Brain Center
Rudolf Magnus

a diagnostic approach to

coma

in children

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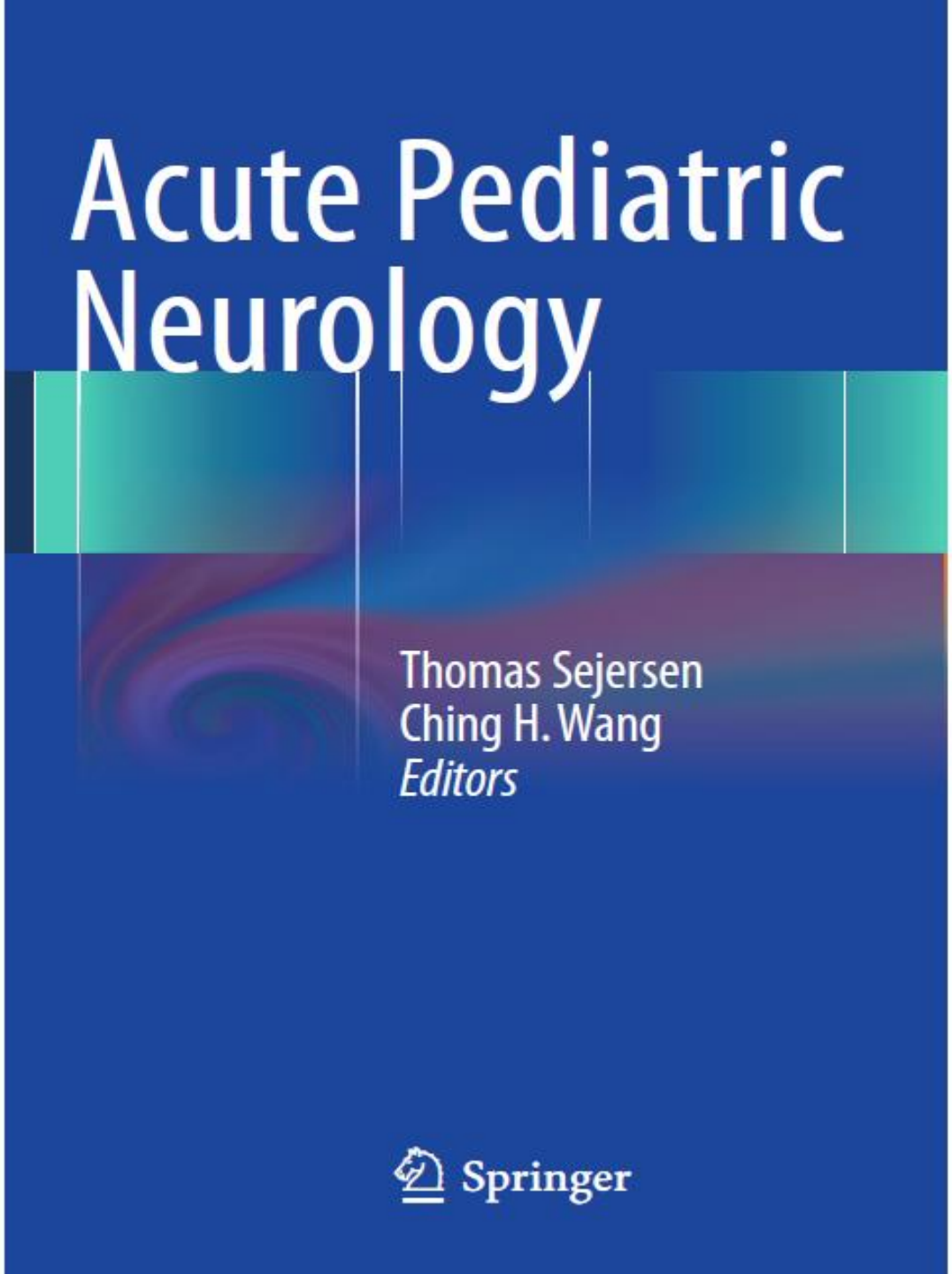
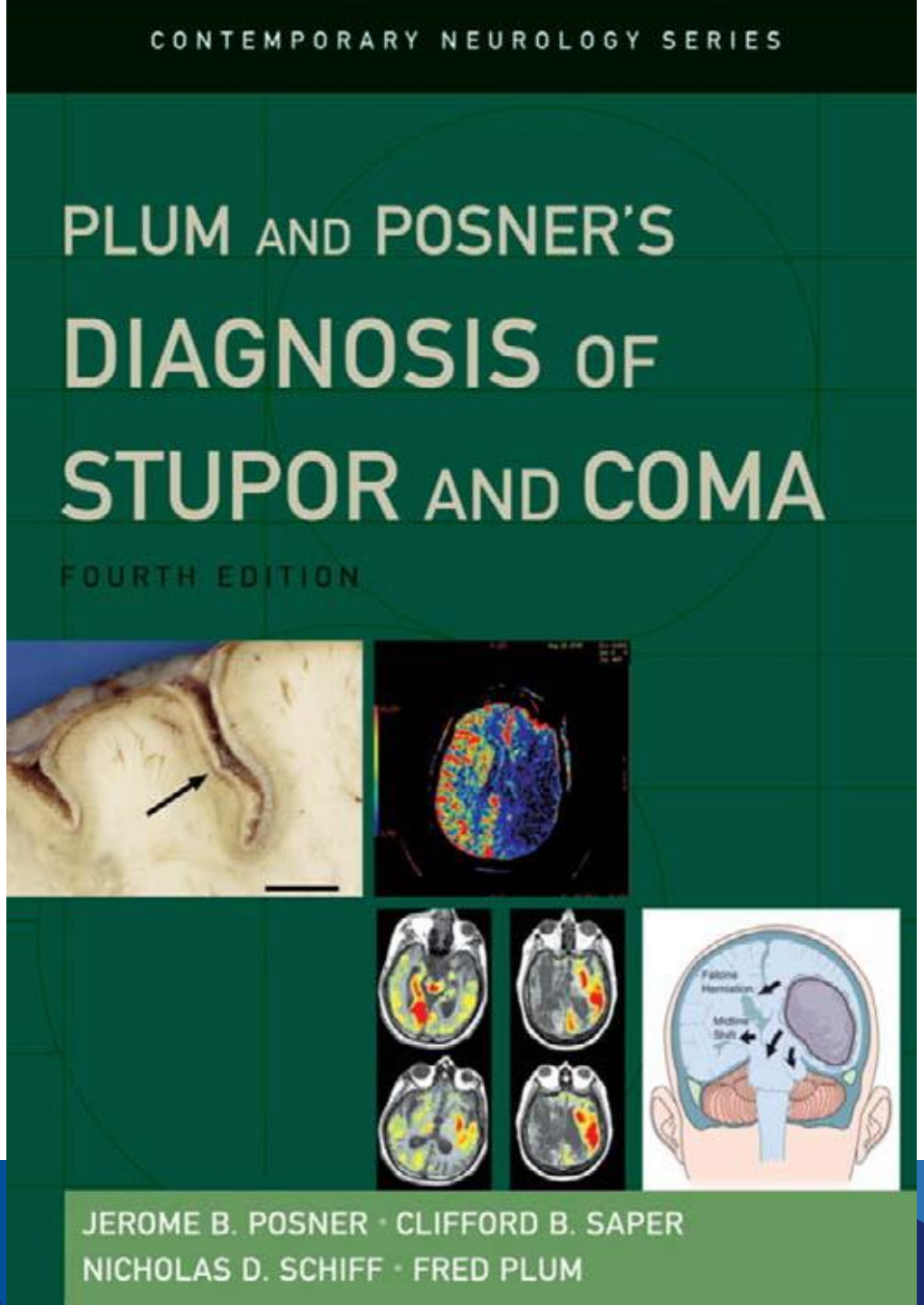




free pdf:
Google search
Plum and Posner's diagnosis of stupor and coma pdf
first hit

definitions

consciousness

state of full awareness of the self and one's relationship to the environment

consiousness ≠ responsiveness

level of **wakefullness** / alertness

content or quality: **awareness** of self/environment, including various and overlapping functions, such as attention, perception, memory

definitions

coma

- a state of deep, unarousable, sustained pathologic unconsciousness with the eyes closed
- persisting for at least 1 hour
- lack of both wakefulness and awareness
- patient cannot be aroused to respond appropriately to painful stimuli

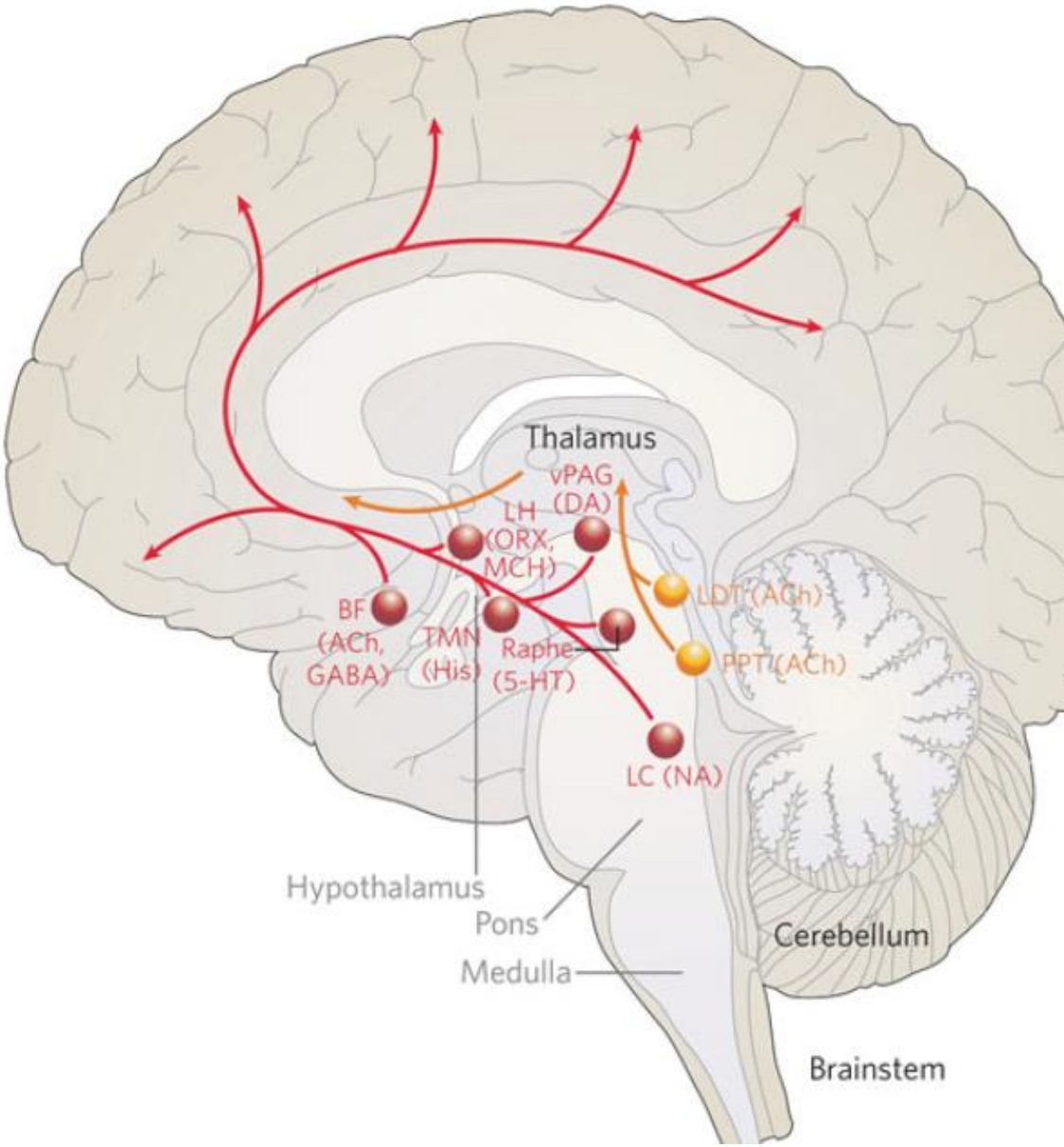
coma – in general

requires dysfunction of:

Ascending (Reticular)
Arousal (or Activating)
System ([A]RAS)
upper brain stem
diencephalon

or

both hemispheres



coma – in general

requires dysfunction of:

Ascending (Reticular)
Arousal (or Activating)
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upper brain stem
diencephalon

or

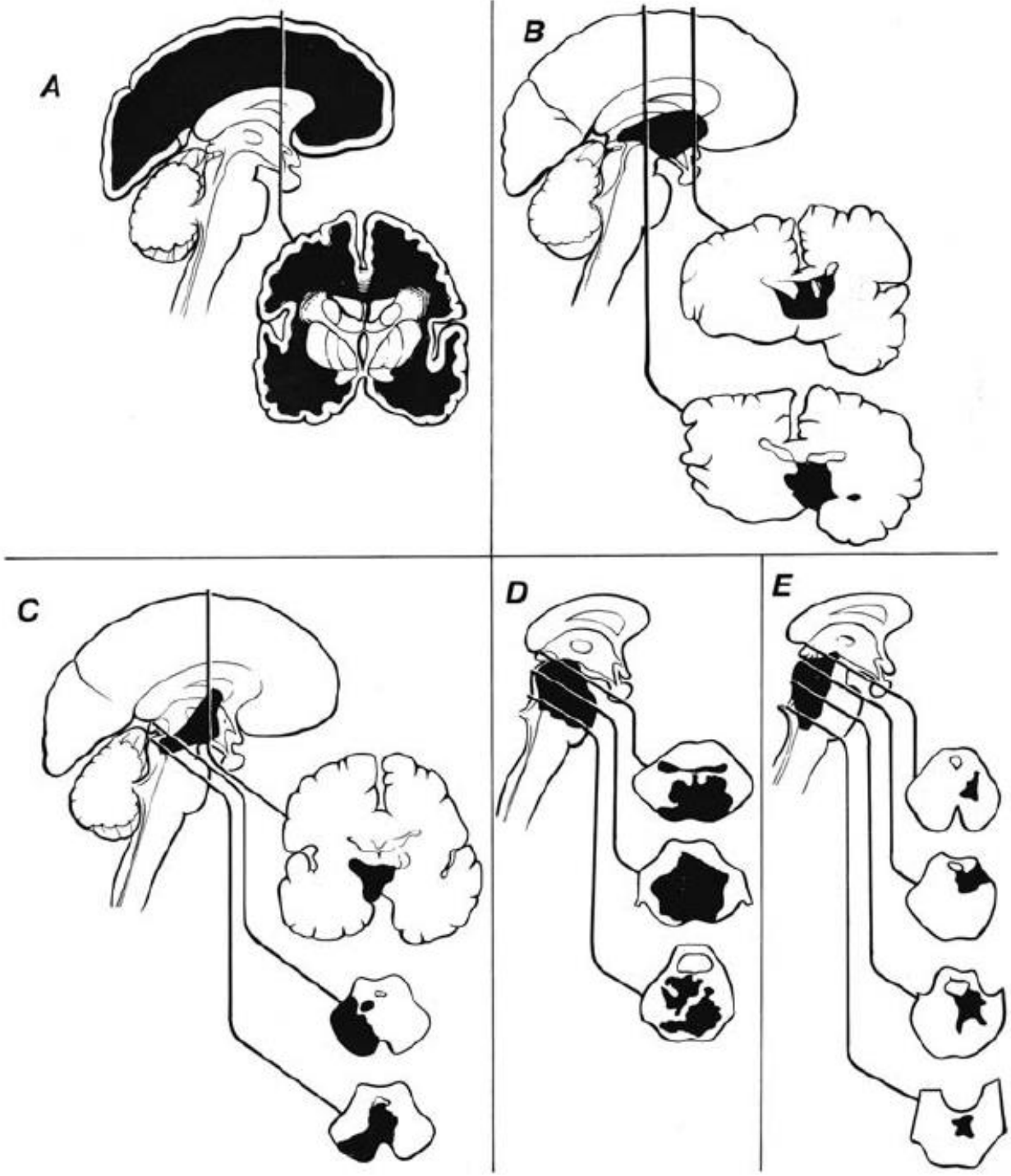
both hemispheres

caused by:

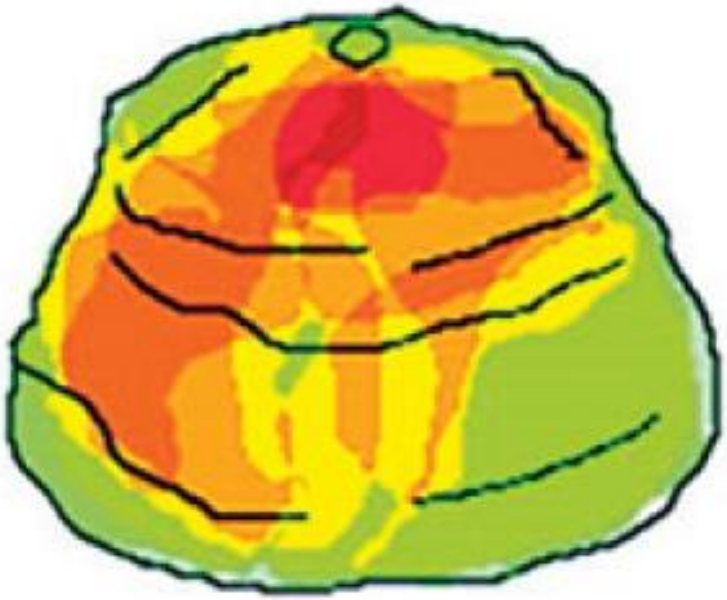
structural lesions

compressive
destructive

diffuse/metabolic causes

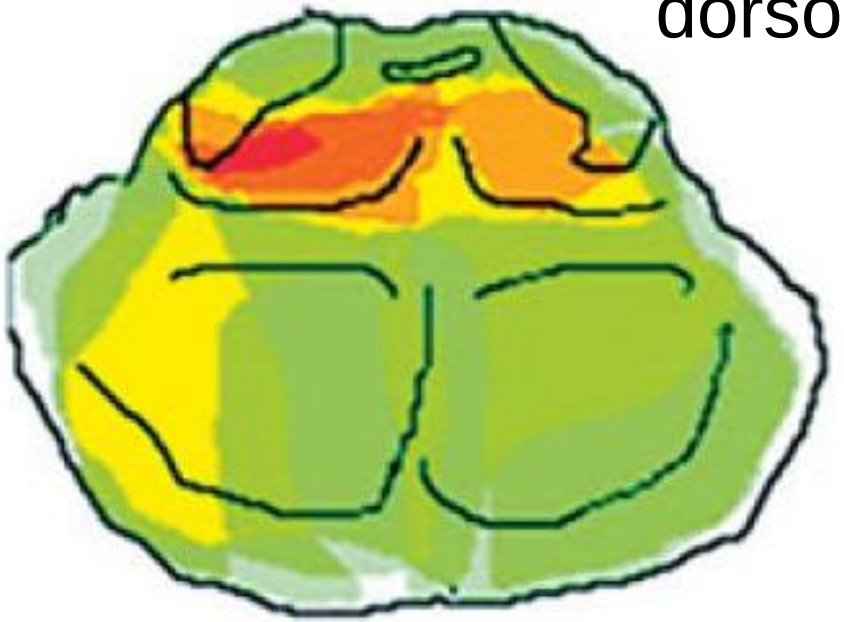


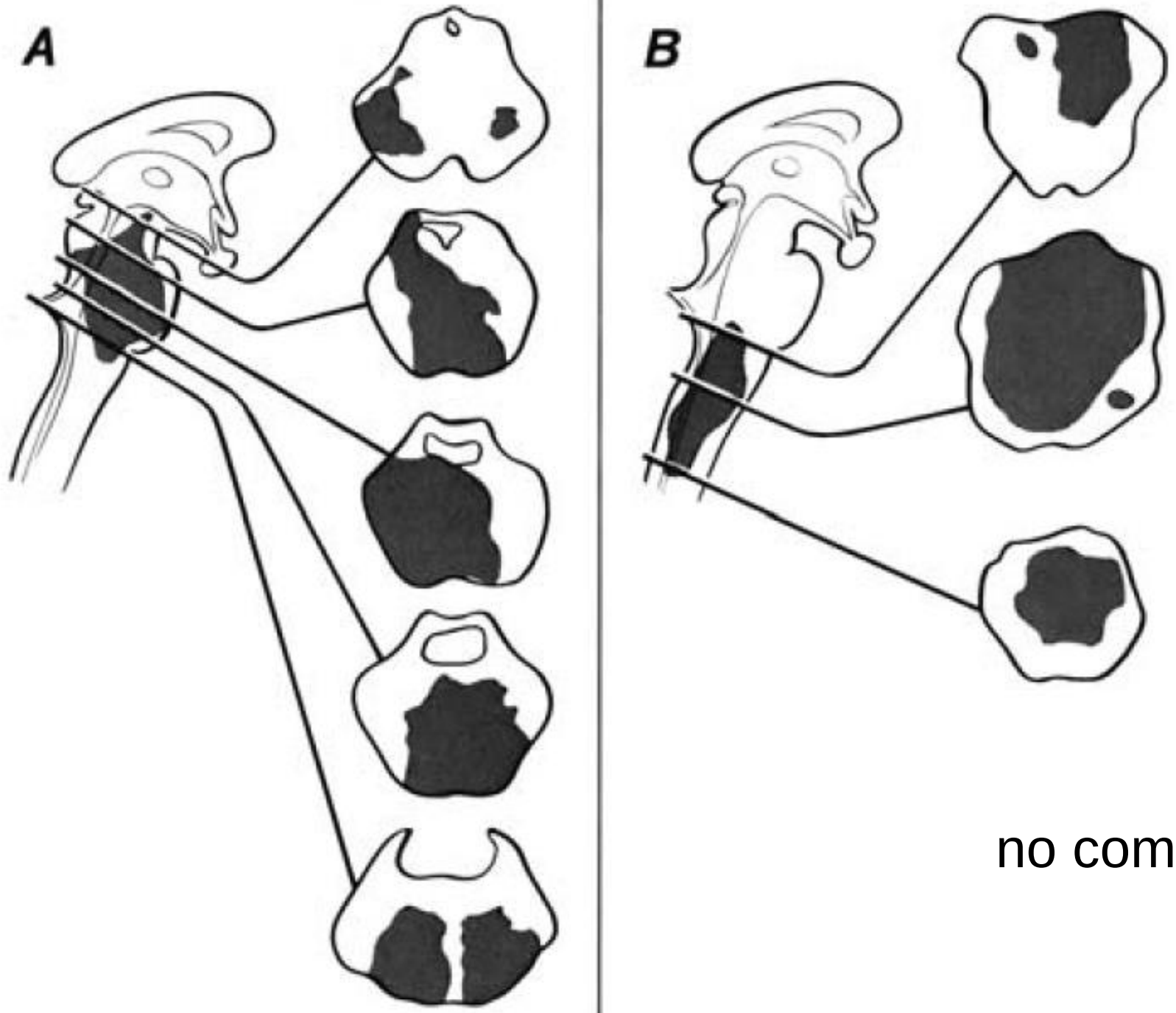
coma



paramedian midbrain

dorsolateral pons





no coma

asessing coma – level of consciousness GCS

Adult/standard	Score	Pediatric (<4–5 years) [6]
Eye opening		
Spontaneous	4	Spontaneous
To speech	3	To speech
To pain	2	To pain
None	1	None
Best verbal response		
Oriented	5	Coos, babbles (age appropriate)
Confused	4	Irritable, cries
Inappropriate words	3	Cries to pain
Incomprehensible sounds	2	Moans to pain
None	1	None
Best motor response		
Obeys commands	6	Spontaneous movements
Localizes pain[a]	5	Withdraws to touch
Withdraws to pain[b]	4	Withdraws to pain[b]
Abnormal flexion[a]	3	Abnormal flexion[a]
Extensor response[a]	2	Extensor response[a]
None[a]	1	None[a]

pitfalls of the GCS

10 year old girl, “acute loss of consciousness”

eyes open

normal pupillary and corneal reflexes

conjugate eye deviation – left

does not obey commands

extends R arm, localizes with L arm

makes sounds to pain

E4M5V2

pitfalls of the GCS

aphasia! MCA infarct L

pitfalls of the GCS

5 year old boy

after breakfast: “sleepy”

within 2 hours: progressive paresis R, later L, unconscious

E4 / M5(L) M2(R) / V2

no words, no movements of face/arms/legs at request

eye deviation to L, no roving movements

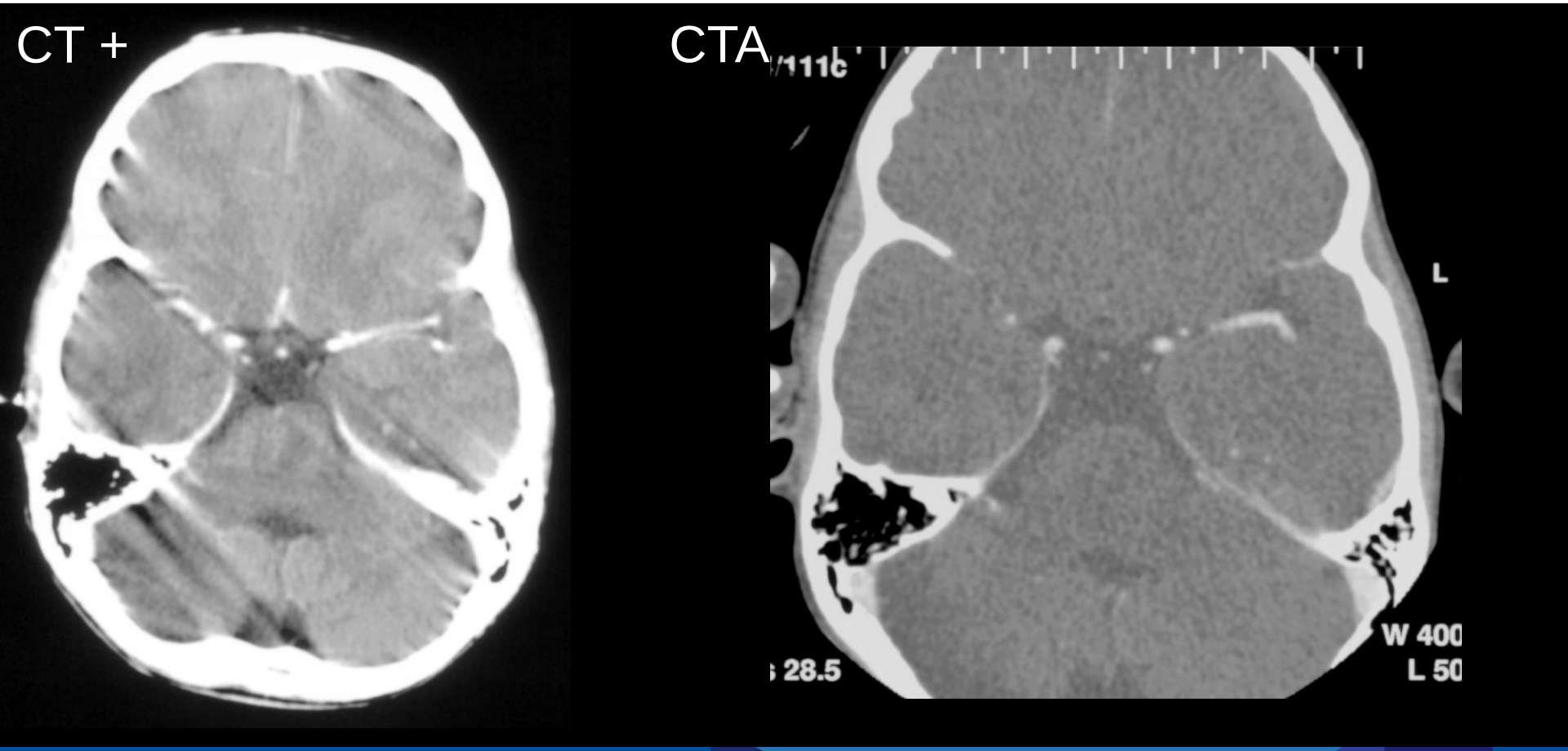
PR +/+, corneal reflexes -/-

oculocephalic reactions: INO

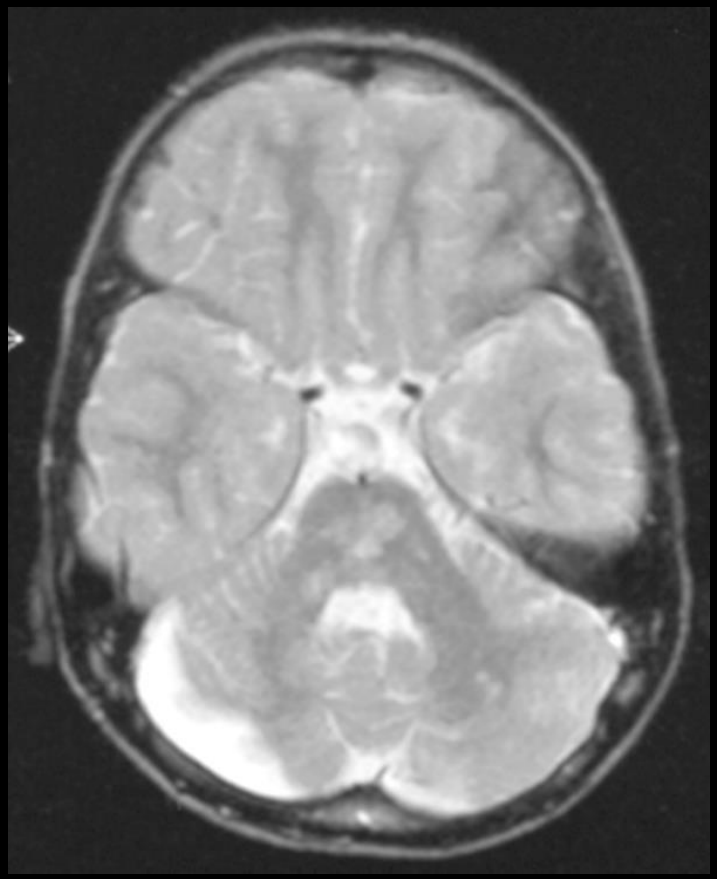
bilateral Babinski’s sign

pitfalls of the GCS

locked in syndrome, basilar artery thrombosis



pitfalls of the GCS



pitfalls of the GCS

insufficiently examined

- too little pain
- not bilaterally

discrepancy E-M-V scores

aphasia

anarthria

tetraplegia

coma – mimics

LOC / coma – mimics

Severe disorders of consciousness and related conditions

Condition	Self awareness	Pain and suffering	Sleep–wake cycles	Motor function	Respiratory function
Brain death	Absent	No	Absent	None or only reflex spinal movements	Absent
Coma	Absent	No	Absent	No purposeful movement	Variably depressed
Vegetative state	Absent	No	Intact	No purposeful movement	Normal
Minimally conscious state	Very limited	Yes	Intact	Severe limitation of movement	Variably depressed
Akinetic mutism **awake**	Limited	Yes	Intact	Moderate limitation of movement	Normal to variably depressed
Locked-in syndrome	Present	Yes	Intact	Quadriplegia; pseudobulbar palsy; eye movements preserved	Normal to variably depressed

vegetative state

Criteria
all of the following:
– no evidence of awareness of themselves or their environment; they are incapable of interacting with others
– no evidence of sustained, reproducible, purposeful, or voluntary behavioral responses to visual, auditory, tactile, or noxious stimuli
– no evidence of language comprehension or expression
– intermittent wakefulness manifested by the presence of sleep-wake cycles.
– sufficiently preserved hypothalamic and brain stem autonomic functions to survive if given medical and nursing care
– bowel and bladder incontinence
– variably preserved cranial nerve (pupillary, oculocephalic, corneal, vestibulo-ocular, gag) and spinal reflexes

minimally conscious state

Diagnostic criteria for the MCS

1. Simple command-following
2. Gestural or verbal 'yes/no' responses (regardless of accuracy)
3. Intelligible verbalization
4. Purposeful behavior including movements or affective behaviors that occur in contingent relation to relevant environmental stimuli and are not due to reflexive activity. Some behavioral examples of qualifying purposeful behaviors include

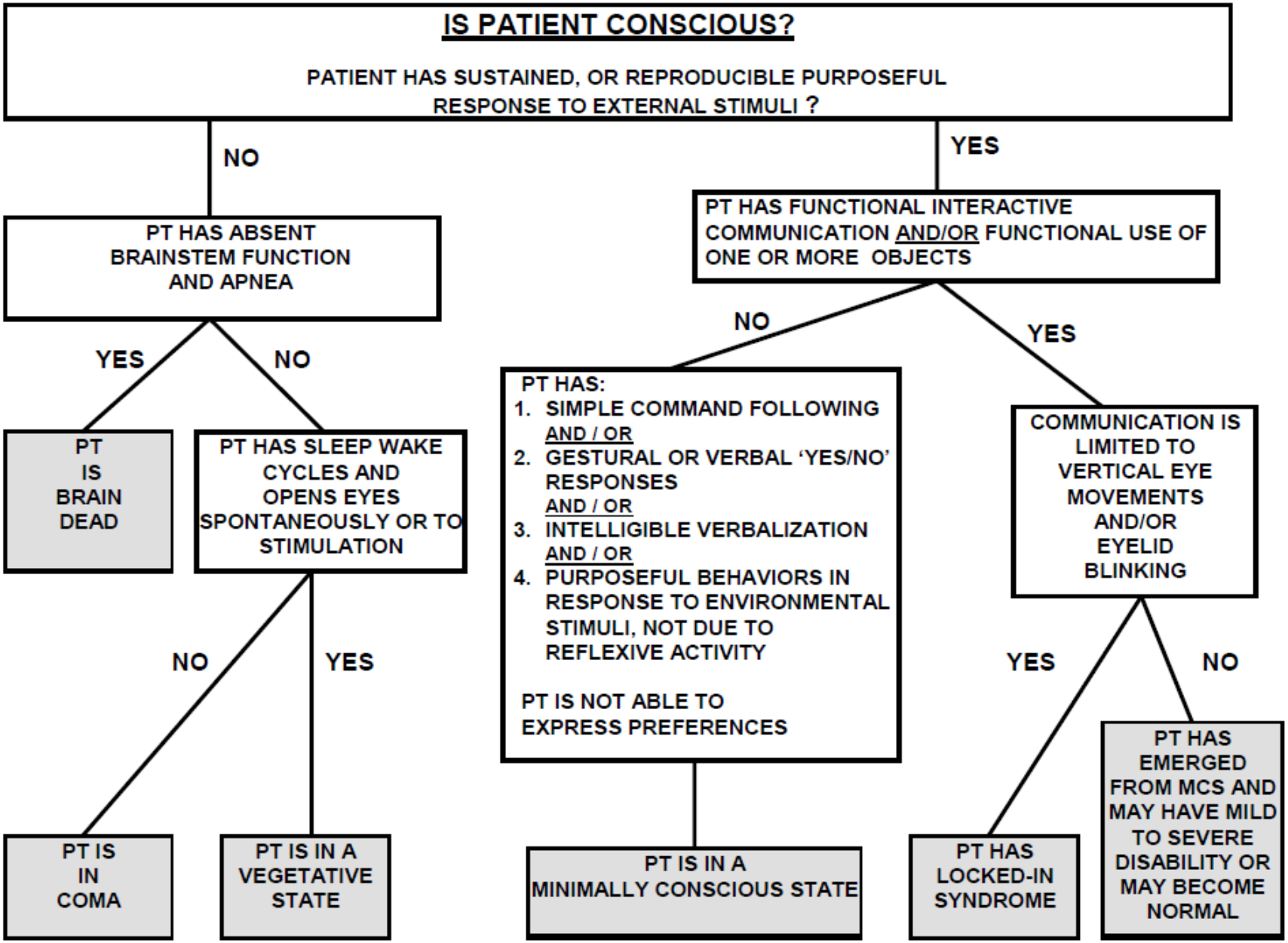
(a) Appropriate smiling or crying in response to the linguistic or visual content of emotional but not to neutral topics or stimuli

(b) Vocalizations or gestures that occur in direct response to the linguistic content of questions

(c) Reaching for objects in a manner that demonstrates a clear relationship between object location and direction of reach

(d) Touching or holding objects in a manner that accommodates the size and shape of the object

(e) Pursuit eye movement or sustained fixation that occurs in direct response to moving or salient stimuli


IS PATIENT CONSCIOUS?
PATIENT HAS SUSTAINED, OR REPRODUCIBLE PURPOSEFUL RESPONSE TO EXTERNAL STIMULI ?
NO
YES
PT HAS ABSENT BRAINSTEM FUNCTION AND APNEA
PT HAS FUNCTIONAL INTERACTIVE COMMUNICATION AND/OR FUNCTIONAL USE OF ONE OR MORE OBJECTS
YES
NO
NO
YES
PT IS BRAIN DEAD
PT HAS SLEEP WAKE CYCLES AND OPENS EYES SPONTANEOUSLY OR TO STIMULATION
PT HAS:
1. SIMPLE COMMAND FOLLOWING AND / OR
2. GESTURAL OR VERBAL 'YES/NO' RESPONSES AND / OR
3. INTELLIGIBLE VERBALIZATION AND / OR
4. PURPOSEFUL BEHAVIORS IN RESPONSE TO ENVIRONMENTAL STIMULI, NOT DUE TO REFLEXIVE ACTIVITY
PT IS NOT ABLE TO EXPRESS PREFERENCES
COMMUNICATION IS LIMITED TO VERTICAL EYE MOVEMENTS AND/OR EYELID BLINKING
NO
YES
YES
NO
PT IS IN COMA
PT IS IN A VEGETATIVE STATE
PT IS IN A MINIMALLY CONSCIOUS STATE
PT HAS LOCKED-IN SYNDROME
PT HAS EMERGED FROM MCS AND MAY HAVE MILD TO SEVERE DISABILITY OR MAY BECOME NORMAL

psychogenic unresponsiveness

lie with eyes closed

normal reflexes and ventilatory patterns

oculocephalic reflexes absent (due to visual fixation)

caloric testing: nystagmus away, no (little) tonic reaction

passive eye opening: upward deviation, active resistance

no slow roving eye movements

normal tone, no active resistance to passive movements

no motor reaction to pain, arm drop: avoids hitting the face

normal EEG

physical examination

vital signs

(airway / breathing / circulation / temp / seizures)

evidence of trauma

(monocle sign / battle sign / hematoma)

evidence of acute or chronic systemic illness?

(jaundice, anemia, cyanosis, rash, petechiae)

evidence of drug ingestion

(needle marks, alcohol on breath)

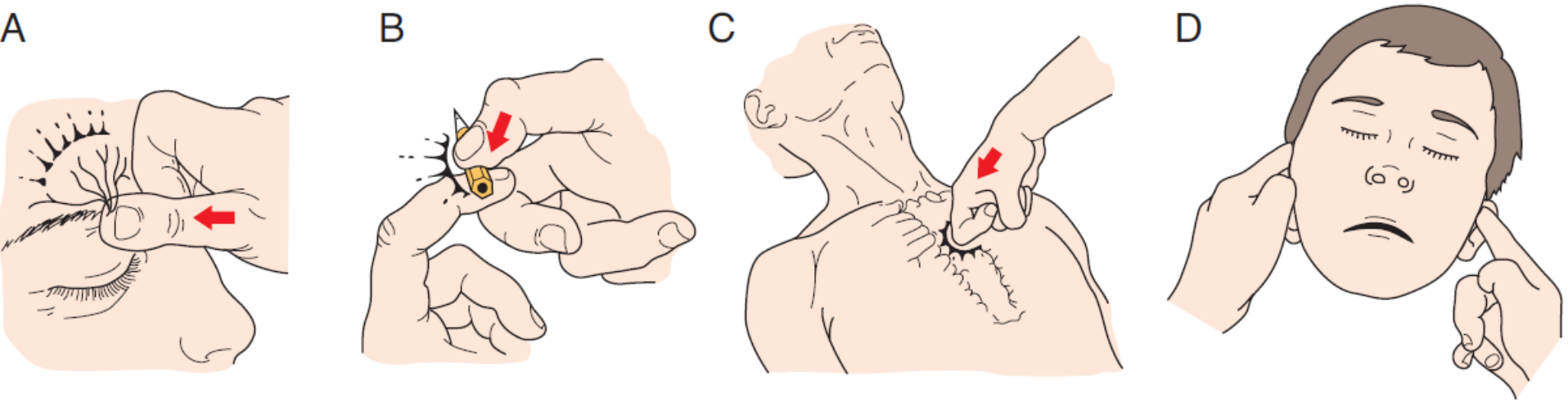
nuchal rigidity

(once cervical trauma excluded)

neurological examination

GCS – consciousness + laterality

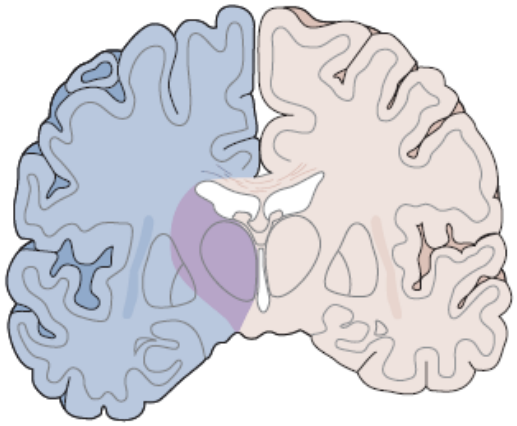
(spontaneous – verbal commands – pain)

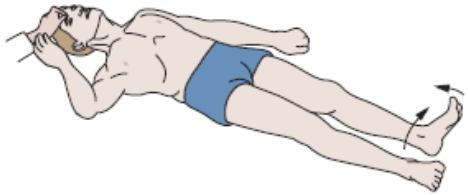


start with A, C, or D:	M2, M3, M5	(check asymmetry)
if no response: B, bilaterally!	M1-5	(check asymmetry)

neurological examination

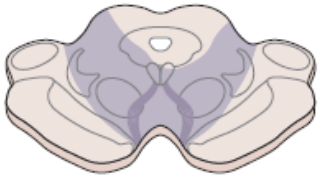
motor responses – posturing

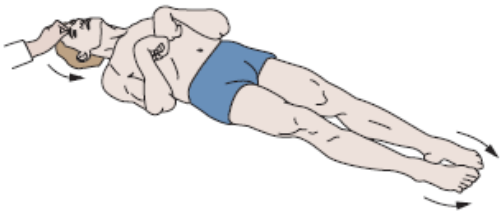




(+ tone + tendon + plantar reflexes)

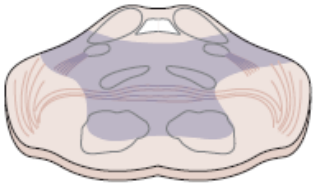
B Upper midbrain damage

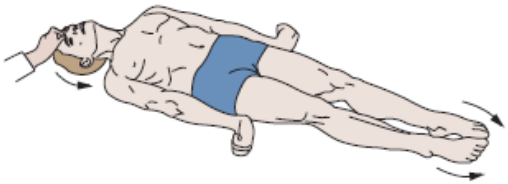




“decortication”

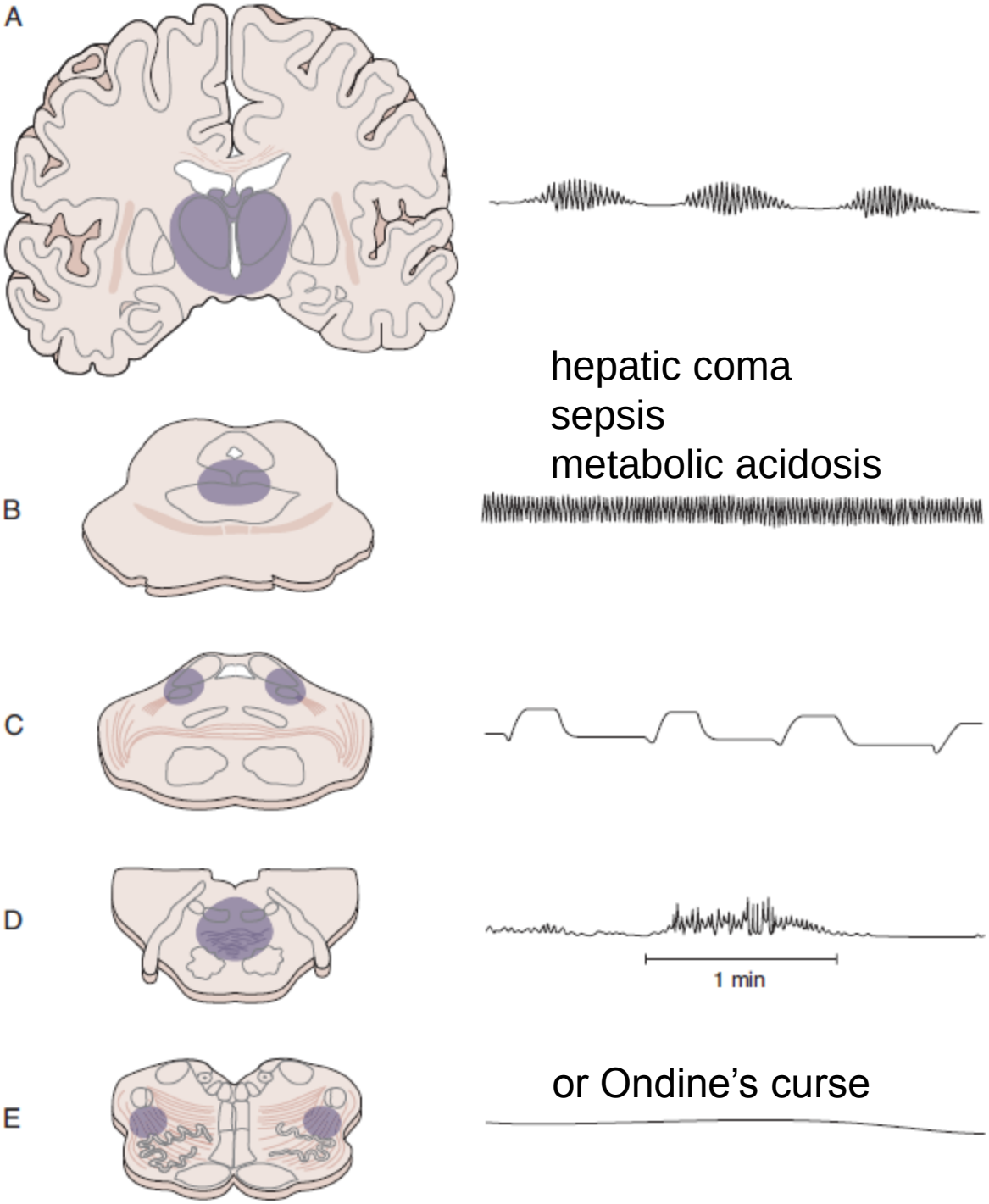
C Upper pontine damage





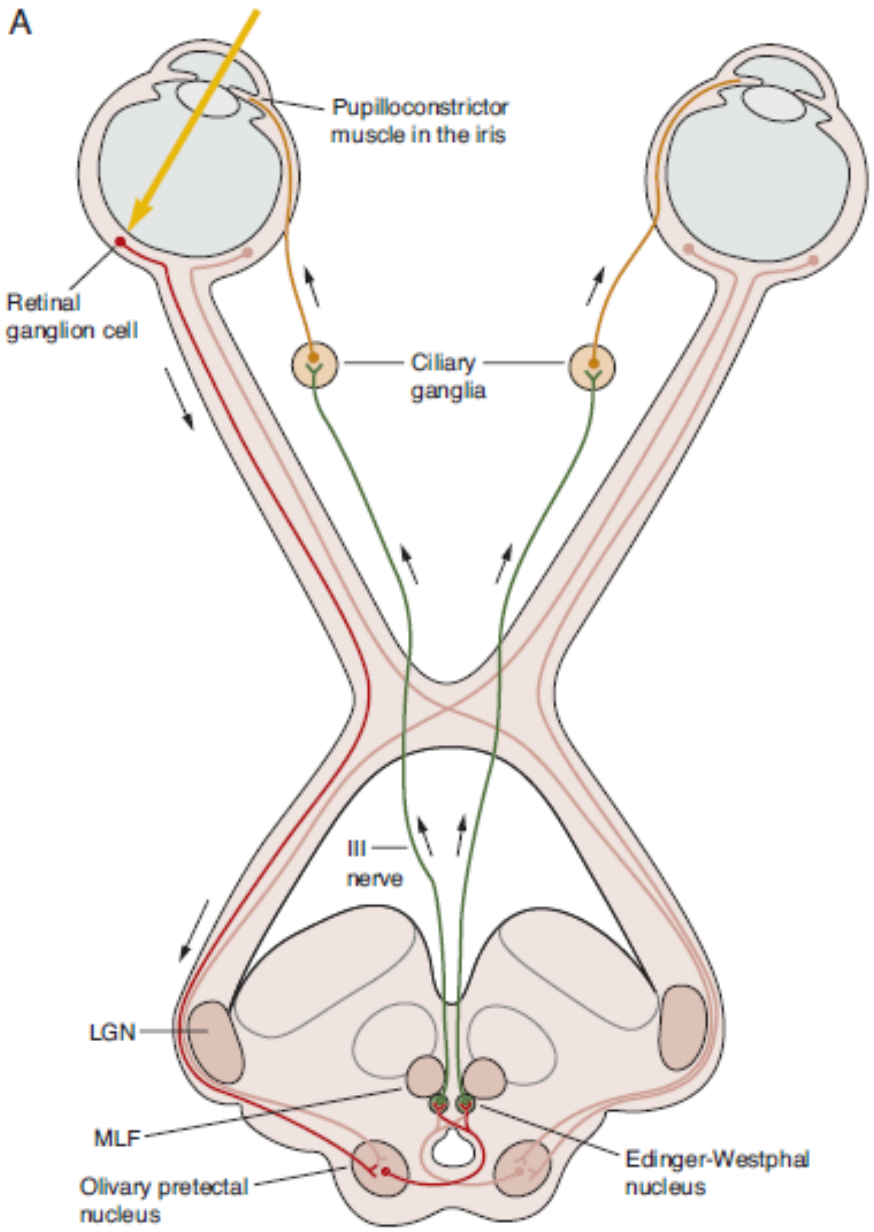
“decerebration”

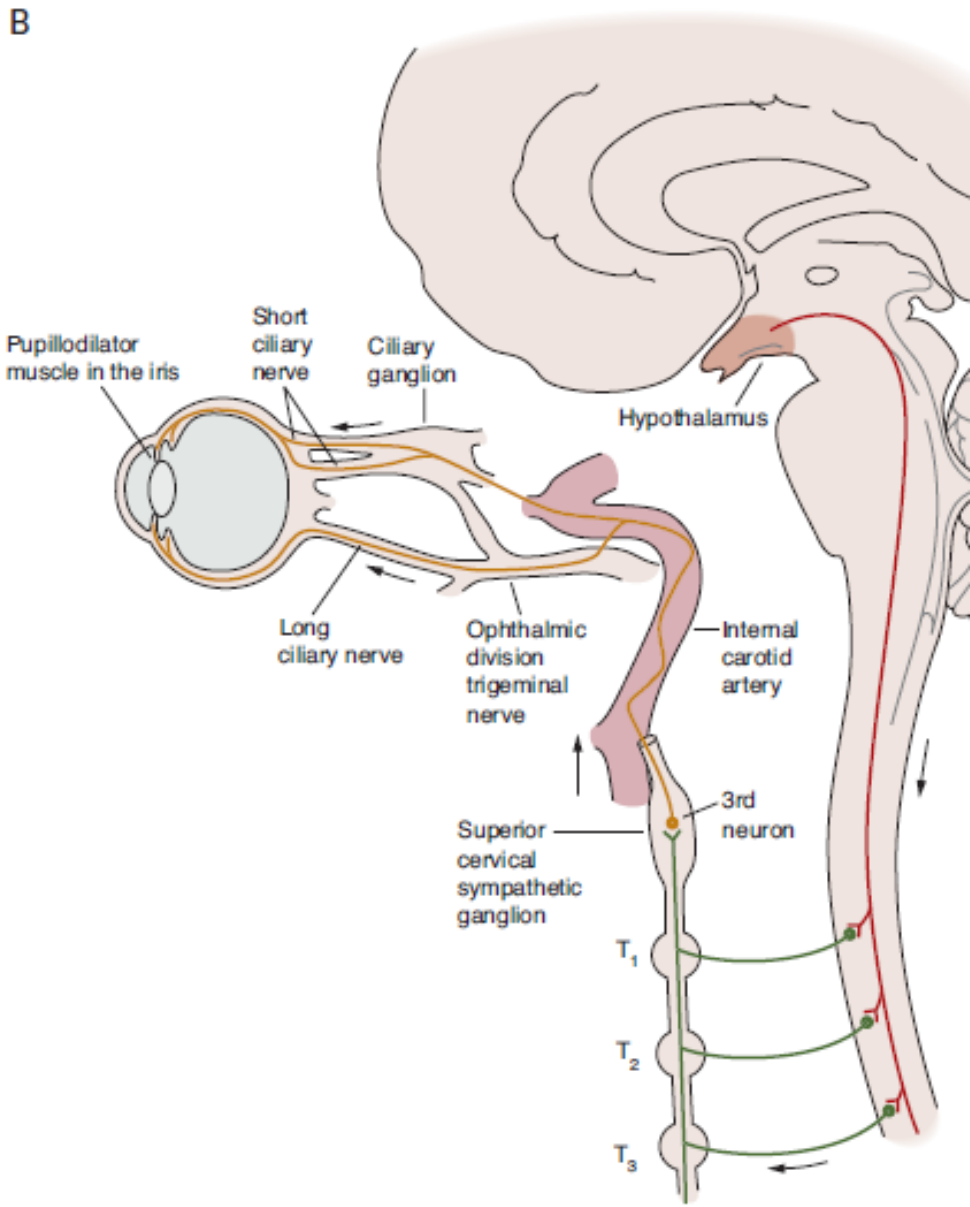
breathing pattern



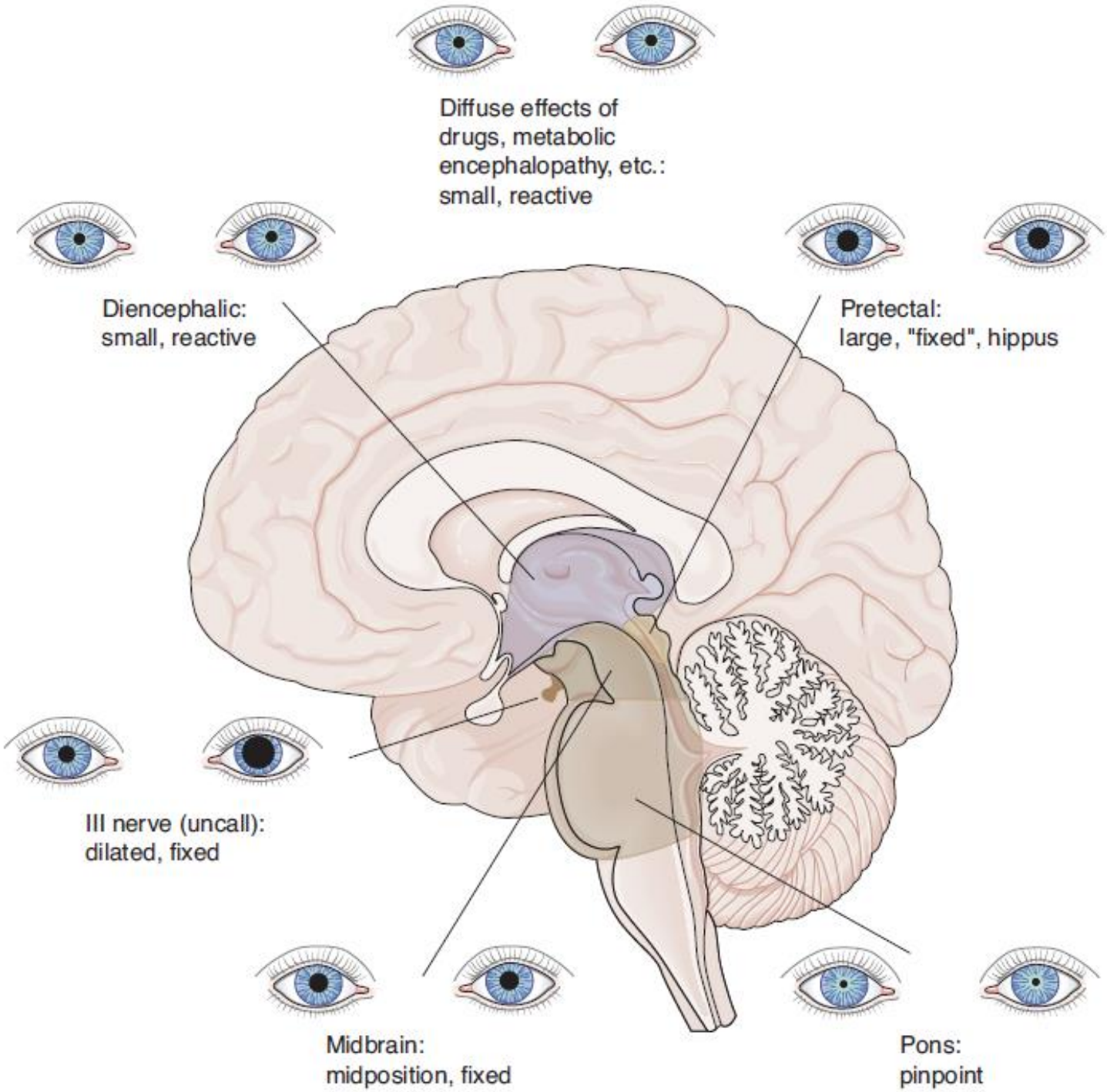
neurological examination – brainstem reflexes

pupillary reflexes


A
Pupilloconstrictor muscle in the iris
Retinal ganglion cell
Ciliary ganglia
III nerve
LGN
MLF
Olivary pretectal nucleus
Edinger-Westphal nucleus


B
Pupillodilator muscle in the iris
Short ciliary nerve
Ciliary ganglion
Hypothalamus
Long ciliary nerve
Ophthalmic division trigeminal nerve
Internal carotid artery
3rd neuron
Superior cervical sympathetic ganglion
T1
T2
T3

pupillary reflexes



metabolic coma:
long retained

after seizures:
transiently
absent

hypoxia/ischemia:
large + fixed

opiates:
pinpoint (~pons)
naloxone reverses

thalamus lesions:
complex oculomotor disturbances

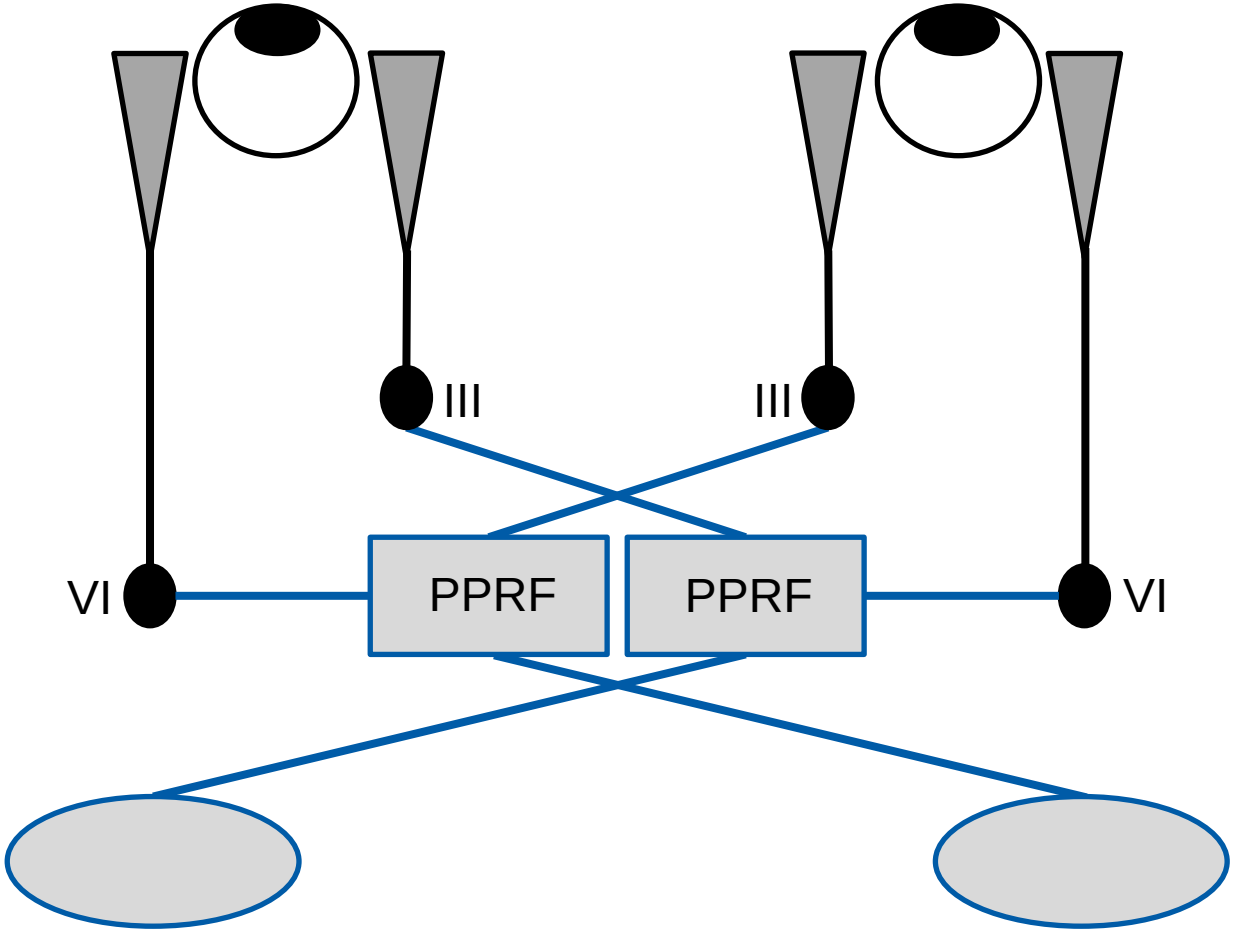
neurological examination – brainstem reflexes

eyelids – corneal responses

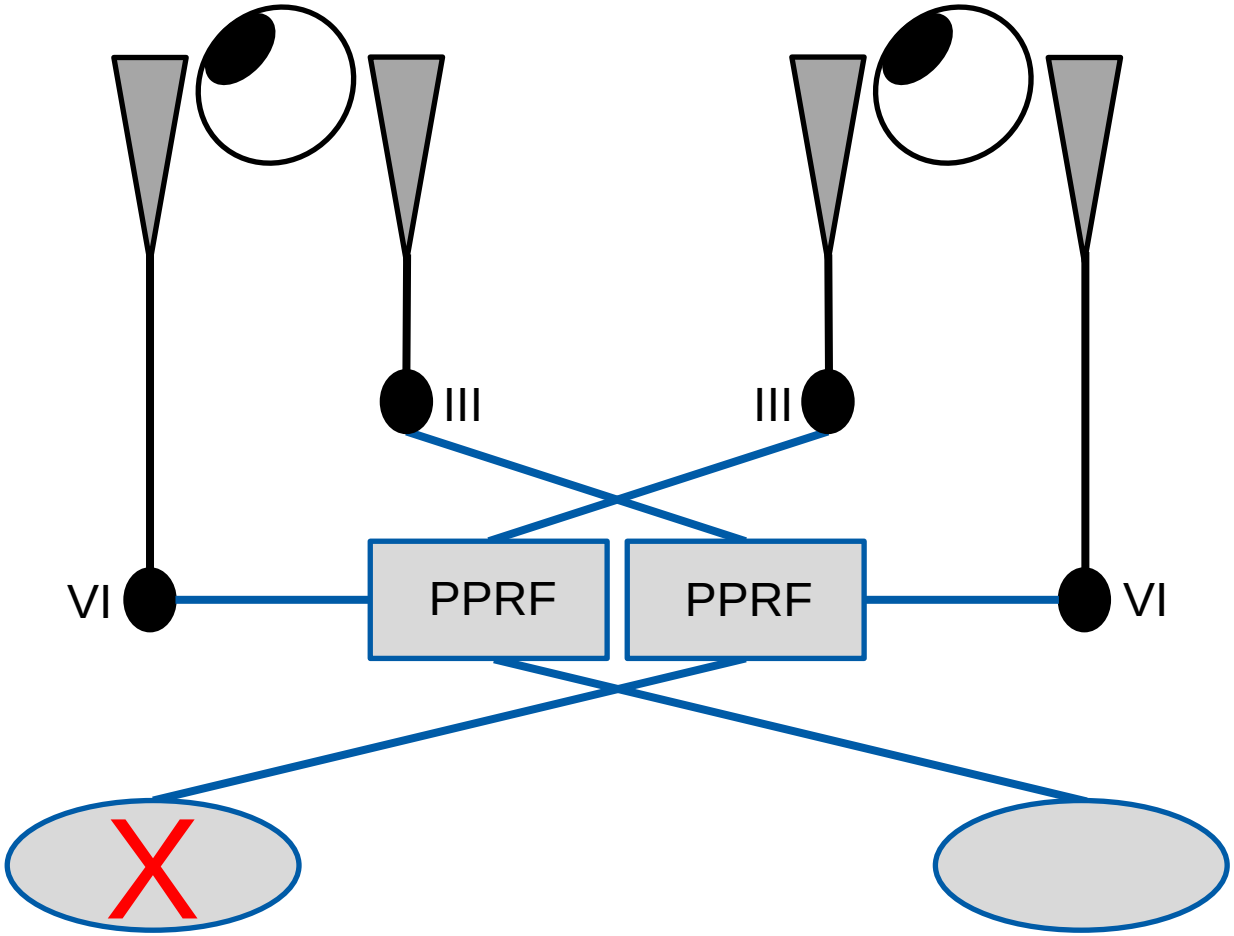
in coma: closed
after passive opening: slow and gradual closing
during seizures: often opened
alternated opening: vegetative state
unilateral ptosis: Horner syndrome, III nerve palsy
blink reflexes to light/threat: may be present in vegetative state

corneal reflex:
intact afferent (n. V) and efferent paths (n. VII and n. III - Bell's phenomenon)
contact lenses!

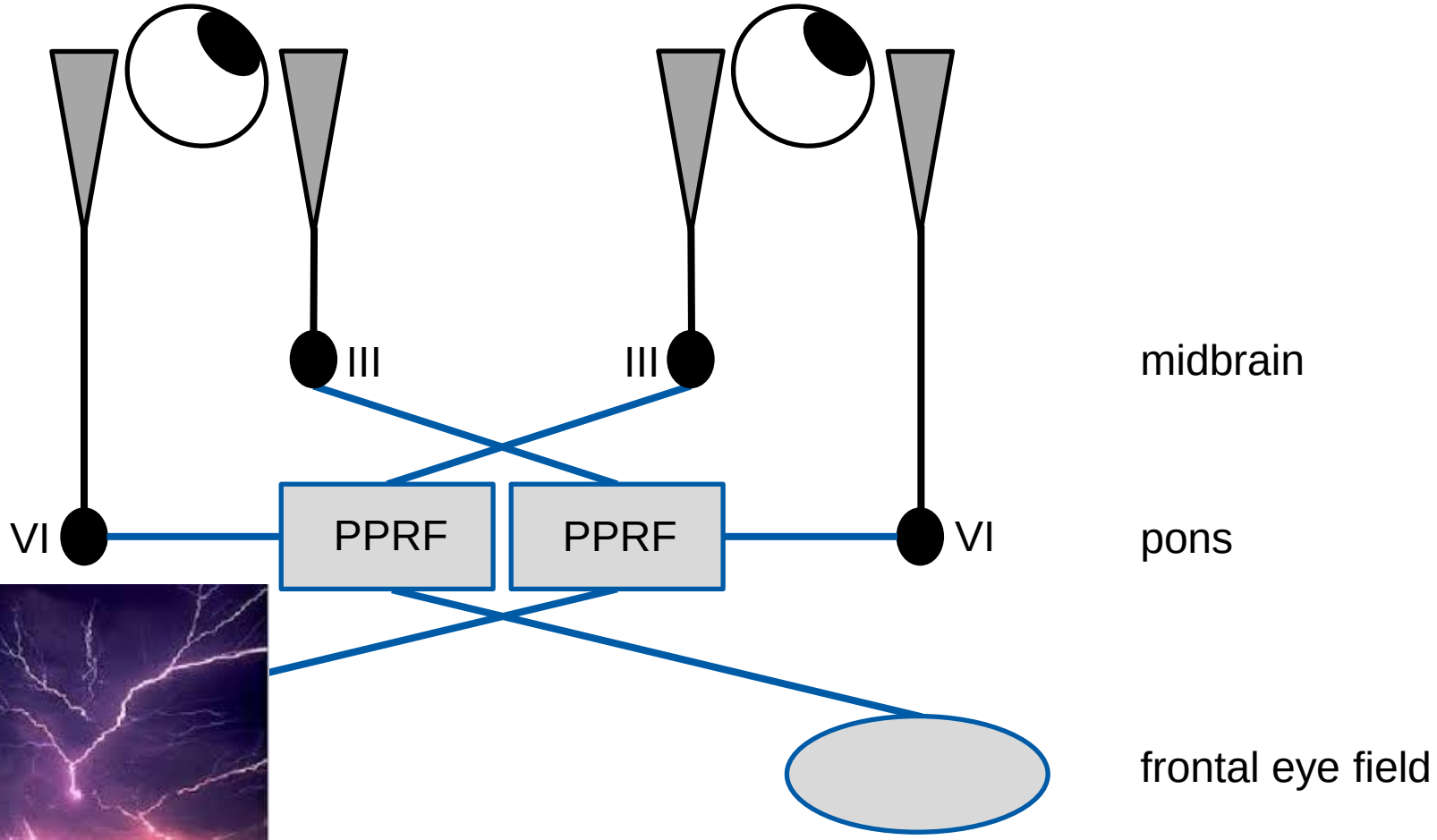
neurological examination – brainstem reflexes



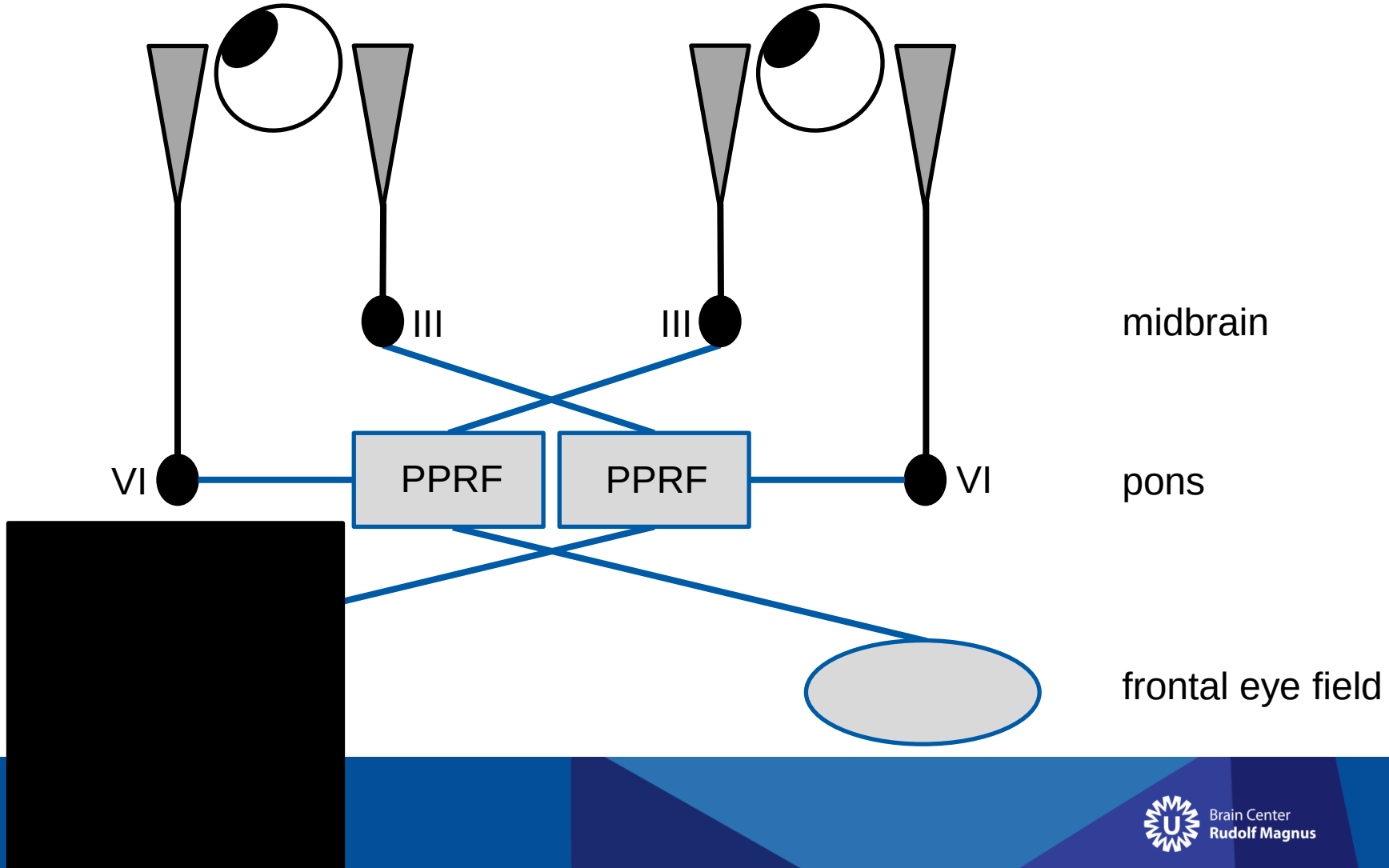
neurological examination – brainstem reflexes



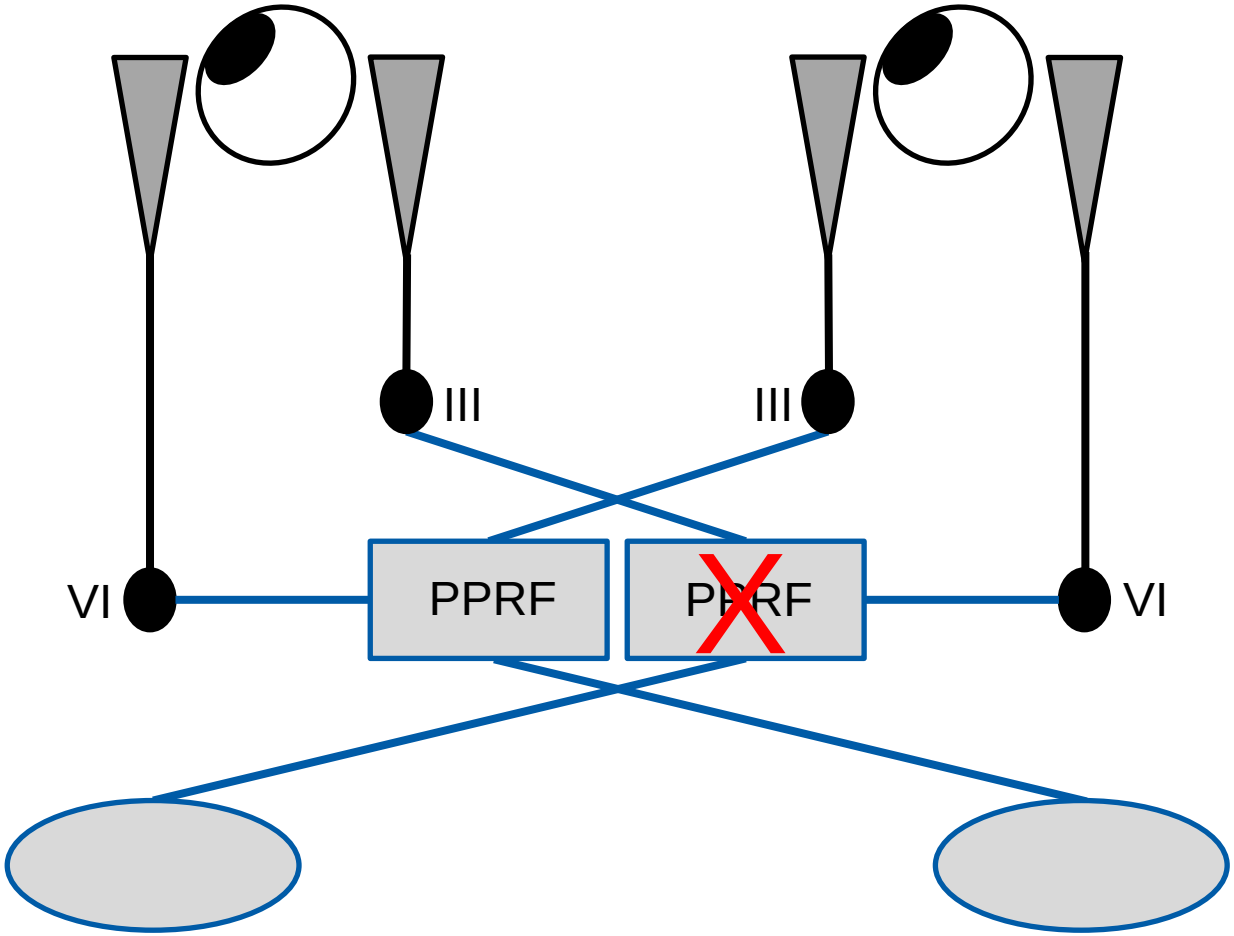
neurological examination – brainstem reflexes



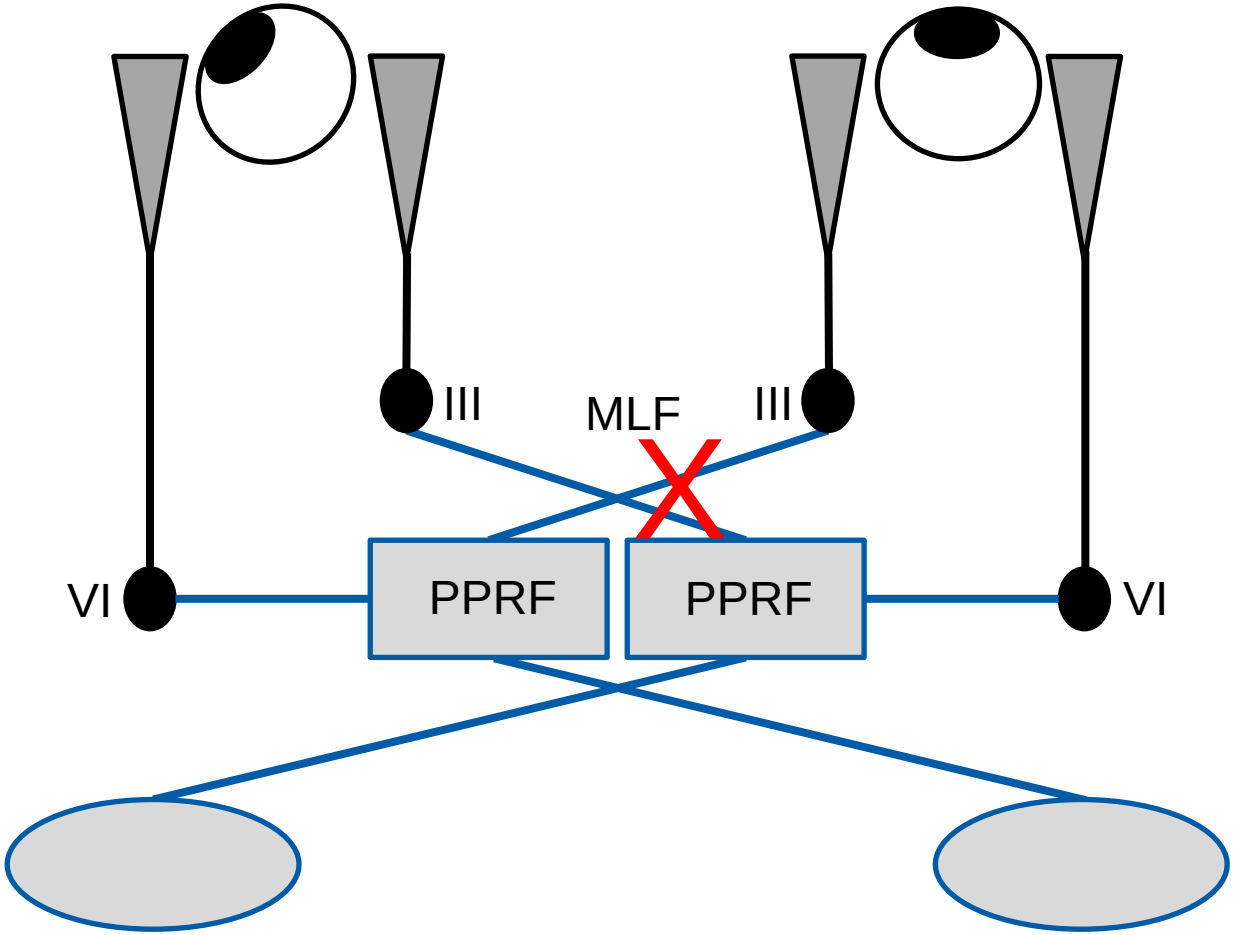
neurological examination – brainstem reflexes



neurological examination – brainstem reflexes



neurological examination – brainstem reflexes



neurological examination – brainstem reflexes

spontaneous eye movements

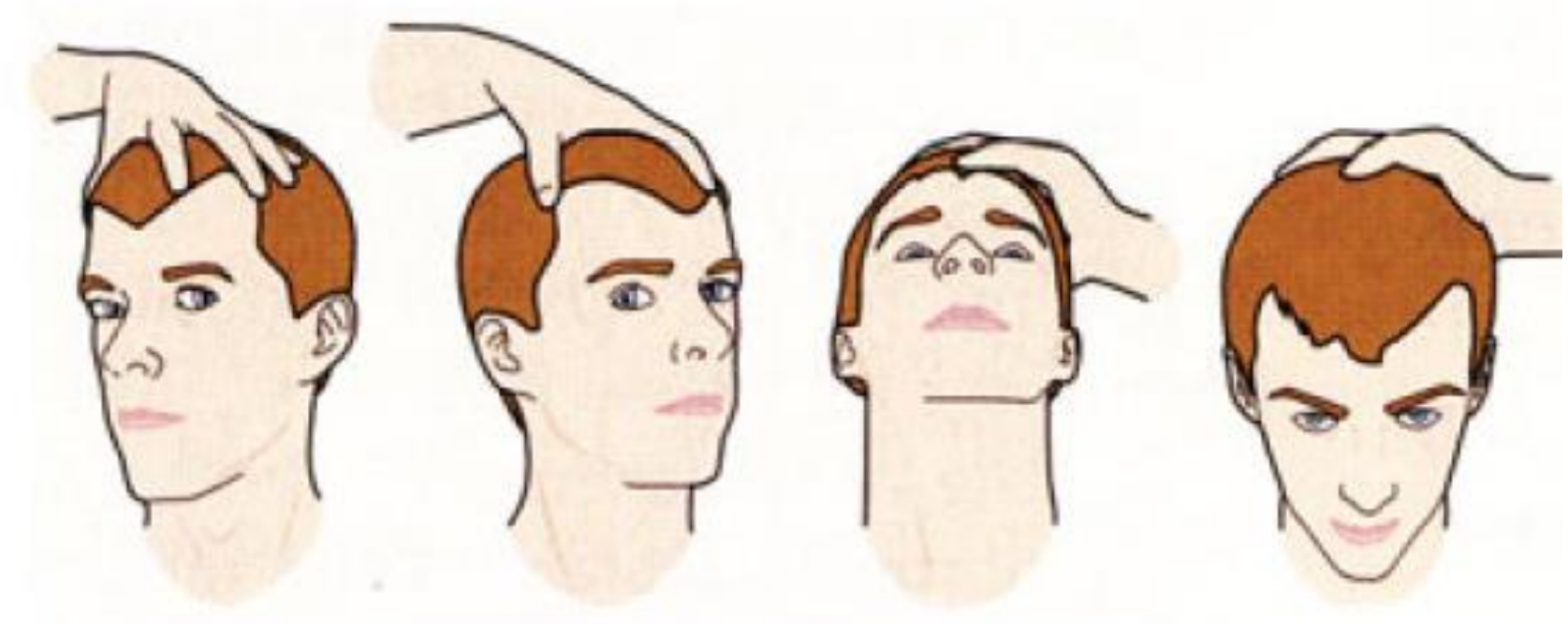
- often slight exophoria
- metabolic coma: often spontaneous roving movements
- conjugate lateral deviation
  * seizure (ictally: away from, postictally: towards lesion)
  * gaze paralysis (hemispheric: towards lesion
    pons: away from lesion)
- disconjugate: brain stem or III / VI nerve lesions
- skew deviation: brain stem
- *bobbing, dipping, ping/pong:* different localizations

neurological examination – brainstem reflexes

oculocephalic reflex

Oculocephalic responses

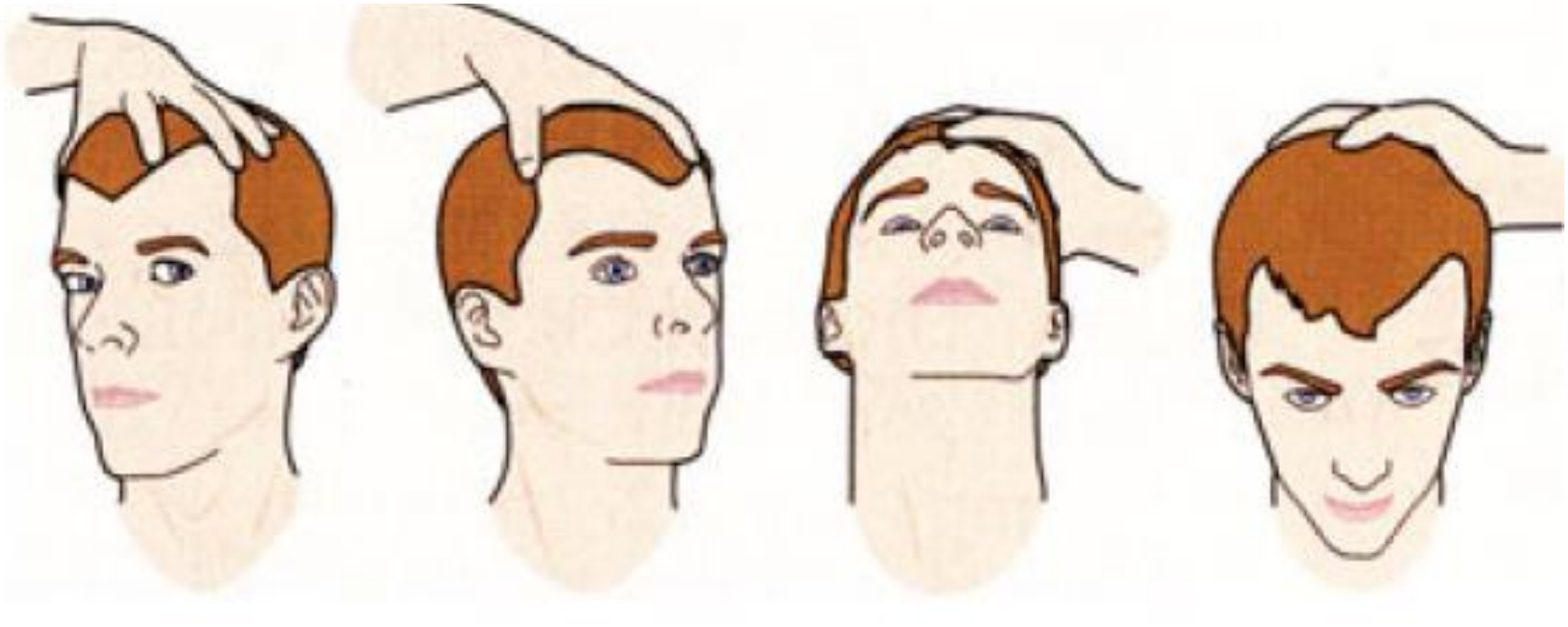
Turn right | Turn left | Tilt back | Tilt forward



normal

Oculocephalic responses

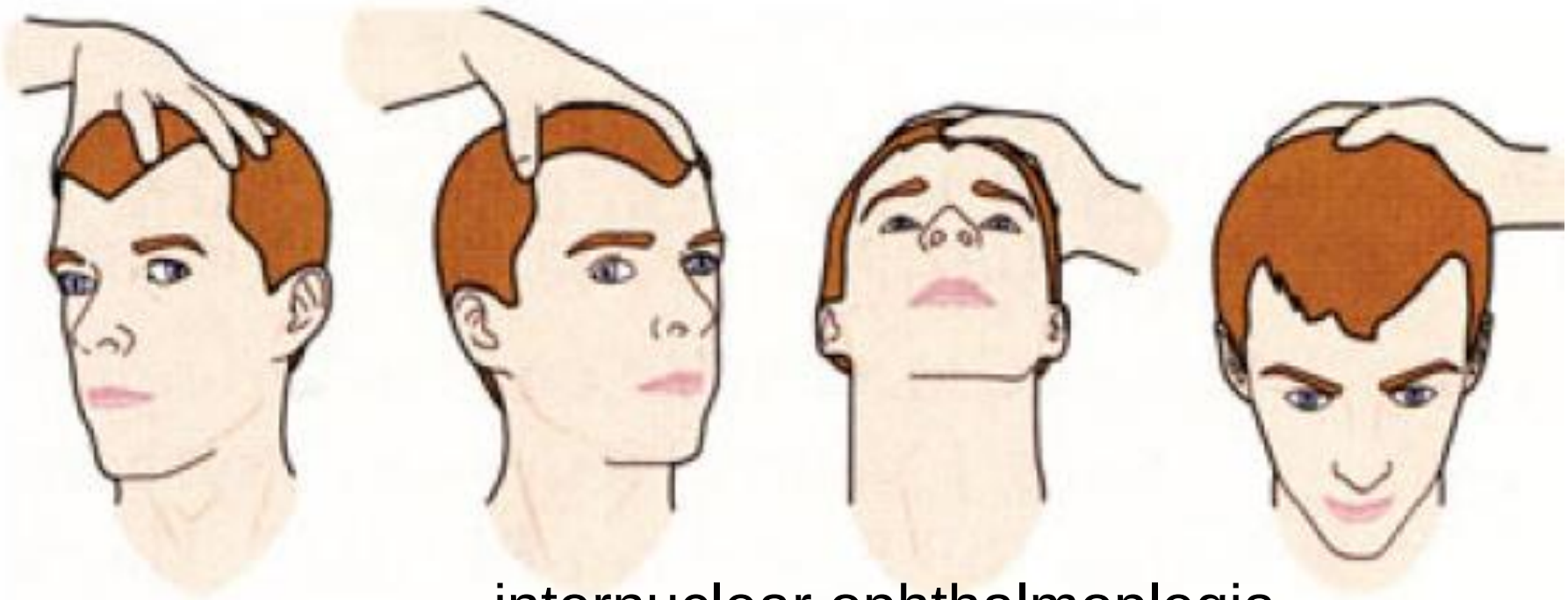
Turn right Turn left Tilt back Tilt forward –



right pontine lesion

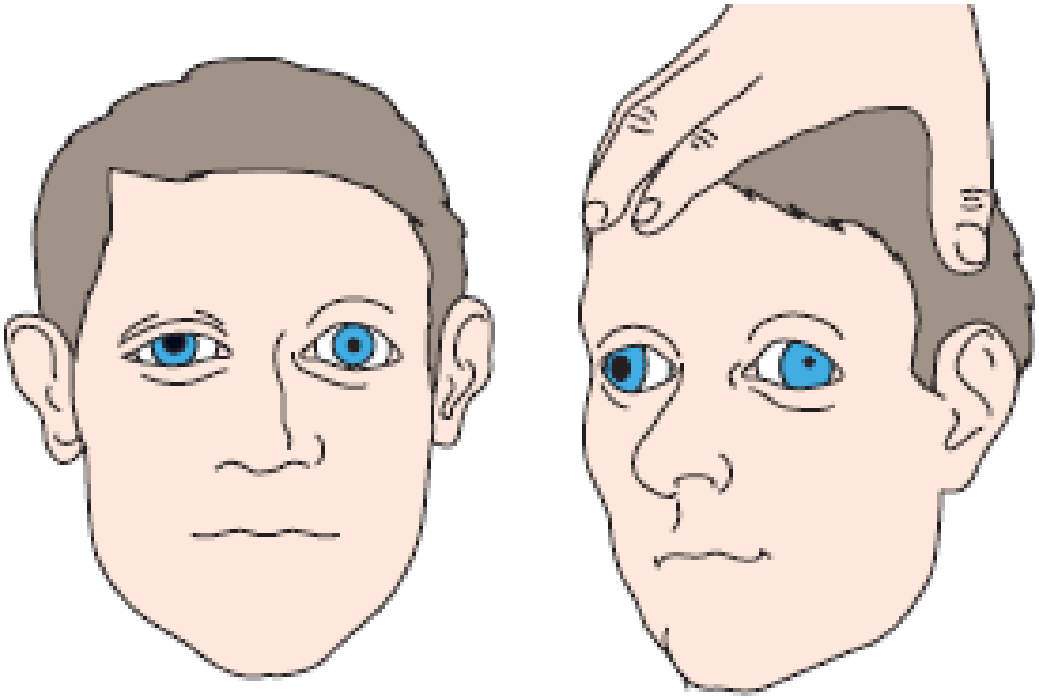
Oculocephalic responses

Turn right Turn left Tilt back Tilt forward



internuclear ophthalmoplegia

Oculocephalic responses



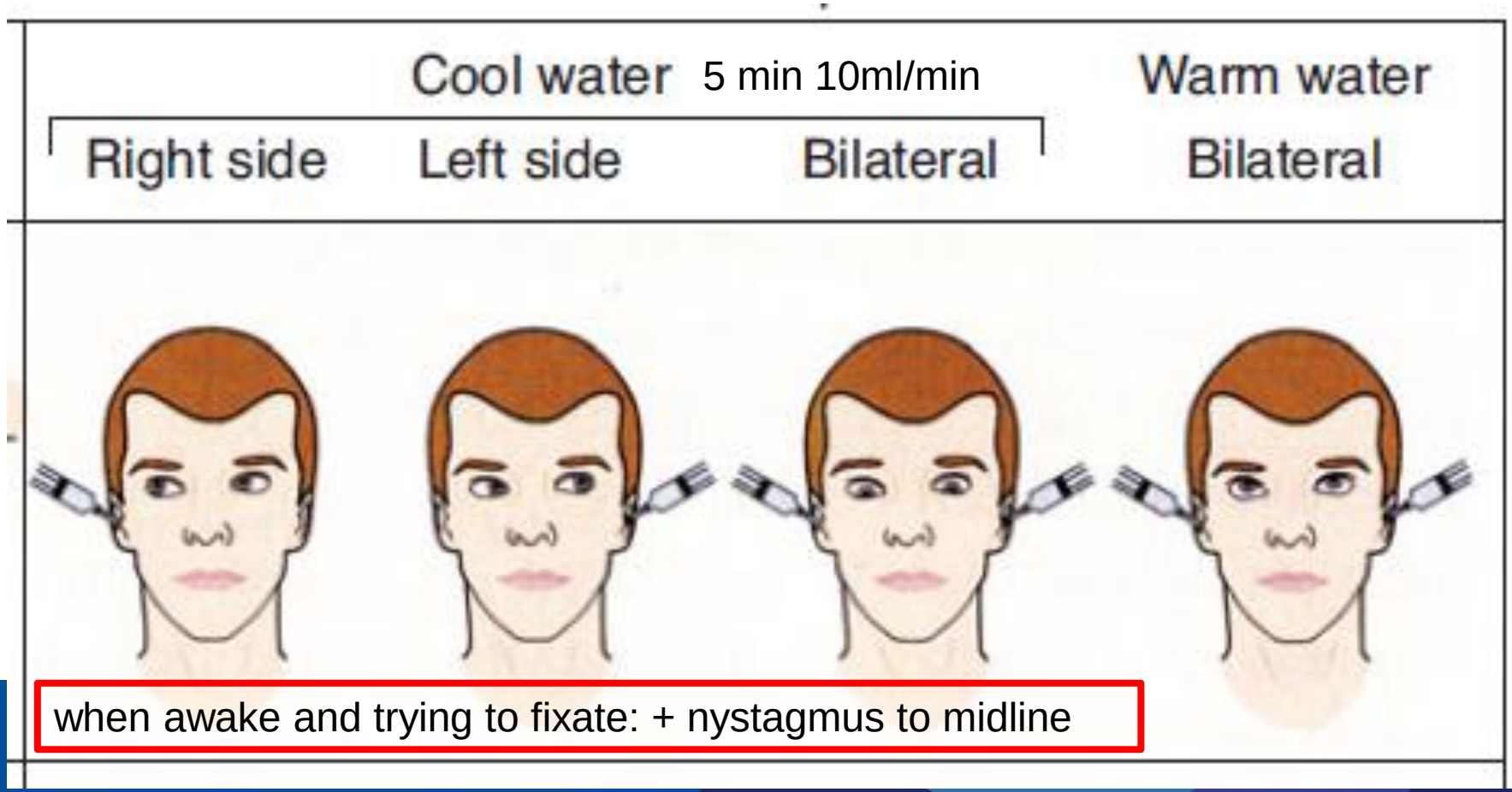
DOLL'S HEAD MANEUVER

right III nerve palsy

neurological examination – brainstem reflexes

caloric responses

in our center reserved for the examination of brain death



psychogenic unresponsiveness

disoriented to time, space and self, retain new information

lie with eyes closed

normal reflexes and ventilatory patterns

oculocephalic reflexes absent (due to visual fixation)

caloric testing: nystagmus away, no (little) tonic reaction

passive eye opening: upward deviation, active resistance

no slow roving eye movements

normal tone, no active resistance to passive movements

no motor reaction to pain, arm drop: avoids hitting the face

normal EEG

causes of coma in children

- Infection
  - CNS infection: meningitis, encephalitis, abscess
  - Systemic infection: sepsis
- Inflammation
  - Postinfectious/postimmunization: ADEM, AHLE, ANE, HSE, other
  - Antibody-related encephalitis: Anti-NMDAR, anti-VGKC, Hashimoto, other
  - CNS vasculitis: primary (PACNS) and secondary
  - Rheumatic disorder: SLE, HLH, MAS, other
- Stroke
  - Ischemia
  - Hemorrhage
- Sinovenous thrombosis
- Hypoxia-ischemia
  - Cardiac failure, cardiac arrest, shock
  - Respiratory failure
  - Near drowning, strangulation, smoke inhalation

causes of coma in children

Metabolic

- Diabetic ketoacidosis, hypoglycemia
- Electrolyte and fluid disturbances
- Endocrine disorder
- Hepatic encephalopathy
- Renal encephalopathy
- Inborn errors of metabolism: organic acidemias, amino acidemias, urea cycle defects, mitochondrial disease, fatty acid oxidation and carnitine defects, carbohydrate disorders, other
- Intoxication: accidental, deliberate, Münchhausen by proxy, medication adverse reaction

Neoplasia

- Infiltration, edema, mass effect, hydrocephalus, herniation

Epilepsy

- Epileptic seizure, status epilepticus, NCSE
- FIRES, other

Other

- Hypertensive encephalopathy, PRES, congenital malformation (hydrocephalus), dissociative (conversion) disorder

causes of coma – in general

requires dysfunction of:

Ascending (Reticular)
Arousal (or Activating)
System ([A]RAS)
upper brain stem
diencephalon

or
both hemispheres

structural lesions

compressive
destructive

diffuse/metabolic causes

structural causes of coma

both hemispheres

anox./isch., trauma, hydrocephalus, meningitis, SAH, ↑ICP, central herniation

one hemisphere – secundary brain stem/ARAS involvement

mass lesion, subfalcine or uncal herniation

posterior fossa – brainstem compression

mass lesion, tonsillar herniation

secundary hydrocephalus

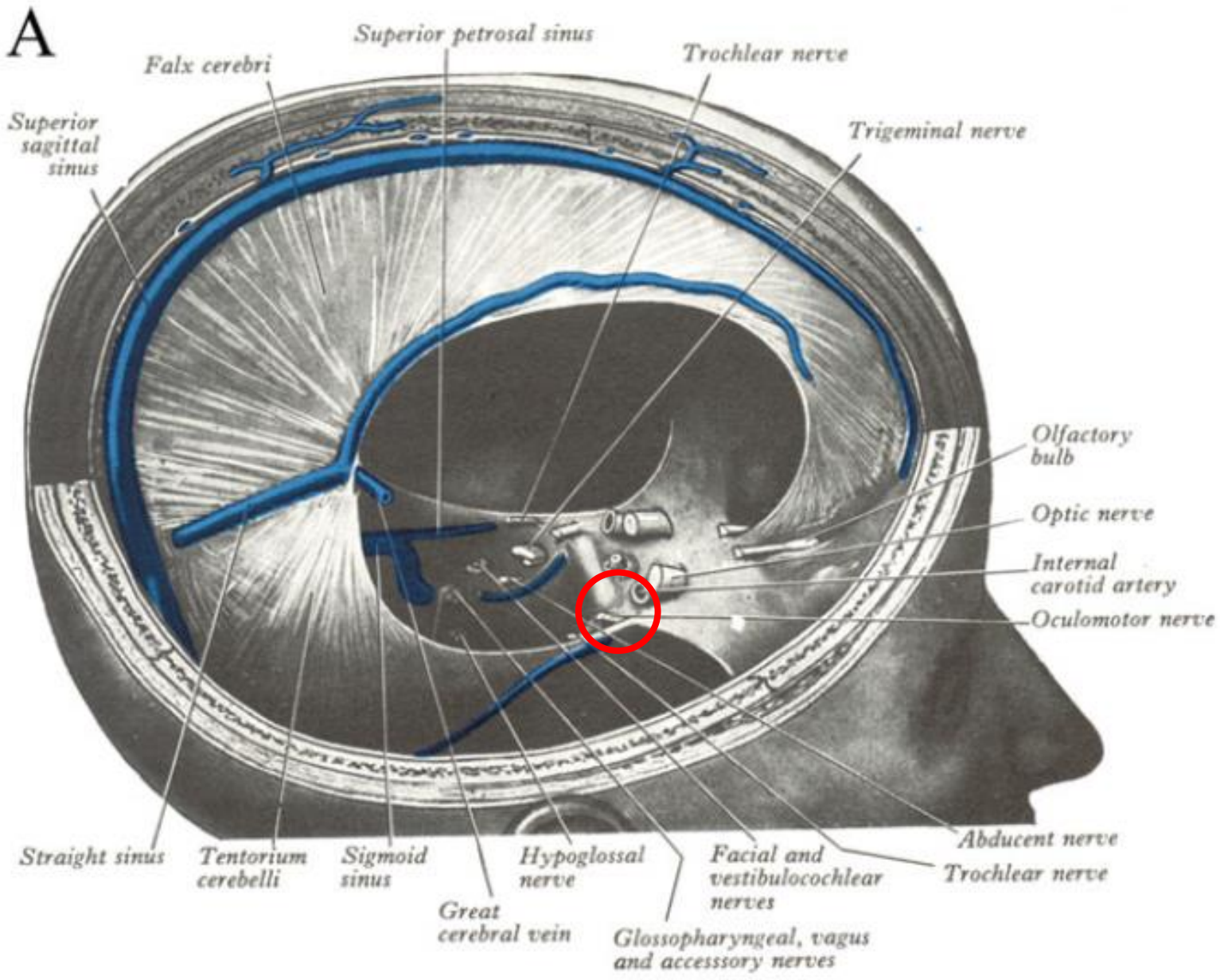
intrinsic brainstem lesion

space-occupying

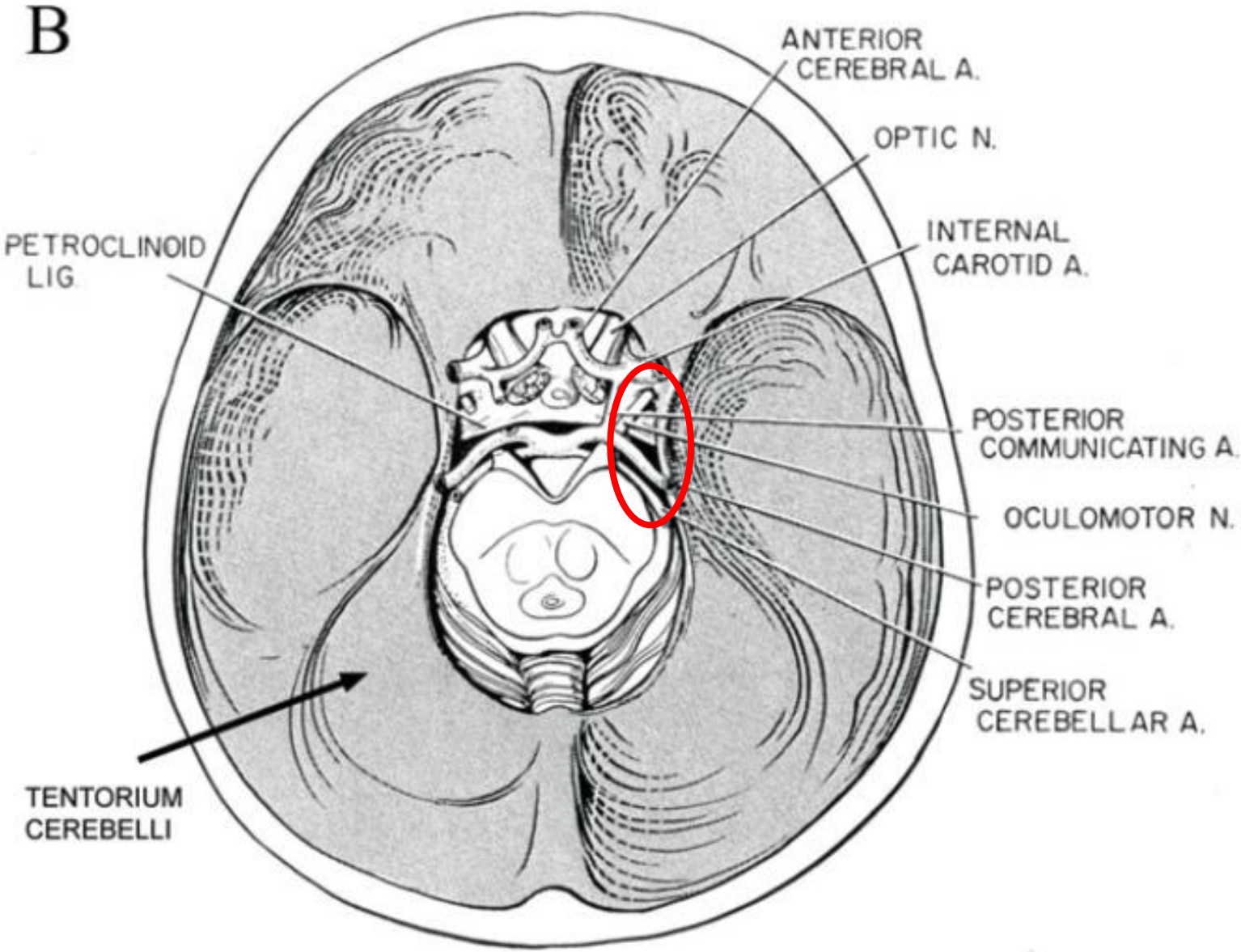
infarct, demyelination

focal signs !
brain stem signs !

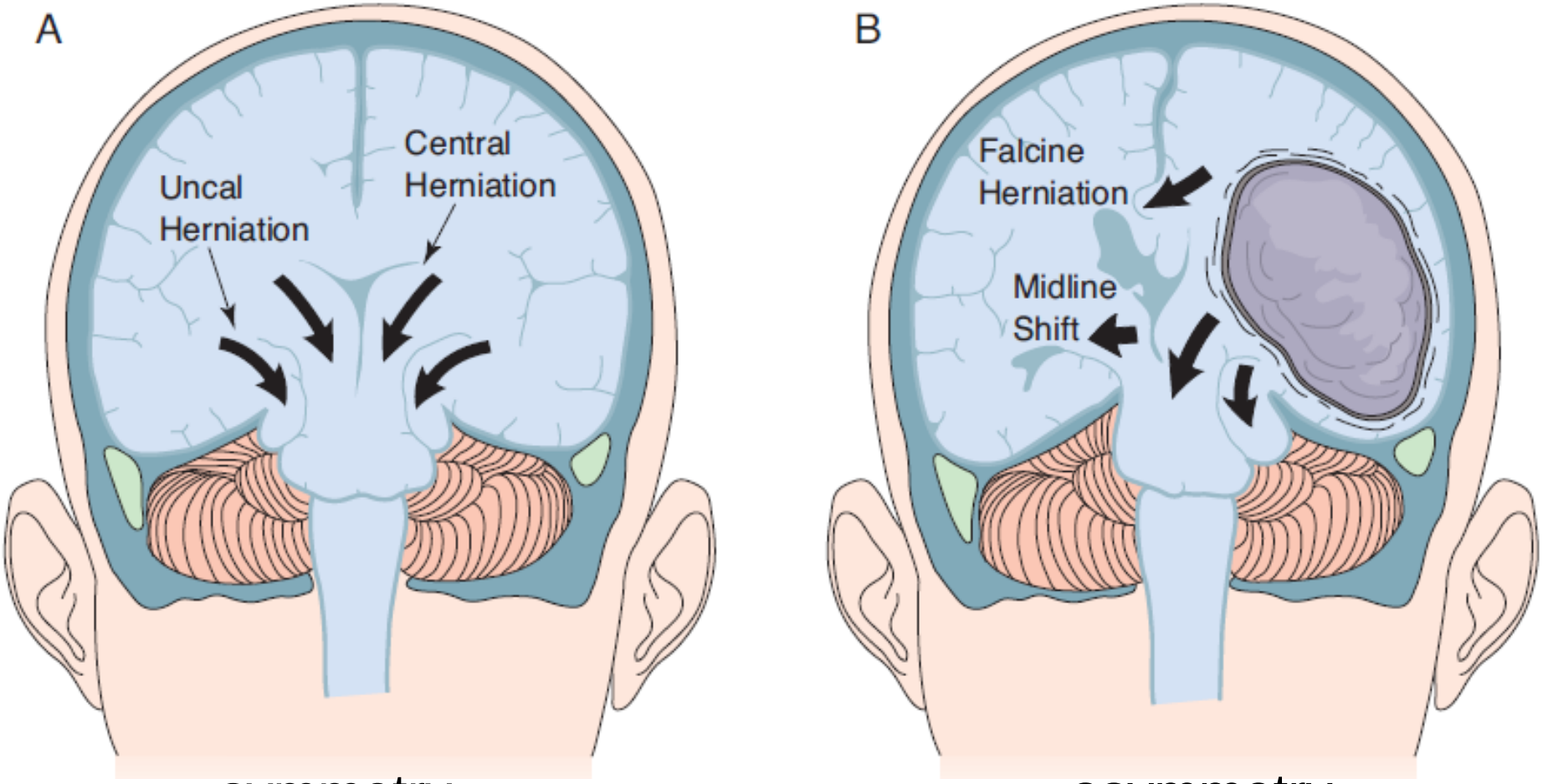
herniation syndromes – pressure gradient



herniation syndromes – pressure gradient



herniation syndromes



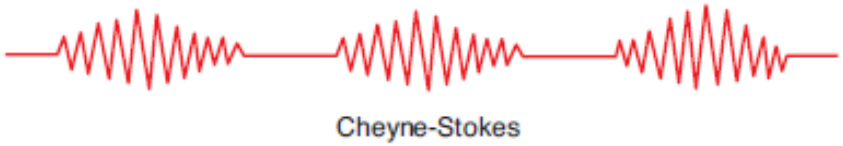
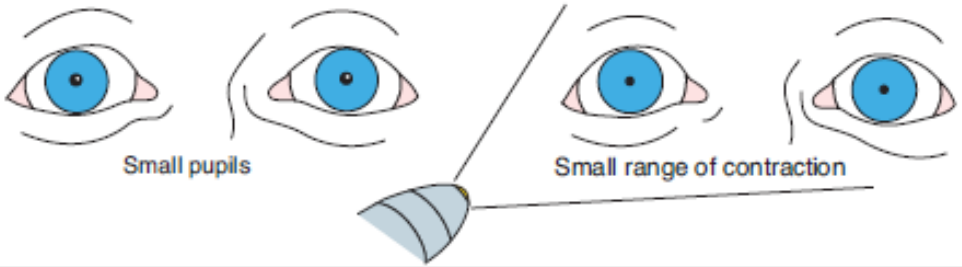
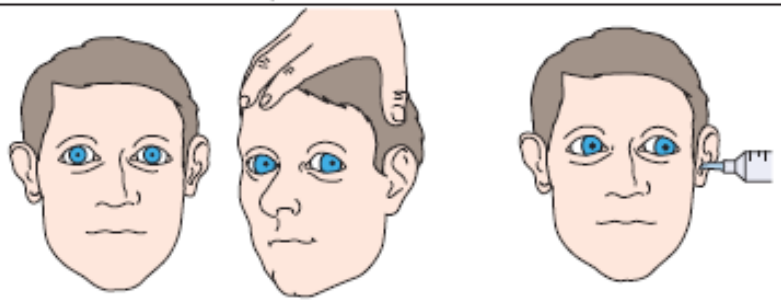
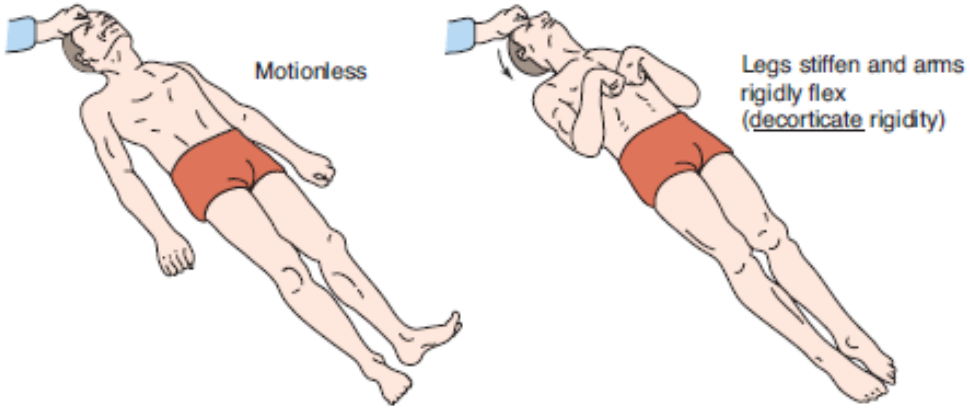
symmetry

asymmetry

herniation syndromes

	Physical findings
Subfalcine	Progressive decrease in level of consciousness, generally in patients with hemispheric deficits (eg, hemiparesis, ipsilateral forced gaze deviation)
Central	Fixed midposition pupils and variable motor responses Pontine reflexes usually remain intact
Uncal transtentorial	Ipsilateral dilated pupil followed by contralateral paresis. Decreased consciousness due to thalamic pressure. Later, the contralateral pupil is affected
Brainstem compression from infratentorial lesion	Bilateral miosis and loss of corneal and oculocephalic reflexes
Tonsillar	Respiratory arrest with loss of medullary function (cough reflex)

Edlow et al. Lancet 2014

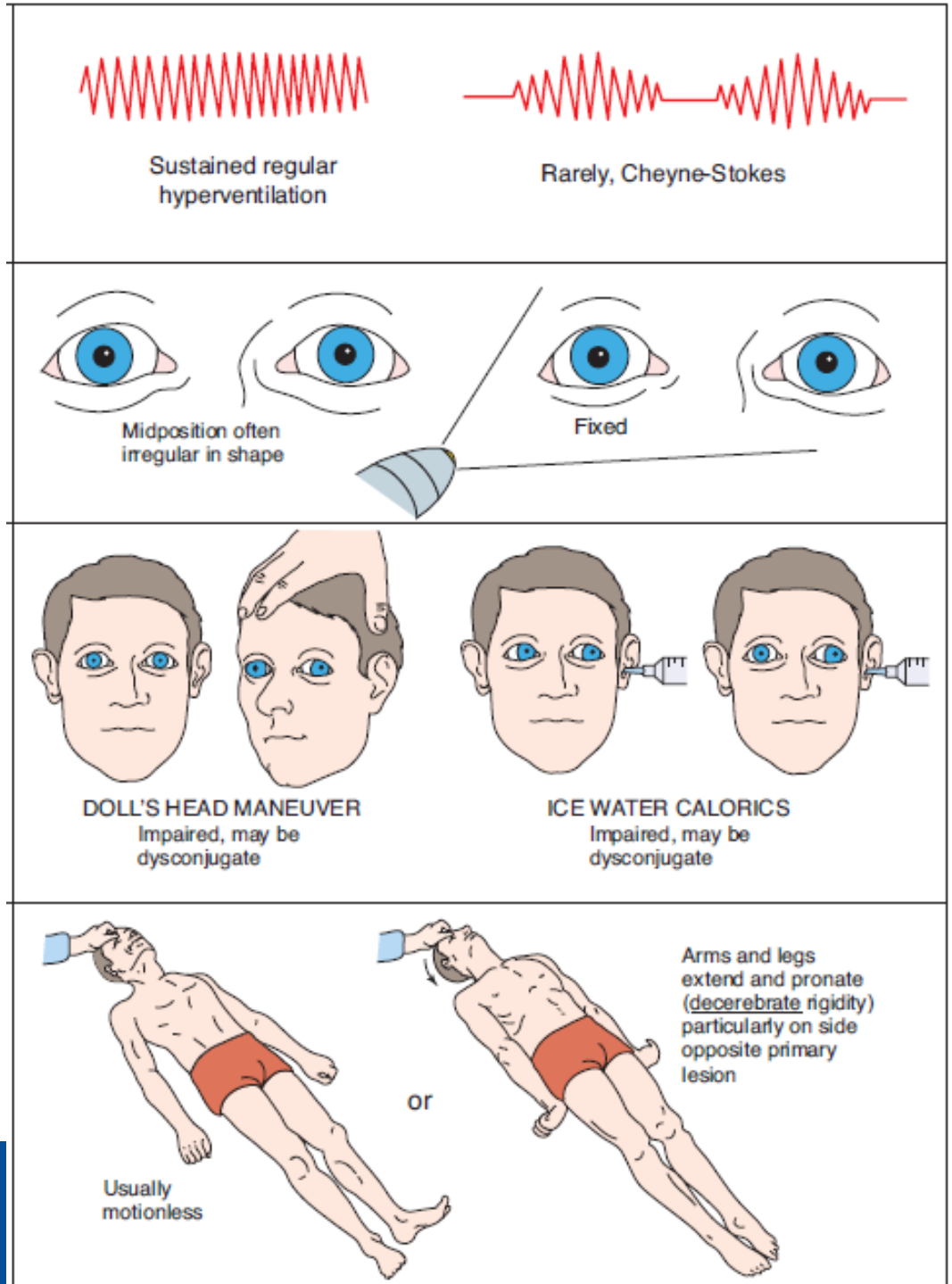
a. Respiratory pattern	 Cheyne-Stokes
b. Pupillary size and reactions	 Small pupils Small range of contraction
c. Oculocephalic and oculovestibular responses	 DOLL'S HEAD MANEUVER Same as Fig 3–11, but easier to obtain (absent nystagmus) ICE WATER CALORICS Same as Fig. 3–11 but easier to obtain (absent nystagmus)
d. Motor responses at rest and to stimulation	 Motionless Legs stiffen and arms rigidly flex (decorticate rigidity)

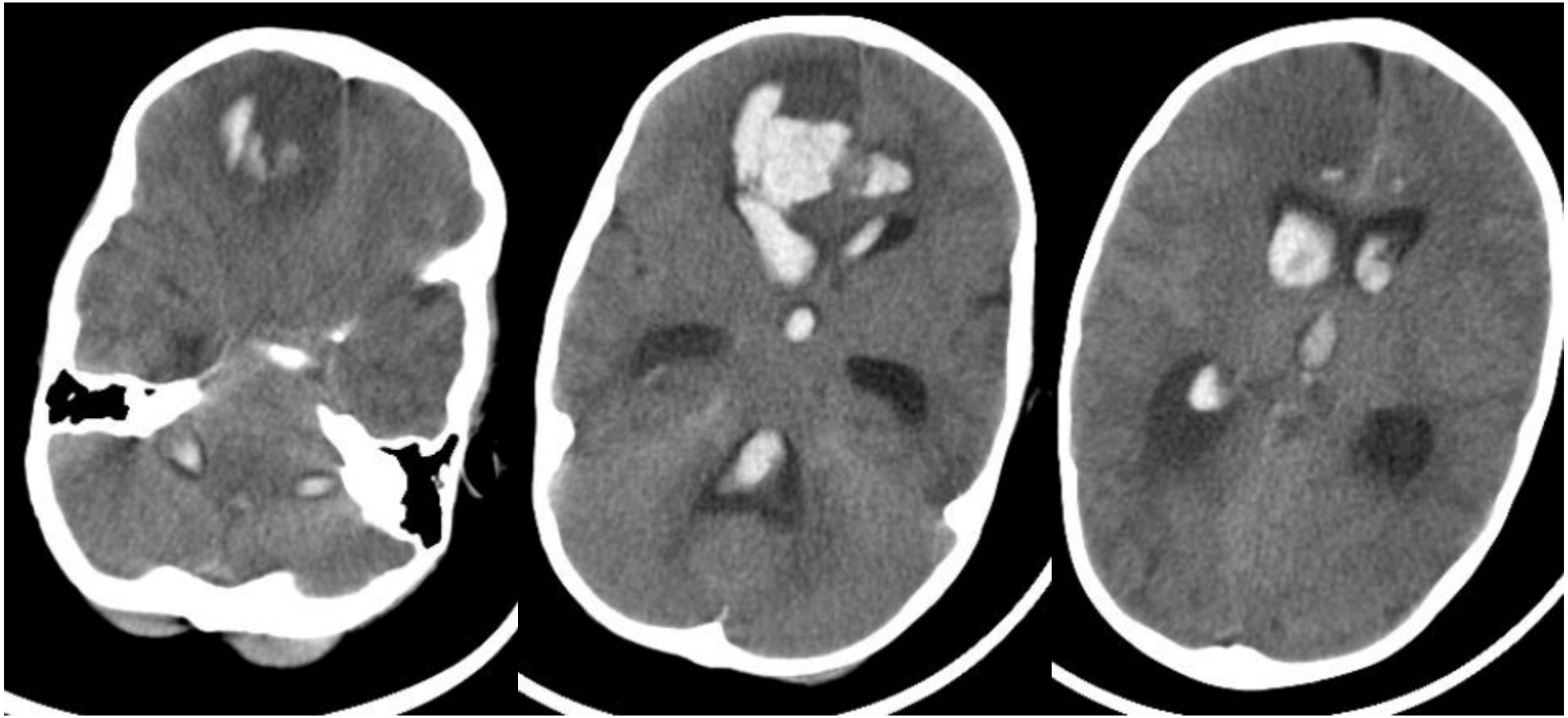
central transtentorial herniation

diencephalic state

central transtentorial herniation

midbrain-pons stage



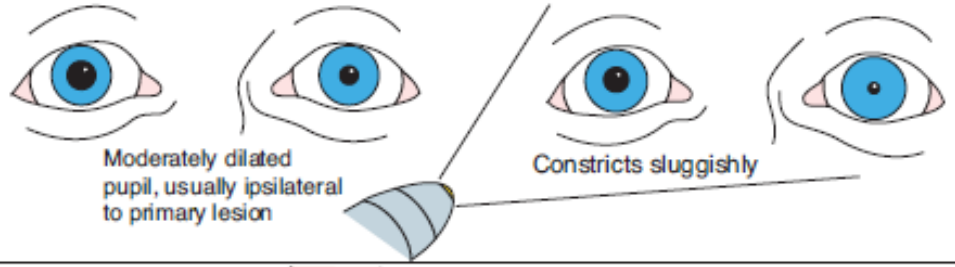
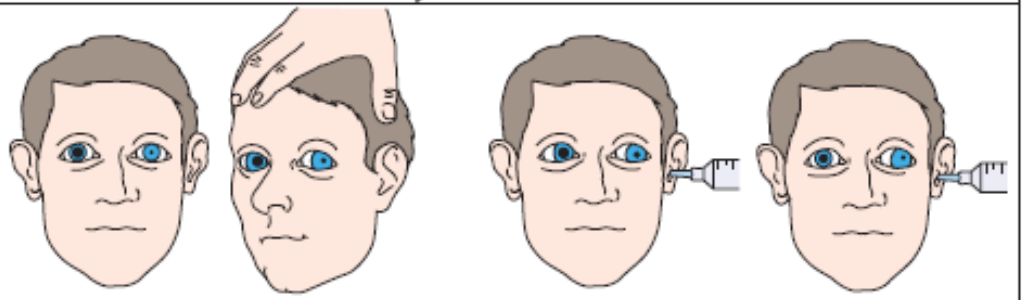
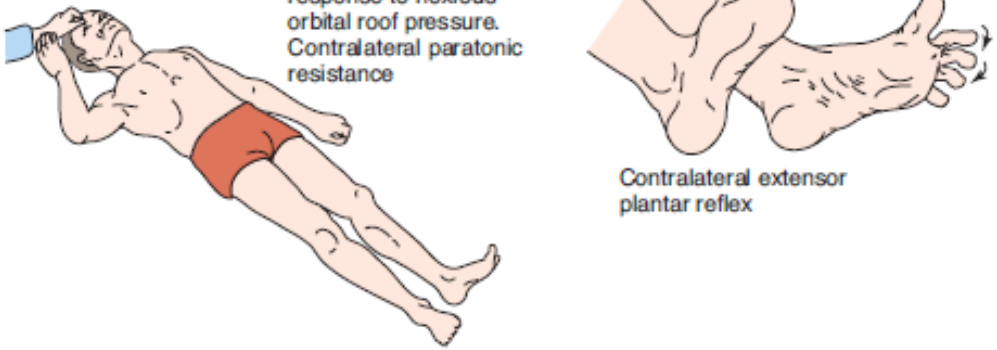


3 year old boy

E1M3V2, small reactive pupils

CR +/+ OCR +/+, posture: flexion arms/hands, extended legs, bilateral Babinski sign

diencephalic stage, central transtentorial herniation

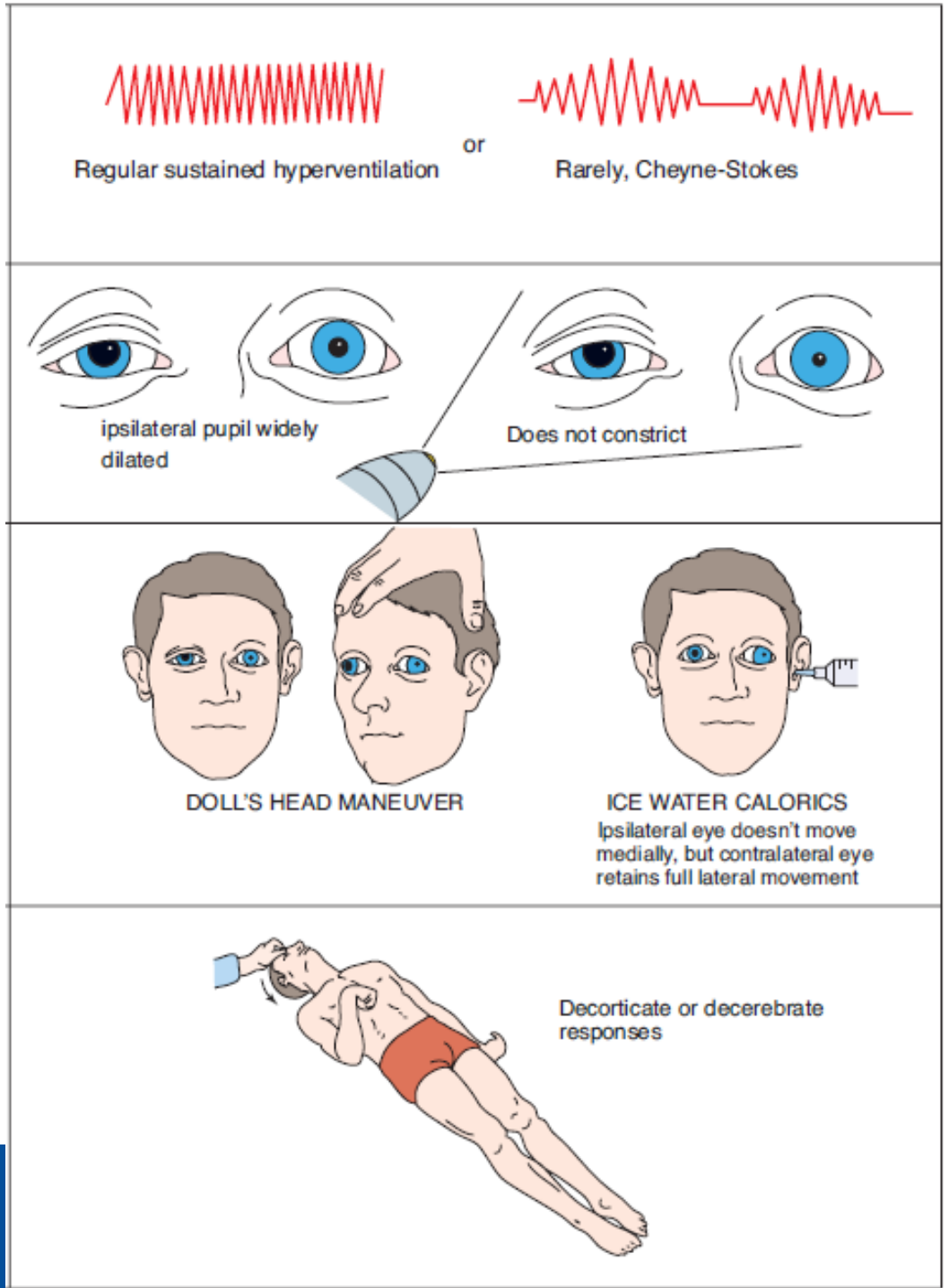
a. Respiratory pattern	 Eupneic
b. Pupillary size and reactions	 Moderately dilated pupil, usually ipsilateral to primary lesion. Constricts sluggishly
c. Oculocephalic and oculovestibular responses	 DOLL'S HEAD MANEUVER: Present or dysconjugate. ICE WATER CALORICS: Full conjugate slow ipsilateral eye movement (impaired nystagmus) or Dysconjugate, because contralateral eye does not move medially
d. Motor responses at rest and to stimulation	 Appropriate motor response to noxious orbital roof pressure. Contralateral paratonic resistance. Contralateral extensor plantar reflex

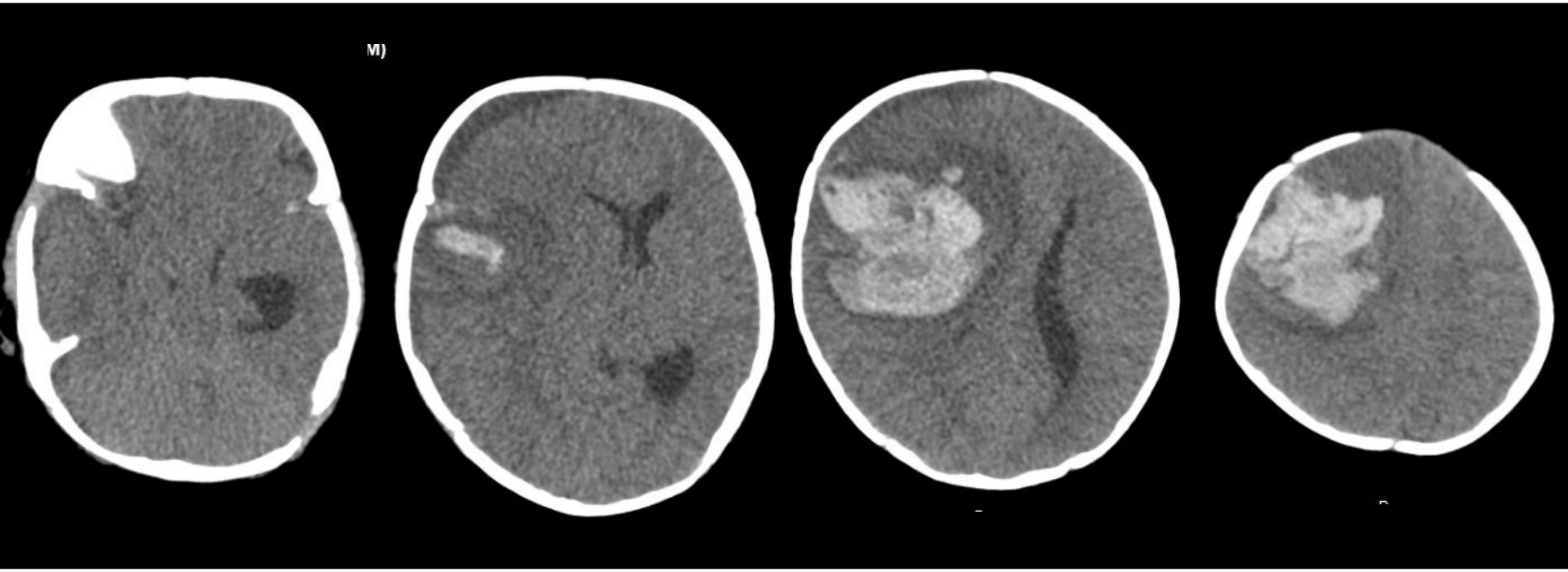
uncal herniation

early III nerve stage

uncal herniation

late III nerve stage





4 months old boy

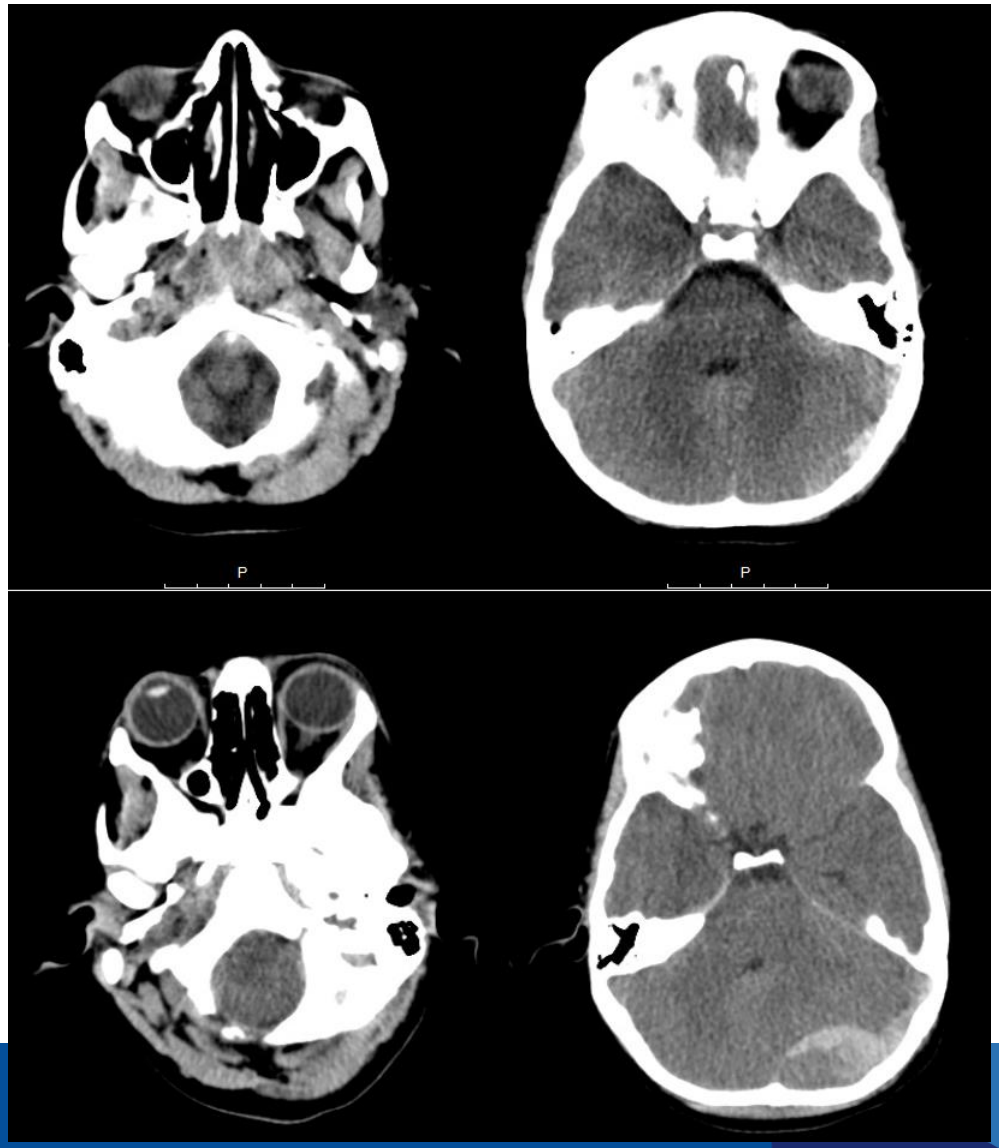
vomited, became drowsy, opisthotonus

E1M4V1

dilated non-reactive R pupil

R: withdraws, L: extends

tonsillar herniation



after 2 days:

diffuse/metabolic causes of coma

II. Systemic derangements causing coma
- Toxic
  - Medication overdose/adverse effects (opioids, benzodiazepines, barbiturates, tricyclics, neuroleptics, aspiri
    acetaminophen, anticonvulsants)
  - Drugs of abuse (opioids, alcohol, methanol, ethylene glycol, amphetamines, cocaine)
  - Exposures (carbon monoxide, heavy metals)
- Metabolic
  - Systemic inflammatory response syndrome-sepsis
  - Hypoxia; hypercapnia
  - Hypothermia
  - Hypoglycemia; hyperglycemic crises (diabetic ketoacidosis, nonketotic hyperosmolar hyperglycemic state)
  - Hyponatremia, hypernatremia
  - Hypercalcemia
  - Hepatic failure
  - Renal failure
  - Wernicke's encephalopathy
- Endocrine
  - Panhypopituitarism
  - Adrenal insufficiency
  - Hypothyroidism; hyperthyroidism

Stevens et al. Crit Care Med 2006

diffuse/metabolic causes of coma

II. Systemic derangeme
Toxic
Medication overdos
acetaminophen,
Drugs of abuse (op
Exposures (carbon
Metabolic
Systemic inflamma
Hypoxia; hypercapn
Hypothermia
Hypoglycemia; hyperglycemic crises (diabetic ketoacidosis, nonketotic hyperosmolar hyperglycemic state)
Hyponatremia, hyp
Hypercalcemia
Hepatic failure
Renal failure
Wernicke's encepha
Endocrine
Panhypopituitarism
Adrenal insufficien
Hypothyroidism; h

+

nonconvulsive generalized status epilepticus
immune-mediated syndromes (NMDA, Hashimoto)
inborn errors of metabolism
genetic causes (FHM)

false localizing signs may occur in metabolic coma

non-reactive pupils
focal deficits in hypoglycaemic coma
bilateral Babinski's sign
symmetrical posturing

Stevens et al. Crit Care Med 2006

ancillary investigations in coma

blood glucose, electrolytes, urea, ammonia, lactate

arterial blood gases

blood cultures

metabolic screen

tox screen

CT

lumbar puncture

EEG

MRI, CTV, MRV, MRA

specific investigations: endocrine, auto-immune antibodies

DNA, cultures, PCR

sequence of investigations

glucose, electrolytes, urea, ammonia, lactate, blood gas

urgent CT

lumbar puncture, blood cultures (meningitis suspected: treat!)

toxicology screen

EEG (NCSE? focal / metabolic causes?)

metabolic screen

MRI/MRA (brain stem signs: posterior circulation AIS? pont. myel.? ADEM?)

MRV/CTV (signs of high ICP: sinovenous thrombosis?)

auto-immune antibodies, genes.....

diagnostic approach – summary

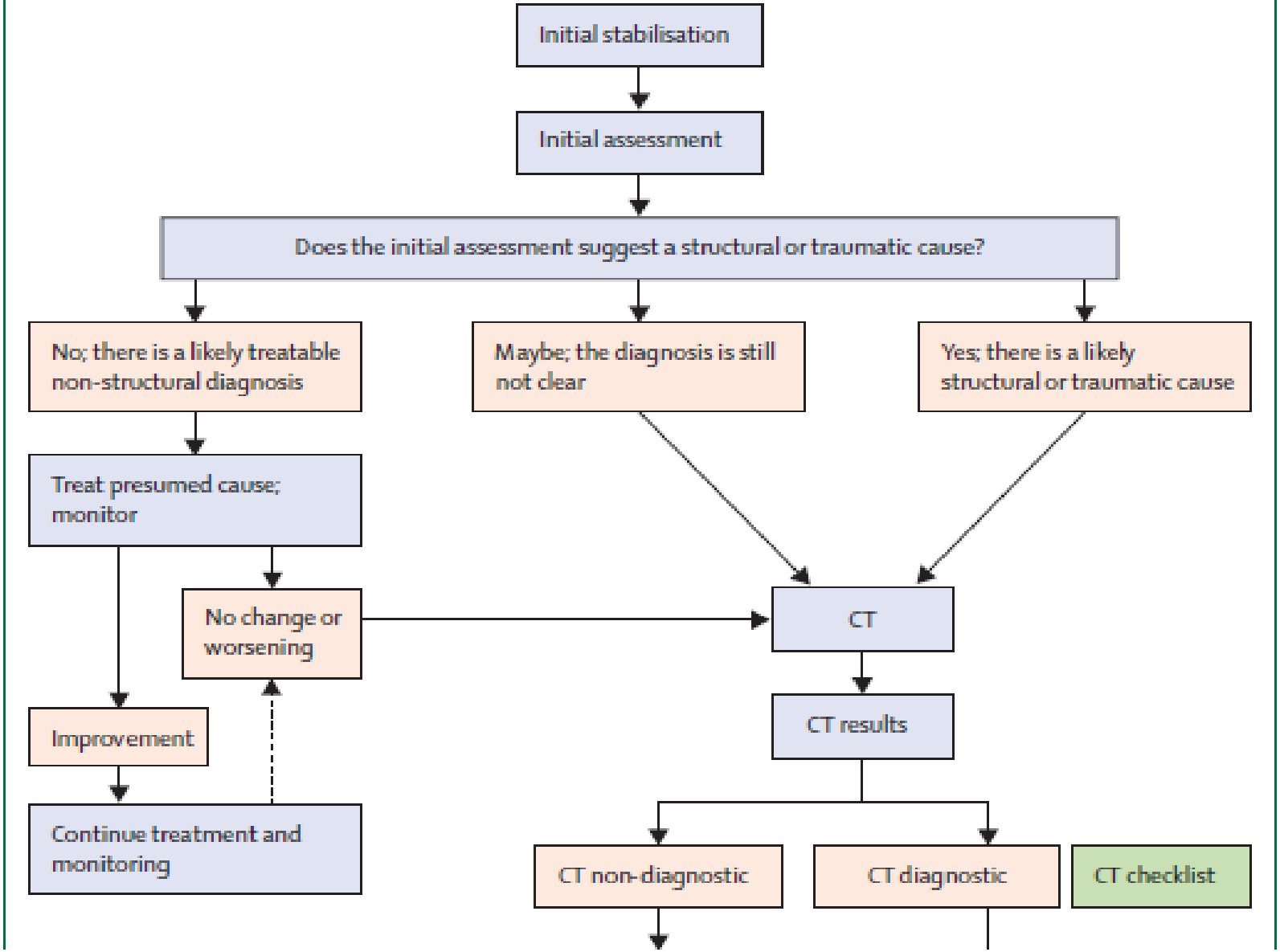
is the patient in a coma?

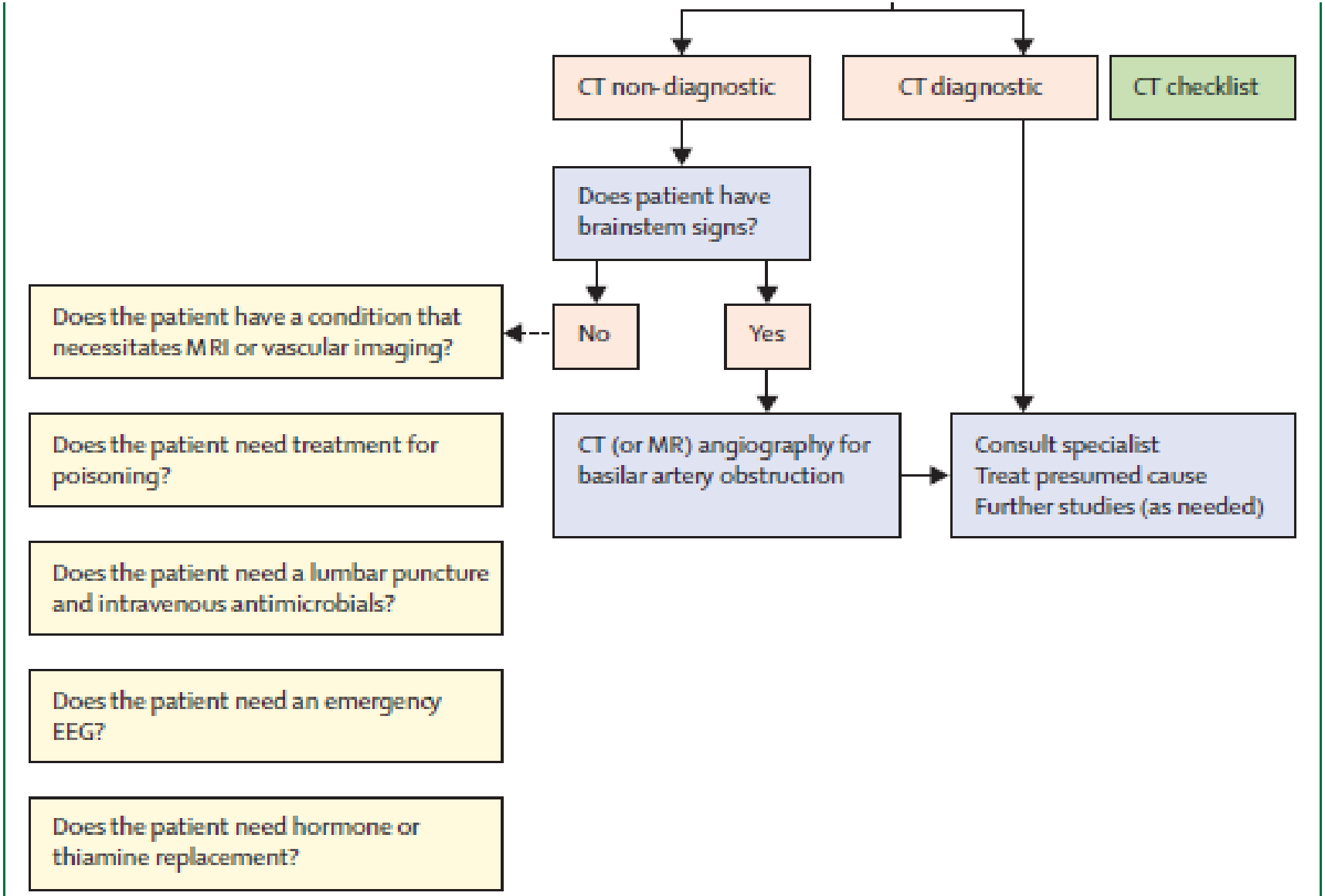
- GCS (exclude aphasia/anarthria/tetraplegia)
- coma mimic (vegetative or minimally conscious state)
- psychogenic unresponsiveness

structural cause?

- bilateral or focal
- sequence of events – herniation?
- focal signs / brain stem signs

diffuse or metabolic cause?


Initial stabilisation
Initial assessment
Does the initial assessment suggest a structural or traumatic cause?
No; there is a likely treatable non-structural diagnosis
Maybe; the diagnosis is still not clear
Yes; there is a likely structural or traumatic cause
Treat presumed cause; monitor
No change or worsening
CT
Improvement
CT results
Continue treatment and monitoring
CT non-diagnostic
CT diagnostic
CT checklist



Edlow et al. Lancet 2014

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