Neurodevelopment

Checkpoints in children with congenital heart disease

Jeehun Lee, M.D., PhD.
Pediatric Neurology
Samsung Medical Center
Sungkyunkwan University, School of Medicine

Heart and Brain : *Why dose the brain matter?*

- **Dramatic decline in mortality rates of young children with congenital heart disease (CHD)**
  by marvelous advances in medical and surgical management

- **A shift of focus from the heart to the brain**
  - **Neurologic injury**
    : One of the most common extracardiac complications
  - **Neurodevelopment outcome and quality of life**
    : Equally important primary outcomes.

Neurologic complications in CHD

Presurgical

- Associated with CHD/circulation
- Genetic

Postsurgical

- Ass. with surgery or CHD/circulation
- Genetic

Neurologic complications in CHD

- **The advance of neonatal heart repair into the earliest days of the newborn period**

  → **Shorter period before cardiac correction**

  → **decreased the brain's exposure to the chronic hypoxia**

Neurologic complications in CHD

- **The marked circulatory changes in patients with a structurally and functionally immature cerebral vasculature**

- **The increased vascular fragility and tenuous autoregulation**

→ **Increase hemorrhagic or ischemic injury**

Contents

- **Description of developmental problems in patients with CHD**

- **Clinical check points according to the developmental stages**

Neurodevelopmental problems in CHD

Clinical presentation : Incidence

Limperopoulos (J Pediatr 2000)

- **Incidence of neurobehavioral abnormalities prior to surgery**
  - **> 50% of newborns**
  - **38% of infants (1months ~ 2 years of age)**

Clinical presentation

- **Hypo/hyper-tonia**
- **Excessive jitteriness, motor asymmetries**
- **Poor sucking**
- **Preoperative seizure (7%)**
- **Microcephaly (36%)**

Clinical presentation : Incidence

Chock et al. (Perinatol 2006)

- **Neurologic complication after surgery**
- **Acute neurological events**
  : Seizure, abnormal tone, choreoathetosis
  - **25% within the first week after surgery**
  - **56% after the first week**

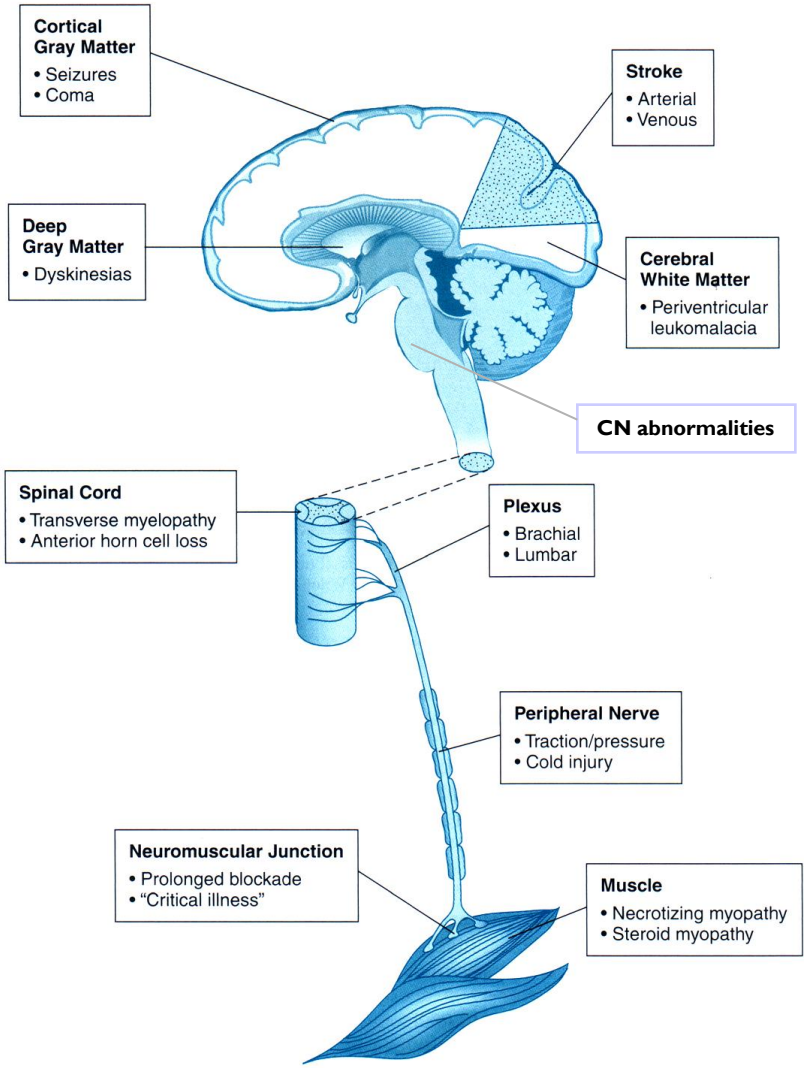
Clinical presentation : Incidence

Miller et al. (Arch Pediatr Adolesc Med 1995)

- **Decreased level of consciousness (19%)**
- **Seizures (5%)**
- **Pyramidal signs (7%)**

– motor abnormalities, swallowing/sucking dysfunction…

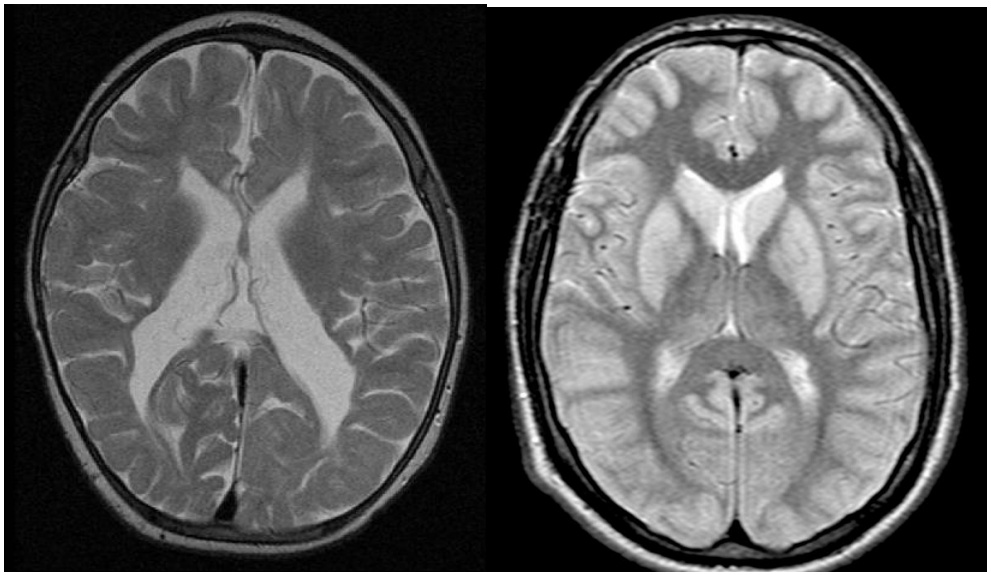
Clinical presentation : Anatomic distribution



Clinical presentation : Time sequence

Preoperative complications: neonatal CVD

- **Etiology**
  - **Structural and functional vascular immaturity**
  - **Systemic hemodynamic instability**
  - **In premature infant: hemorrhagic or ischemic injury- IVH, PVL**
  - **CHD prolongs the risk period for the maturity-dependent injury**



Clinical presentation : Time sequence

Preoperative complications: neonatal CVD

- **The incidence of antenatal CVD is increased in CHD patients**

  van Houten et al. (Am J Perinatol 1996)

  - **Cerebral abnormalities in 59% of patients (term infants)**
  - **Cerebral atrophy (41%), Linear echodensities of the deep GM (20%)**
  - **IVH (16%)**
  - **Parenchymal echodensities (16%)**

Postoperative complications

Early complications

- **Incidence: up to 25%**
- ***Transient and of little long-term consequences***
- **However, may be associated with long-term adverse outcomes**

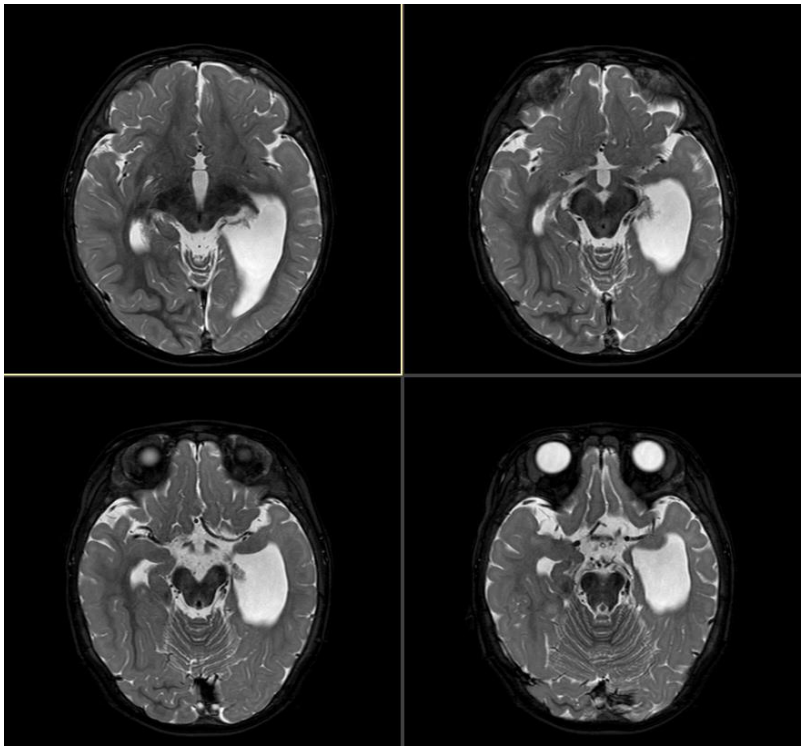
Postoperative complications

- **Early complications; Clinical manifestations**
  - **Delayed recovery of consciousness**
  - **Seizures**
  - **Movement disorders**
  - **Spinal cord injury**
  - **Peripheral neuromuscular injury**

- **Late complications**
  - **Stroke, headache**

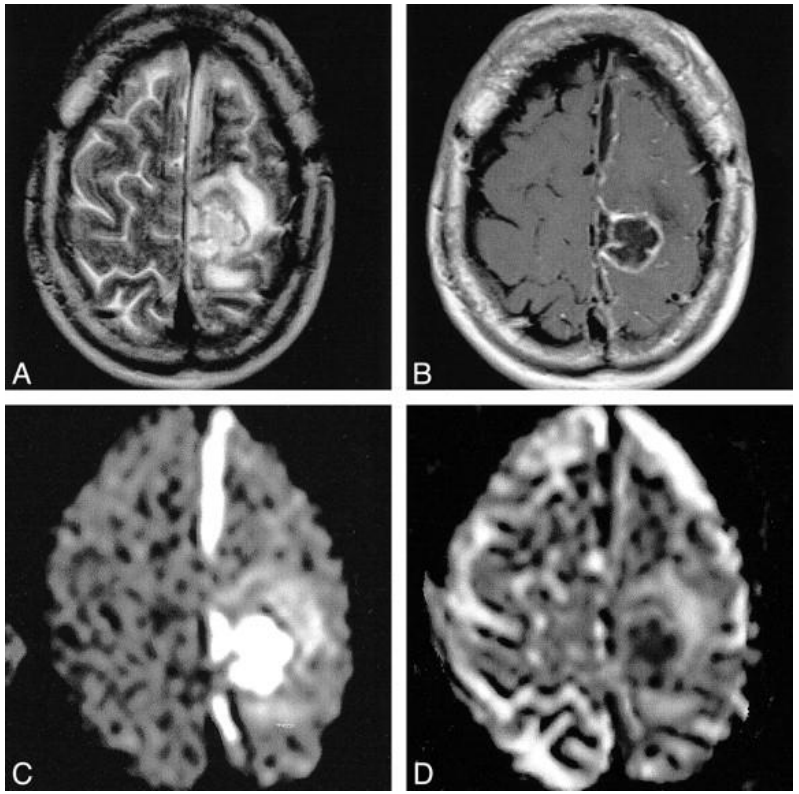
Neurologic Complications unrelated to surgery

- **Cerebral dysgenesis**
  - **Incidence: 10~29% in postmortem exam studies**
  - **Manifests as seizures, altered conscousness, abnormal motor tone, and developmental delay**
  - **Cerebral dysgenesis is more frequent in infants with *hypoplastic left heart syndrome***



Neurologic Complications unrelated to surgery

- **Infectious complications**
  - **Brain abscess**
  - **Cerebral mycotic aneurysms**



Inherited disease

- **Inborn errors of metabolism**

- **Disorders of energy production**
  : mitochondrial disease

- **Storage disease**
  : glycogen storage disease, lysosomal storage disease

Inherited disease

- **Inherited neuromuscular disorders with cardiac complications**
  - **X-linked muscular dystrophy – DMD, Emery-Dreifuss MD**
  - **Myotonic dystrophy**
  - **Friedreich's ataxia**

- **Chromosomal disorders**
  - **CATCH-22 spectrum**
  - **Williams' syndrome**

Neurodevelopment : clinical check-points

Components of neurologic examination

- **Physical examination**
- **Mental status examination**
- **Cranial nerve examination**
- **Motor examination – muscle bulkiness, tone, strength**
- **Sensory**
- **Deep tendon reflexes**
- **Pathologic reflexes**
- **Coordination**

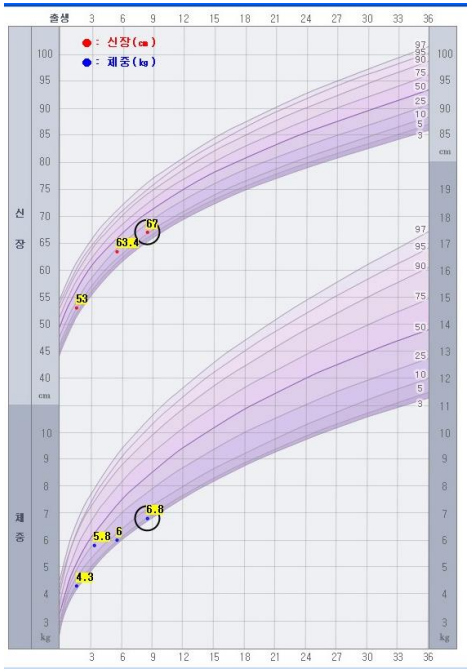
How to apply? - Neurologic examination

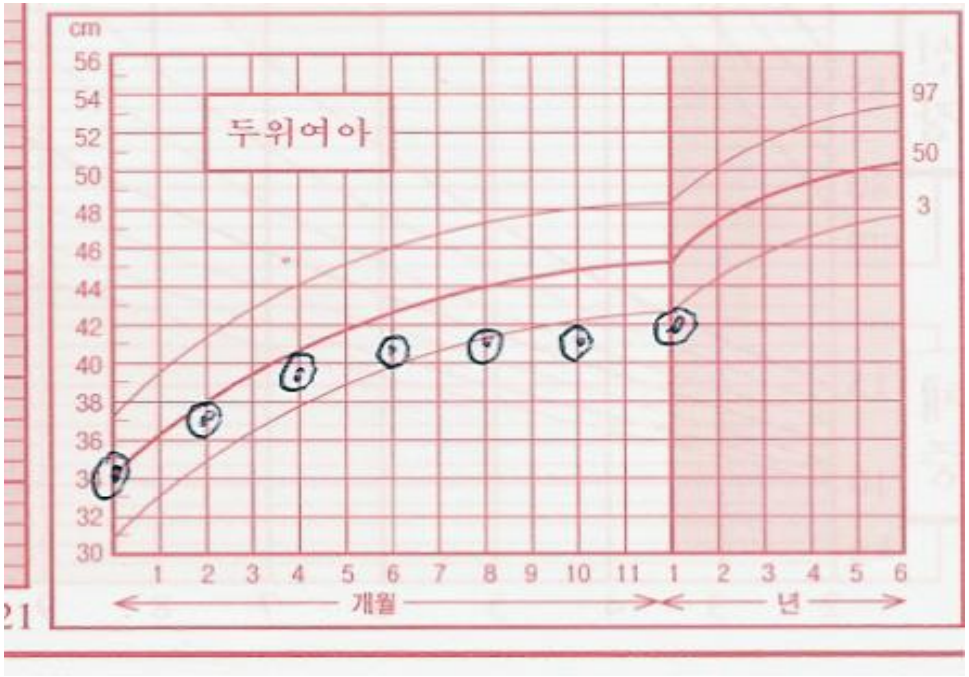
- **Inspection and observation are the first step in N/E.**
- **Before handling, just see!**

- **Delineate the presence of congenital abnormalities**
- **Skin**
- **Mental status, CNE, motor tone and strength, posture, asymmetricity, movements of face and extremities**

Physical examination

- **Physical check-up: head circumference, Ht./Bwt.**





Observation

- Dysmorphism
- Skin
- Posture
- Motor asymmetry
- Genetic disease

Mental status examination

- **Usually depends on observation and the patient's response during examination**

- **Consciousness rating scales**
- **Glasgow coma scale and modification for children**

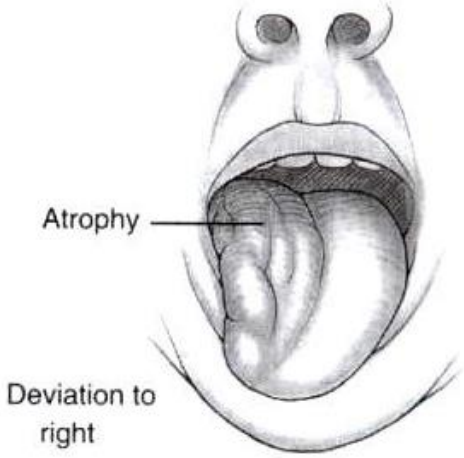
GCS modified for children

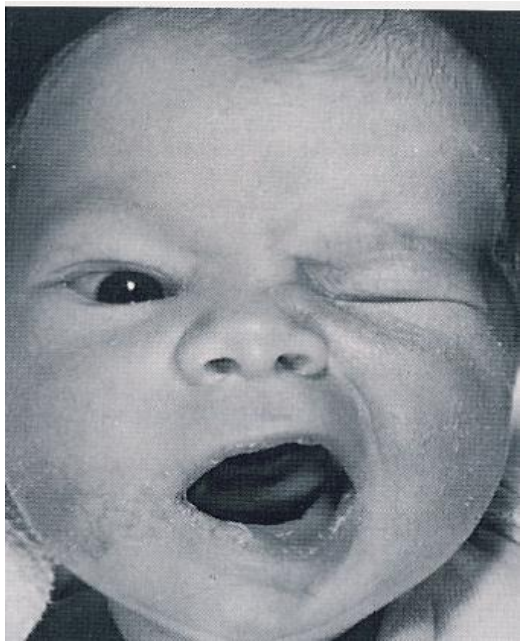
SIGN	GCS	GCS-modified	SCORE
Eye opening	Spontaneous	Spontaneous	4
	To command	To sound	3
	To pain	To pain	2
	None	None	1
Verbal response	Oriented	Age appropriate verbalization	5
	Confused	Cries, but inconsolable	4
	Disoriented	Irritable, uncooperative, aware of environment	3
	Inappropriate words	Irritable persistent cries, inconsistently consolable	2
	Incomprehensible sounds	Inconsolable crying, unaware of environment or parents, restless, agitated	1
	None	None	1
Motor response	Obeys commands	Obeys commands, spontaneous movement	6
	Localized pain	Localized pain	5
	Withdraws	Withdraws	4
	Abnormal flexion to pain	Abnormal flexion to pain	3
	Abnormal extension	Abnormal extension	2
	None	None	1

Cranial nerve examination

- **Light reflex (CN II→III)**
  - **Dilated pupil: brain herniation, anoxia, atropine, scopolamine**
  - **Constricted pupil: pontine injury, morphine, meperidine**

- **Facial motor: CN VII**
- **Gag reflex: CN IX→ CN X**
- **Bulbar palsy: CN IX ~ XII**





Upper motor signs

- **Motor tone and strength: spastic/rigid, weakness**
- **no decrease of muscle bulkiness**
- **No fasciculation and fibrillation**
- **Hyperreflexia**
- **Positive Babinski signs and ankle clonus**

Lower motor signs

- Motor tone and strength: flaccid paralysis
- Decreased muscle bulkiness: atrophy
- Presence of fasciculation and fibrillation
- Hyporeflexia
- No Babinski sings and ankle clonus
- Lesions from anterior horn cell to muslces

Seizure

- **Seizure**

  “ paroxysmal electrical discharges from the cortical neuron

→ result in a LOC, alteration of sensory or impairment of psychic function, convulsive movements, disturbance of sensation, or some combination”

- **Epilepsy: diagnosed after two or more unprovoked seizures**

  ***Unprovoked*: no closely associated concurrent illness, fever, or acute brain injury**

  ***cf.* Reflex seizure, stresses related to personal activity**

Choreoathetosis

- **Chorea: involuntary, forcible, rapid, jerky movements, usually involving proximal part of the extremities**

- **Athetosis: inability to maintain the fingers, toes, tongue, or other body parts in a stable position, resulting in continuous slow, sinusoidal, and flowing involuntary movements (distal part)**

- **Choreoathetosis is the most frequently reported dyskinesia after cardiac surgery**

Neuromonitoring

Initial evaluation for development

- **Record the PHYSICAL MEASUREMENTS (ex. HC)**

- **Ask the KEY DEVELOPMENT**
  : gross motor, fine motor, communication

- **N/E**

- **Delineate the STATUS OF HEART DISEASE**
- **Ascertain the feeding, infection, and other GENERAL MEDICAL CONDITION**
- **Check the CO-MORBIDITIES**

Immediate postoperative evaluation

- **Observe MENTAL STATUS using rating scale with time SEQUENCE**
- **Record CNS INFLUENCING DRUGS such as sedatives, opioids**
- **BEDSIDE N/E: observation, L/R, posture, motor, reflexes**
- **Reports the ABNORMAL MOVEMENTS: use home video**

Immediate postoperative evaluation

Consider EEG, brain imaging

- **DELAYED RECOVERY OF CONSCIOUSNESS**
- **SEIZURE**
- **MOVEMENT DISORDER**

Clinical follow-up for development

- Serial record for the physical measurement

- Compare the developmental mile stones to norms and previous status
- N/E

- Delineate the status of heart disease
- Ascertain the feeding, infection, and other general medical condition
- Check the co-morbidities: vision, hearing
- Developmental evaluation using the scales (ex. Bayley scales): 1.5-2 years of age

Brain imaging

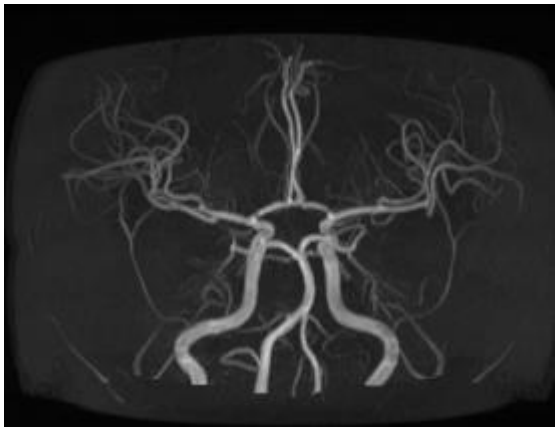
- **Brain USG**
  - **Convenient for bed side evaluation**
  - **Limitation: useful for up to 4months of age, poor resolution**

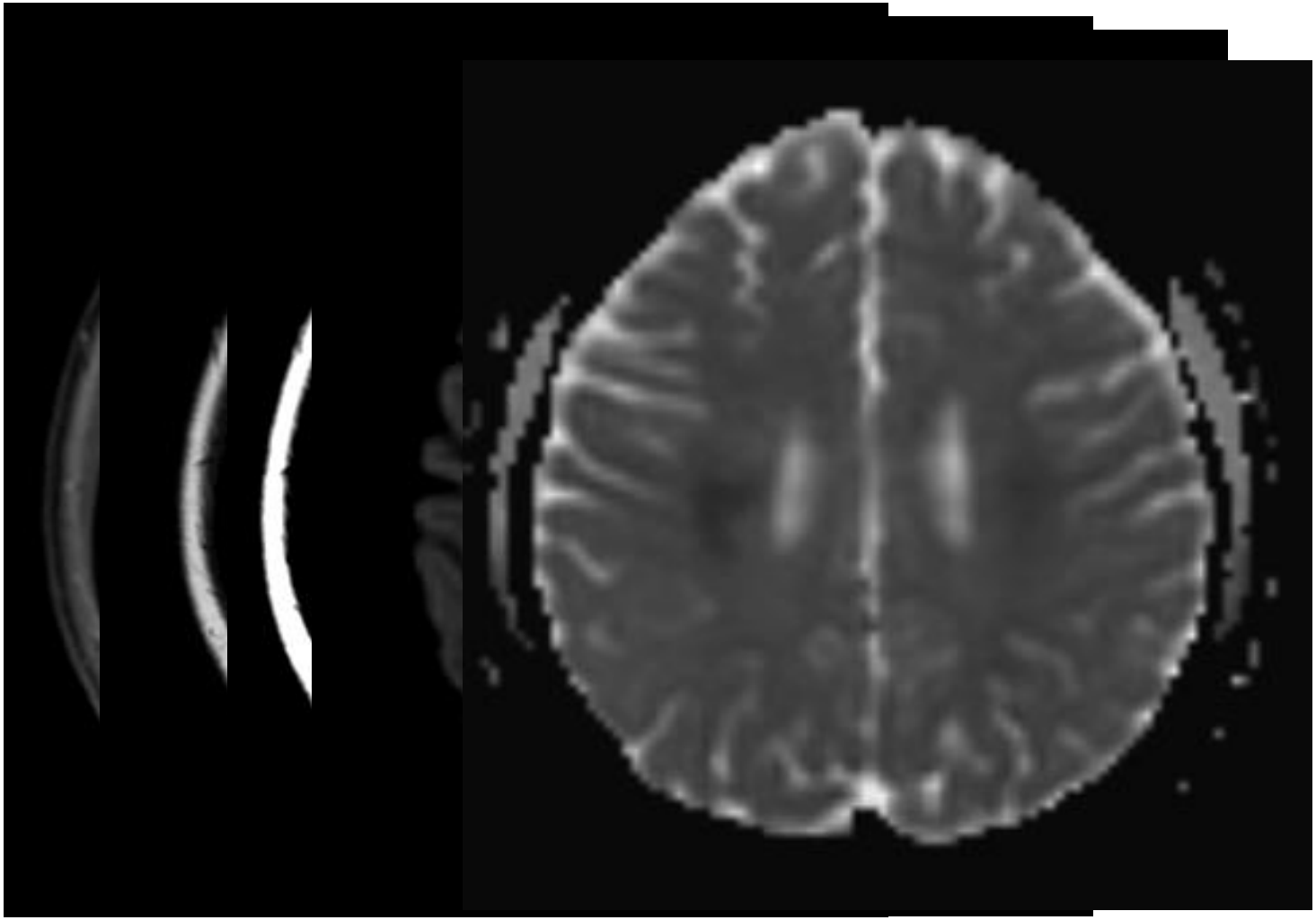
- **Brain CT**
  - **Use only to diagnosis of hemorrhage and fracture, limitation to find infarct**

Brain MRI

- Method of choice in evaluating the CNS
- Limitations in applying to unstable patients

- Useful MR sequences
  - MRA
  - Diffusion-weighted imaging





Brain MRI

- **Mahle et al. (Circulation 2002)**
  - **Evidence of ischemic injury in 25% of patients**
  - **Elevated lactate on MRS in over 50% of patients**

- **Licht et al. (J Thorac Cadriovasc Surg 2004)**
  - **53% of patients showed developmental or acquired brain lesions including brain dysgenesis and PVL**

- **McQuillen et al (Stroke 2007)**
  - **39% of patients showed evidence of brain injury**
  - **Stroke – white matter injury**

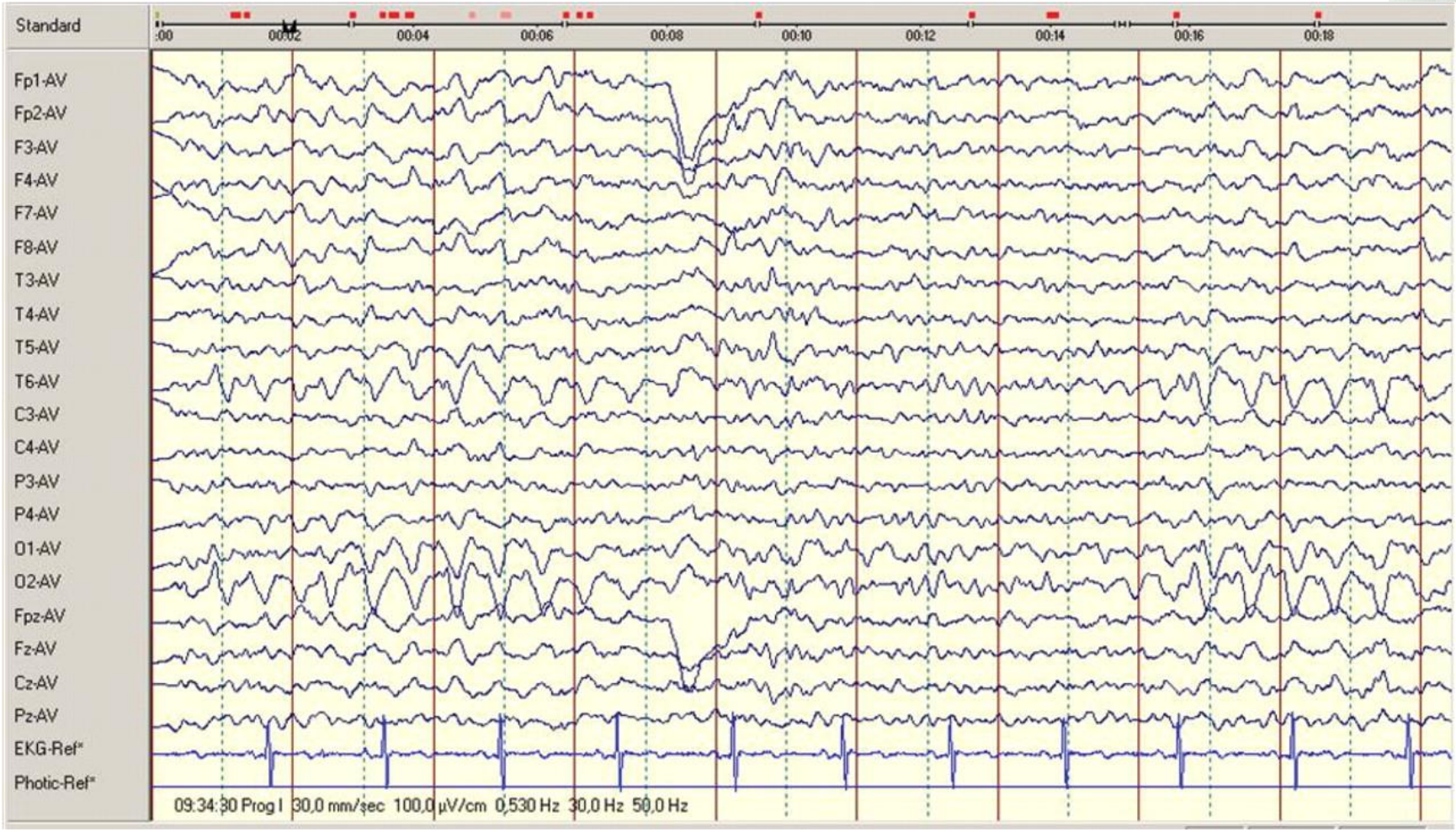
Intraoperative MRI

EEG

- **Functional electrophysiologic study**
  - **Evaluate the normal rhythms and indicators**
  - **Diagnosis of focal lesions**
  - **Diagnosis of subclinical seizure**

- **Continuous EEG monitoring and signal-processed EEG algorithms**
  - **Bispectral Index**
  - **Amplitude integrated EEG**

- **Evoked potentials: auditory, somatosensory, and visual**


Standard
:00
00:02
00:04
00:06
00:08
00:10
00:12
00:14
00:16
00:18
Fp1-AV
Fp2-AV
F3-AV
F4-AV
F7-AV
F8-AV
T3-AV
T4-AV
T5-AV
T6-AV
C3-AV
C4-AV
P3-AV
P4-AV
O1-AV
O2-AV
Fpz-AV
Fz-AV
Cz-AV
Pz-AV
EKG-Ref*
Photic-Ref*
09:34:30 Prog I 30,0 mm/sec 100,0 µV/cm 0,530 Hz 30,0 Hz 50,0 Hz


Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
FZ-CZ
CZ-PZ
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
[EKG1-EKG2]
CZ-C3
C3-T7
T7-T1
T1-T2
T2-T8
T8-C4
C4-CZ


Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
FZ-CZ
CZ-PZ
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
[EKG1-EKG2]
CZ-C3
C3-T7
T7-T1
T1-T2
T2-T8
T8-C4
C4-CZ

Summary

- **Preoperative neurologic abnormalities associated with CHD exist in about 50% of neonates and 38%of infants.**

- **Neurologic complications after surgery present as seizure, abnormal motor tone, or choreoathetosis in 25% patients within a week.**

- **Well organized preoperative and immediate postoperative neurologic assessment, and scheduled follow-up in neurologic clinic are helpful for the timely applying neuroimaging and intervention.**

- **Brain MRI and EEG monitoring are useful for the postsurgical monitor and evaluation of neurologic injury.**