Neonatal Intracranial Hemorrhage

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Objectives

Upon completion of this course, the learner will be able to:

- Identify the primary stages of neurodevelopment
- Discuss the use of diagnostic imaging in the neonate
- Differentiate between the different types of intracranial hemorrhages
- Describe the nursing interventions to reduce the incidence of intracranial hemorrhage in the preterm infant
- Use evidence based practice to influence care of the infant at risk for intraventricular hemorrhage
Neurodevelopment – Embryonic Review

- Primary neurulation (3 to 4 weeks gestation)
- Prosencephalic development (8 to 12 weeks gestation)
- Neuronal proliferation (12 to 16 weeks gestation)
- Neuronal migration (12 to 20 weeks gestation)
- Organization (20 weeks gestation to years postnatal)
- Myelination (24 weeks to adulthood)

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Brain Development

(Giedd, 1999)
Let’s review circulation in the brain
Let’s review circulation in the brain

What is Intracranial Hemorrhage?

• ICH is bleeding *inside* the skull
Consequences of ICH

- Blood accumulates either within the brain tissue or on the surface of the brain tissue causing compression and cell damage or death.

Types of Intracranial Hemorrhage

**EXTRA-AXIAL**
- Subarachnoid
- Subdural
- Epidural

**INTRA-AXIAL**
- Cerebellar
- Intraparenchymal/Intracerebral
- Intraventricular
### Types of ICH

<table>
<thead>
<tr>
<th>Type of Hemorrhage</th>
<th>Preterm vs. Term</th>
<th>Frequency</th>
<th>Clinical Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subdural</td>
<td>More common in term</td>
<td>Uncommon</td>
<td>Serious</td>
</tr>
<tr>
<td>Subarachnoid</td>
<td>More common in preterm</td>
<td>Common</td>
<td>Benign</td>
</tr>
<tr>
<td>Cerebellar</td>
<td>More common in preterm</td>
<td>Uncommon</td>
<td>Serious</td>
</tr>
<tr>
<td>Intraventricular</td>
<td>More common in preterm</td>
<td>Common</td>
<td>Serious</td>
</tr>
<tr>
<td>Intraparenchymal/Stroke</td>
<td>More common in term</td>
<td>Uncommon</td>
<td>Variable</td>
</tr>
</tbody>
</table>

Volpe JJ. Intracranial hemorrhage: Subdural, Primary Subarachnoid, Cerebellar, Intraventricular (Term Infant), and Miscellaneous. In: Neurology of the Newborn, Fifth Ed. Philadelphia: WB Saunders, 2008: 484

### Causes of Intracranial Hemorrhage

#### Maternal

- Drug usage; including aspirin and illicit drugs
- Pre-eclampsia
- Placental abruption
- Placental alloimmunization
- Autoimmune disorders
Causes of Intracranial Hemorrhage

<table>
<thead>
<tr>
<th>Term</th>
<th>Preterm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Trauma</td>
<td>Hemodynamic Instability</td>
</tr>
<tr>
<td>Birth asphyxia; secondary to ischemia-reperfusion injury</td>
<td>Vascular and Anatomic immaturity</td>
</tr>
<tr>
<td>Infection</td>
<td>Possibly inflammatory factors</td>
</tr>
<tr>
<td>Coagulation abnormality</td>
<td>Possibly genetic factors</td>
</tr>
<tr>
<td>Vascular abnormality</td>
<td></td>
</tr>
<tr>
<td>Cardiac diagnosis that results in increased cerebral venous pressure</td>
<td></td>
</tr>
<tr>
<td>Thrombocytopenia</td>
<td></td>
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</tbody>
</table>

Symptoms of ICH

Will vary according to size and location of hemorrhage. Will also vary by term vs. preterm infant. Unfortunately, symptoms are non-specific to ICH.

- Cardiorespiratory symptoms: apnea, bradycardia, hypo/hypertension
- Unexplained drop in Hct
- Seizures
- Bulging fontanelles
- Encephalopathic; altered level of consciousness, absent or weak reflexes, hyper/hypotonia
True of ALL ICHs

- True incidence of ICH is unknown.
- For all types of ICH, incidence is estimated at 4 per 1,000 live births. The incidence increases for instrumented births (forceps, vacuum).
- Many of the symptoms of ICH are similar and it will be very difficult to distinguish between the types of ICH without imaging.
- Sequelae from ICH will vary depending on the size and location of the bleed in all types.
- Unless hydrocephalus develops, ICH is not identifiable by assessment of the skull.
- It is common for hemorrhages to occur in multiple sites both intra and extra cranial.

“So many layers, so many hemorrhages…”

Fig. 9.5 The coverings of the brain. (Reproduced from ‘Vascular lesions of mature infants’ in Neonatal Central Ultrasound by Janet Rennie, Cambridge University Press, 1997) [http://www.mrineonatalbrain.com/ch04-09.php]
Diagnostic Imaging in the NICU

- Imaging provides a noninvasive means to diagnose, screen, and monitor patients in the NICU
- Radiography (X-ray): differentiates densities (air, fat, water, bone, metal)
- Ultrasonography (US): converts electrons into mechanical vibrations to create high frequency sound waves within the body – best to compare vibrations of bone and other structures as the sound waves resonate in the body
- Computed Tomography (CT): a series of X-rays taken from multiple positions around a single axis to create a composite image
- Magnetic Resonance Imaging (MRI): images hydrogen ions in the body (your body is 98% water)

Subarachnoid Hemorrhage
Subarachnoid Hemorrhage

- Asymptomatic SAH is rarely identified
- Symptomatic SAH is usually the result of a medium or large bleed; most common type of hemorrhage in infants with symptoms.
- More strongly associated with forceps or vacuum-assisted birth.
- Medium sized bleeds may cause seizures. However, 90% of these babies go on to have normal neurodevelopmental outcomes. Blood is reabsorbed, and symptoms resolve.
- Negative neurologic sequela from this type of bleed are very rare.
- If bleed is large, babies appear very encephalopathic, have seizures, apnea and/or bradycardia. They can deteriorate quickly if bleed progresses without intervention.
- Large bleeds can impair flow of CSF, and baby can develop hydrocephalus.

Subarachnoid Hemorrhage

- Clinical presentation:
  - Most commonly asymptomatic
  - Seizure activity on day 2 of life (term infant)
  - Otherwise “well-appearing”
  - Recurrent apnea (preterm infant)
Subarachnoid Hemorrhage

- Diagnostic:
  - CT scan leads to a diagnosis by exclusion
  - LP with uniformly bloody CSF
- Outcome:
  - 90% of term infants with seizure have normal follow up

Subdural Hemorrhage

- Diagram showing torn cerebral vein, subdural hematoma, compressed brain tissue, dura mater, and arachnoid layer.
Subdural Hemorrhage

- Most common form of ICH in term infants without symptoms
- Usually infants are asymptomatic and bleeds resolve without any intervention
- 2.9% PER 10,000 NSVD vs. 8 – 10% NSVD with forceps or vacuum
- Can be traumatic if lesion/tear is large; can result in brain stem compression and death
- Large lesions within major vessels = baby very encephalopathic at birth and quickly progresses downward
- Small but progressive lesions = Baby may be “fine” 24 hours up to 5 days. Will slowly show signs of neurological deterioration as bleed evolves and/or clot forms; lethargy, irritability, apnea, bradycardia
- Treatment: close surveillance without neurologic signs or surgery may be indicated in large lesions with rapidly increasing ICP
- 80% of infants with SDH have normal outcomes.

Subdural Hemorrhage

- Diagnostic:
  - CT scan
  - MRI if the hemorrhage is posterior
  - X-ray to determine skull fracture
- Outcome:
  - Major laceration will result in massive hemorrhage
  - Mortality approximately 45%
  - Survivors develop hydrocephalus
  - Often worsened by close association with HIE
Epidural Hemorrhage

- *Very* rare in term infants
- The artery that is the cause of bleeds in this region is more pliable in neonates and thus much less likely to rupture.

Cerebellar Hemorrhage

- More common in preterm infants, esp. < 750 grams.
- Very difficult to ID; not visualized on head US unless specifically searched
- In preterm, cause is similar to IVH. In term, cause is usually trauma.
- Symptoms will be secondary to brainstem compression; apnea, bradycardia and/or full fontanelles from blockage of flow of CSF.
- Outcome:
  - More favorable in term than preterm infants
  - Probable neurologic deficits
Cerebellar Hemorrhage

Intracerebellar Hemorrhage

- Hemorrhage within the cerebellum resulting from primary bleeding or an extension of bleeding of intraventricular or subarachnoid hemorrhage into the cerebellum
- Risk factors: respiratory distress, hypoxic events, prematurity, traumatic delivery
- More common in preterm than term infants
- Incidence:
  - present in 5 to 10% of all neonatal deaths on autopsy
  - 15 to 25% of preterm infants < 32 weeks or less than 1500 grams
Intracerebellar Hemorrhage

- Clinical presentation:
  - Catastrophic deterioration with apnea, bradycardia, decreasing Hct
  - LP with bloody CSF
  - Most common in the first 2 days of life up to 3 weeks of life

Intracerebellar Hemorrhage

- Diagnostic:
  - Cranial ultrasound
  - CT to define the hemorrhage
  - MRI for definitive diagnosis

- Outcome:
  - More favorable in term than preterm infants
  - Probable neurologic deficits
Intra-axial ICH: Intraparenchymal

- Usually co-exist with a hemorrhage somewhere else in the brain.
- Can be focal or multi-focal

Intraparenchymal Hemorrhage - Stroke

- The term “stroke”, when referring to intraparenchymal hemorrhage, really only applies to term infants.
- Hemorrhagic stroke accounts for 50% of childhood strokes
- However, there is not much literature on hemorrhagic stroke in the infant & childhood population
Stroke

- All intraparenchymal/intracranial hemorrhage is stroke, but not all strokes are hemorrhagic.
- The definition of stroke encompasses not only intracranial bleeding, but also non-traumatic subarachnoid bleeds and isolated intraventricular bleeds in the TERM infant.
- Prevalence of hemorrhagic stroke in the perinatal population is 6.2/100,000, with the vast majority intracranial.
- Most hemorrhagic strokes are idiopathic.

Definition

- Stroke
  - Blockage (ischemic stroke) or breakage (hemorrhagic stroke) of a blood vessel (artery or vein) in the brain.
Hemorrhagic vs. Ischemic

Hemorrhagic Stroke - Outcomes

- Neurodevelopmental outcomes for children with hemorrhagic stroke are poorer than those with ischemic stroke.
- Because of limited data on this patient population, statistics are wide-ranging. Mortality for hemorrhagic stroke is estimated anywhere from 5% - 33%.
- Poor neurodevelopmental outcome is estimated at 25% - 52%.
- Outcomes are determined by:
  - The size of the stroke
  - Presence of hydrocephalus
  - Presence of herniation
  - Location of the stroke
Periventricular-Intraventricular Hemorrhage (IVH)

- Occurs once germinal matrix hemorrhage extends into the lateral ventricle
- Risk factors: prematurity (less than 34 weeks), respiratory failure, increasing arterial blood pressure, perinatal asphyxia
- Incidence:
  - 10 to 15% of infants with hemorrhages
  - 30 to 40% of preterm infants <30 weeks or <1500 grams
  - 3 times higher risk if <28 weeks
  - 2 to 3% of term infants

So why are preemies at high risk?!
Intraventricular Hemorrhage - Term

- Very rare.
- Source of the bleed differs from that of preterm infants.
- Coagulopathy and trauma play a bigger role in the cause of IVH bleed in the term infant vs. preterm infant.
- Seizures are a symptom in 50 – 65% of cases.
- Approximately 50 % of infants have normal neurologic outcomes.
Pathogenesis

Thought to be caused by capillary bleeding.

- Major factors:
  - Intra-vascular factors
    - Loss of cerebral autoregulation
    - Abrupt alterations in cerebral blood flow and pressure
  - Vascular factors
    - Germinal matrix-vulnerable to hypoxia
    - Reperfusion injury
  - Extravascular factors
    - Poor vascular support in cerebral tissue

IVH Risk Factors

Abrupt changes in cerebral circulation

- Rapid changes in PaCO2
- Rapid changes in aortic pressure
- Rapid infusion of volume expander
- Excessive increase in vasopressor infusion
- Noxious procedures
  - suctioning, PIV insertion, CT insertion, loud noises, aggressive handling
- Large PDA with left-to-right shunt
- Elevated venous pressure from tension pneumothorax or excessive ventilator pressures
IVH Timing and Progression

- May begin in utero, but usually begins after birth
- Hemorrhages may be small at first, then progress to larger hemorrhages later
- Most large or progressive IVH’s begin in the first week of life

Why is this important to the bedside nurse?

Symptoms of IVH

- Majority are asymptomatic
  - Dx is cranial ultrasound
    - 4th day 90% detected
    - Serial ultrasounds

- Timing of onset:
  - 50% by 24 hours of age
  - 80% by 48 hours of age
  - 90% by 72 hours of age
  - 99.5% by 7 days of life
  - 20 to 40% have progression of the hemorrhage over 3 to 5 days
Acute/ Catastrophic Presentation

- Clinical signs include:
  - Bulging anterior fontanelle/split sutures
  - Decreasing hematocrit
  - Bradycardia
  - Hypotension (or reactive hypertension)
  - Temperature instability
  - Glucose intolerance or hypoglycemia
  - Metabolic acidosis

Surveillance for Intracranial Hemorrhage

- Stable neonate
  - HUS at end of the first week of life
  - If HUS normal repeat at 1 month of age
  - Repeat HUS sooner if infant has a predisposing event or deteriorates
    - Weekly head circumference measurements
Anatomy!!

- Ventricles
- Intraventricular Foramen
- Cerebral aqueduct
- Choroid plexus
- Germinal matrix

Germinal Matrix

- Highly vascularized and poorly supported
- Involutes over time
  - 23-24 weeks 2.5 mm width
  - 32 weeks 1.4 mm width
  - 36 weeks involute
IVH

- Diagnostic:
  - Cranial ultrasound (serial) – Papile Classification (1988):
    - Grade I: Subependymal hemorrhage in the periventricular germinal matrix.
    - Grade II: Partial filling of the lateral ventricles without ventricular dilation.
    - Grade III: Intraventricular hemorrhage with dilation
    - Grade IV (PHI): Intraventricular hemorrhage with parenchymal involvement or extension of blood into the cerebral tissue
  - LP to rule out septic shock or meningitis
Grade I IVH

Grade II IVH

http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants
Grade II IVH

http://pediatriceducation.org/2005/03/14/

Grade III IVH

http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants
Grade III IVH

http://pediatriceducation.org/2005/03/14/

http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants

http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm

Grade IV IVH

http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants

http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm
Periventricular Hemorrhagic Infarction

Early Evolving PVHI

Coronal Section

http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants
http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm

Periventricular Hemorrhagic Infarction
(3 weeks of age)

Cyst Formation
• tissue necrosis
• clot retraction

Parasagittal View

Periventricular Hemorrhagic Infarction
(2 months of age)

Porencephalic cyst

Parasagittal View


IVH Outcomes

- Small (Grade I)
  - Neurodevelopmental disability similar to premature infants without IVH
- Moderate (Grade II-III)
  - Neurodevelopmental disability in 40%
  - Mortality 10%
  - Progressive hydrocephalus in 20%
- Severe (Grade PVHI)
  - Major neurodevelopmental disability in 80%
  - Mortality rate 50-60%
  - Hydrocephalus common in survivors

Periventricular Leukomalacia (PVL)

- Ischemic, necrotic periventricular white matter lesions of arterial origin
- Risk factors: systemic hypotension, recurrent apnea with bradycardia
- Incidence:
  - Unknown
PVL

• Clinical presentation:
  • Acute phase: hypotension and lethargy
  • 6 to 10 weeks later:
    – Irritable
    – Hypertonic
    – Increased arm flexion and leg extension
    – Frequent tremors
    – Abnormal Moro reflex

PVL

• Diagnostic:
  • Cranial ultrasound
  • CT
  • MRI

• Initial presentation: PV echodensities
• Later: PV cystic changes
Periventricular Leukomalacia

PVL

- Outcome:
  - Based on location and extent of the injury
  - Major motor deficits
  - Significant upper arm involvement is associated with intellectual deficits
  - Visual impairment
  - Lower limb weakness
PVL Outcome

Posthemorrhagic Hydrocephalus

- Progressive dilation of the ventricles after IVH caused by injury to the periventricular white matter; inhibition of CSF flow
- Two types:
  - Acute
  - Chronic (subacute)
- Incidence:
  - Acute dilation in up to 50% of infants with IVH (generally resolves)
  - Slightly more than 50% of severe cases will result in progressive ventricle dilation
Post Hemorrhagic Hydrocephalus

- Frequent complication of GM-IVH
  - Clot obstructing CSF flow at the level of the aqueduct of Sylvius

Hydrocephalus

- Clinical presentation:
  - Rapid increase in head size
  - Episodic apnea and bradycardia
  - Lethargy
  - Increased ICP
  - Tense, bulging anterior fontanel
  - Separated cranial sutures
  - Ocular movement abnormalities
Hydrocephalus

- Diagnostic:
  - Measure weekly OFC
  - CT
  - Cranial ultrasound
  - MRI

- Outcome:
  - Poor outcomes if decompression is not successful with shunt placement
  - Motor and cognitive deficits

Post Hemorrhage Ventricle Device
External Ventricular Drain/Reservoir/Shunt/

- EVD
- Ommaya reservoir
- Ventriculoperitoneal (VP) shunt

Patient Care and Management

- Prevent preterm birth
- Promote in utero transport
- Promote a no stressful intrapartum course
- Provide efficient resuscitation with expedient intubation
- Cluster care activities and promote appropriate handling
- Minimize noxious stimuli
- Avoid events associated with wide swings in arterial and venous pressures (i.e.: seizures, apnea, etc.).
- Prevent blood pressure swings – slow volume replacement
Patient Care and Management

▪ Avoid over ventilation leading to pneumothorax
▪ Use inline suctioning devices
▪ Use noninvasive monitoring devices
▪ Monitor and maintain normal pH
▪ Correct abnormal clotting
▪ Be alert to signs of hemorrhage (changes in LOC, etc.)
▪ Educate and support the parents
Neuroprotection in the NICU

- Antenatal steroids and Magnesium Sulfate
- Delayed Cord Clamping
- The “Golden” Hour / CPQCC Delivery Room Toolkit
- Neutral head positioning
- NIDCAP
- Developmental care

IVH Bundles
Potentially Better Practices to Prevent Brain Injury

1. Antenatal steroids & magnesium
2. Optimize management and delivery at center with a NICU
3. Early management by a Neonatologist/NNP
4. Minimize pain and stress
   1. Avoid pain and stress
   2. Developmental Care
5. Optimal positioning (midline)
6. Treat hypotension
7. Judicious indomethacin use
8. Optimize respiratory management
9. Limit sodium bicarbonate use
10. Use post-natal dexamethasone judiciously

Delayed Cord Clamping (DCC)

- ACOG Committee Opinion, Number 684, January 2017
- **DCC in vigorous term and preterm infants for at least 30-60 seconds after birth**
- DCC increases hemoglobin levels at birth and improves iron stores
- Improves transitional circulation
- Decreases need for pRBC transfusion
- Lowers incidence of NEC and IVH
- Does not increase risk of postpartum hemorrhage
- What is done in your center?

The “Golden” Hour (Delivery Room Toolkit)

▪ Based on principles from cardiovascular and emergency medicine
▪ First hour of life is a time of critical transition and adaptation
▪ Management has been shown to impact long term outcomes
▪ Structured focus on thermoregulation, minimizing energy consumption, and respiratory support
▪ Measurable data points include: time to admission, admission temperature, admission glucose, initiation of IV fluids with glucose and amino acids
▪ What does your “Golden” hour look like?

Neutral Head Positioning

▪ First studied in adults in the 1980s
▪ Infants less than 32 weeks are positioned in neutral midline position with the head of the bed tilted upward for 72 hours
▪ Goal: to reduce alterations in cerebral blood flow associated with turning of the head from side to side in efforts to reduce the incidence of IVH
▪ Thoughts?
▪ Key stakeholders? Equipment needs?
▪ How is this audited?
Cerebral blood flow

- ELBW s have impaired cerebral autoregulation
- Everyday ICN tasks that affect Cerebral Blood Flow (CBF)
  - Diaper changes
  - Suctioning
  - Blood sampling
- Can we prevent harm to our patients?


Blood Sampling

- Evidence has shown blood sampling techniques from UACs affect cerebral blood flow and oxygenation
- 20 second vs. 40 second push-pull

Permissive hypotension

- Current practice
- Preterm infants with a MAP<GA often have no clinical signs of shock
  - Presumably have adequate tissue oxygen delivery
  - May not need treatment.


Permissive hypotension

- Numerical blood pressure value lower than gestational age should not be used as the only indicator for treating early period hypotension
- Hemodynamic status should be included in assessment
  - unstable vital signs, impaired perfusion, skin color, capillary refill rate, urine output, blood lactate level, and acidosis
Treatment for hypotension

▪ Treat the cause!
  • Normal Saline
  • PRBCs

▪ Medications
  • Dopamine
  • Hydrocortisone

Reperfusion injury

▪ Tissue damage caused when blood supply returns to the tissue after a period of ischemia or lack of oxygen

▪ Absence of oxygen and nutrients from lack of blood supply during ischemic insult

▪ Restoration of circulation results in inflammation and oxidative damage rather than restoring normal function

Premature Infants-
Developmental Consequences

Evolution of developmental delay is evident by term equivalents:

Compared to full term infants:
- Poor orientation (p<.001)
- Poor tolerance of handling (p<.001)
- Poor self regulation (p<.001)
- More sub-optimal reflexes (p<.001)
- More stress (p<.001)
- More hypertonicity (p<.001)
- More hypotonia (p<.001)
- More excitability (p=.007)

Emotional and Behavioral Problems of Preterm and Full-Term Children at School Entry

Hornman et al, 2016
- 401 early preterm (25–31 weeks’ gestational age)
- 653 moderately preterm (32–35 weeks’ gestational age)
- 389 term

“Compared with term children… all preterm children are at risk for persistent and changing EB-problems at school entry”
Psychiatric Disorders and General Functioning in Low Birth Weight Adults: A Longitudinal Study

(Lærum et al. 2016)

- Term SGA group increase in the estimated probability of psychiatric disorders from 9% to 39%
- At 26 y/o, preterm VLBW and term SGA had increased psychiatric disorders (36%, 38% vs 14%)
- Both low birth weight groups had lower educational level and functioning scores than controls and a higher frequency of unemployment and disability benefit.

Neuro-developmental Care

- Efforts focused on promoting positive neuronal organization and myelination
  - Cluster care
  - Reduce environmental stimuli
  - Positive touch
  - Early skin to skin
  - Procedural support
- Nutrition
- Neuro-protection
- What else are you doing in your unit?
Minimize pain, stress & noxious stimuli

Important aspect of care for the ELBW

Pain, stress & noxious stimuli can all lead to physiologic instability

ALL handling and care of the ELBW infant and their experiences affect BRAIN DEVELOPMENT

“What fires together, wires together”
Neuro-developmental Care

Offsetting stress with POSITIVE experiences

- Stressful experiences in NICU are inevitable
- How do we provide positive experiences?
  - Tactile
  - Vestibular
  - Gustatory
  - Olfactory
  - Auditory
  - Visual
- How do we document this?

Sleep Preservation

- Touch times should allow for ample sleep
- Promote & protect sleep cycles
- Never wake a baby in REM sleep
- Sleep deprivation or disruption leads to:
  - Disordered sensory system
  - Decreased learning and memory capabilities
  - Smaller adult brain
  - Irritability

http://dx.doi.org/10.1036/j.nainr.2008.10.011  
11/22/2016
QUESTIONS??

References

Take care of this brain

UCSF Benioff Children's Hospital
San Francisco