsAg
- ALT
- IgM anti-HBc
- Anti-HBs
- HBV DNA

**B** Chronic Hepatitis B

- Symptoms
- HBeAg
- HBe
- Total anti-HBc
- IgM anti-HBc
- HBsAg
- ALT
- HBV DNA

ALT = alanine transaminase
Chronic HBV

- Virus is not cytopathic (!) for hepatocytes
- CTL kill infected hepatocytes
- T cell exhaustion may lead to T cell dysfunction
- During chronic infection, fibrosis leads to cirrhosis, liver failure
- HCC 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
VIRAL HEPATITIS C
IN THE WORLD

71m
GLOBAL

15m
EASTERN
MEDITERRANEAN

14m
EUROPE

10m
SOUTH-EAST ASIA

14m
WESTERN PACIFIC

10m
AFRICA

7m
AMERICAS

World Health Organization

Virology Lectures 2018 • Prof. Vincent Racaniello • Columbia University
Persistence via multiple immune modulation mechanisms
HEPATITIS C AND OPIOID INJECTION ROSE DRAMATICALLY AMONG WHITE AMERICANS FROM 2004-2014

- HCV increased by 300%
- Admissions for opioid injection increased by 134%

Source: Centers for Disease Control and Prevention and Substance Abuse and Mental Health Services Administration
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
Reactivation

- 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
Trigeminal ganglion
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

Latency

H3K9me2/3 H3K27me3

HSV Lytic Promoters

Phase I (animation)

IE E L

H3pS10

VP16 histone demethylases

Phase II (full reactivation)

IE E L

acH3
 Persistence of herpes simplex virus in nerve ganglia requires which of the following?

A. Continuous episomal DNA replication
B. Low level production of virions
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

B cells are essential for EBV latency

Infectious mononucleosis
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)

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

![Graph showing the seroprevalence of CMV IgG by age and ethnicity]
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/trends-stats.html
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
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