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# NEUROLOGICAL ASSESSMENT OF COMA

David E Bateman

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**T**he neurologist is often required to evaluate the unconscious patient from both the diagnostic and prognostic perspective. Knowledge of the anatomical basis of coma is essential for competent evaluation but must be combined with an understanding of the many, often multi-factorial, medical conditions that result in impaired consciousness.

Consciousness is a state of awareness of self and the environment. This state is determined by two separate functions:

- ▶ awareness (content of consciousness)
- ▶ arousal (level of consciousness).

These are dependant upon separate physiological and anatomical systems. Coma is caused by disordered arousal rather than impairment of the content of consciousness, this being the sum of cognitive and affective mental function, dependent on an intact cerebral cortex. The absence of all content of consciousness is the basis for the vegetative state.

Arousal depends on an intact ascending reticular activating system and connections with diencephalic structures. Like awareness, arousal is not an all or nothing concept and gradations in awareness have been described in the past as inattentiveness, stupor, and obtundation. Such terms lack precision and coma can be more objectively assessed using measures such as the Glasgow coma scale (GCS) (table 1). This analyses three markers of consciousness—eye opening, and motor and verbal responses—bringing a degree of accuracy to evaluation.

The GCS arbitrarily defines coma as a failure to open eyes in response to verbal command (E2), perform no better than weak flexion (M4), and utter only unrecognisable sounds in response to pain (V2). The GCS is of no diagnostic value, but is a reliable way of objectively monitoring the clinical course of the patient with an acute cranial insult without elucidating cause.

## NEUROANATOMICAL BASIS OF COMA

Clinicopathological correlation and neurophysiological experimentation has shown that coma is caused by diffuse bilateral hemisphere damage, failure of the ascending reticular activating system, or both. The reticular activating system is a core of grey matter continuous caudally with the reticular intermediate grey lamina of the spinal cord and rostrally with the subthalamus, hypothalamus, and thalamic nuclei. It runs in the dorsal part of the brain stem in the paramedian tegmental zone.

A unilateral hemisphere lesion will not result in coma unless there is secondary brain stem compression, caused by herniation, compromising the ascending reticular activating system. Extensive bilateral damage or disturbance of the hemisphere function is required to produce coma. Bilateral thalamic and hypothalamic lesions also cause coma by interrupting activation of the cortex mediated through these structures. In hypothalamic lesions, phenomena associated with sleep, such as yawning, stretching, and sighing, are prominent. The speed of onset, site, and size of a brainstem lesion determine whether it results in coma, so brain stem infarction or haemorrhage often causes coma while other brain stem conditions such as multiple sclerosis or tumour rarely do so. Lesions below the level of the pons do not normally result in coma. Drugs and metabolic disease produce coma by a depression of both cortex and ascending reticular activating system function.

## CAUSES OF COMA BY ANATOMICAL SITE

The causes of coma by anatomical site are summarised in fig 1, and can be simply divided into:

- ▶ diffuse or extensive processes affecting the whole brain
- ▶ supratentorial mass lesions causing tentorial herniation with brain stem compression (associated with other neurological signs such as third nerve palsy and crossed hemiparesis)
- ▶ brain stem lesions—for example, compression from posterior fossa mass lesions such as cerebellar haemorrhage/infarction and disorders primarily affecting the brain stem (for example, basilar artery thrombosis).

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**Table 1** Glasgow coma scale. Adapted from Teasdale *et al*<sup>1</sup>

<b>Eye opening (E)</b>			
Nil	1		
Pain	2		
Verbal	3		
Spontaneous	4		
<b>Motor response (M)</b>		<b>Verbal response (V)</b>	
Nil	1	Nil	1
Abnormal extension	2	Incomprehensible	2
Abnormal flexion	3	Inappropriate	3
Weak flexion	4	Confused	4
Localising	5	Oriented fully	5
Obeys commands	6		

When assessing record best motor and verbal response  
 Record as E4; M6; V5 =15 (top line)  
 Tracheostomy/ET tube/facial injuries invalidate V  
 Patients are considered in coma with a GCS of E2; M4; V2 or less

ET, endotracheal tube; GCS, Glasgow coma score.

When evaluating patients with medical causes for coma the neurologist should be aware of its many causes and various outcomes. In a large study of patients presenting with “medical coma” cerebrovascular disease accounted for 50%, hypoxic ischaemic injury 20%, and various metabolic and infective encephalopathies the remainder.<sup>2</sup>

### Assessment of coma

Coma is an acute, life threatening situation. Evaluation must be swift, comprehensive, and undertaken while urgent steps are taken to minimise further neurological damage.<sup>3</sup> Emergency management should include: resuscitation with support of cardiovascular and respiratory system; correction of immediate metabolic upset, notably control of blood glucose and thiamine if indicated; control of seizures and body temperature; any specific treatments—for example, naloxone for opiate overdose.

Assessment now should comprise:

- ▶ history—through friend, family or emergency medical personnel
- ▶ general physical examination
- ▶ neurological assessment—to define the nature of coma (table 2).

This article will address the approach to neurological assessment alone, though the trainee must remember that this should not be done in isolation from general evaluation.

The neurologist has to determine:

- ▶ where is the lesion responsible for coma?
- ▶ what is its nature?
- ▶ what is it doing?

Neurological diagnosis is based on history, thoughtful examination, and the appropriate choice of investigations. This is essential, as there is little point in performing a cranial computed tomographic (CT) scan in a patient in

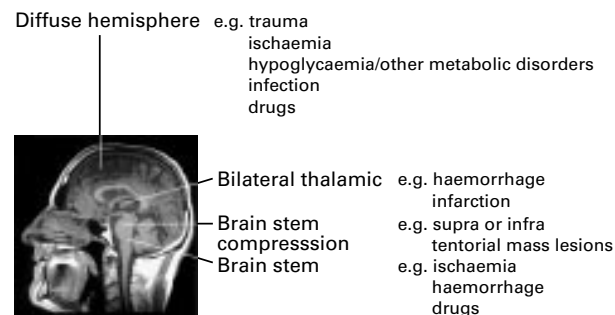


Figure 1 Sites and causes of coma

**Table 2** Clinical assessment of coma

#### General examination

Skin (for example, rash, anaemia, cyanosis, jaundice)  
 Temperature (fever-infection /hypothermia-drugs/circulatory failure)  
 Blood pressure (for example, septicaemia/Addison's disease)  
 Breath (for example, fetor hepaticus)  
 Cardiovascular (for example, arrhythmia)  
 Abdomen (for example, organomegaly)

#### Neurological (general)

Head, neck and eardrum (trauma)  
 Meningism (SAH/meningitis)  
 Fundoscopy

#### Level of consciousness

Glasgow coma scale  
 Verbal response  
 Eye opening  
 Motor response

#### Brain stem function

Pupillary responses  
 Spontaneous eye movements  
 Oculocephalic responses  
 Caloric responses  
 Corneal responses

#### Motor function

Motor response  
 Deep tendon reflexes  
 Muscle tone  
 Plantars

#### Respiratory pattern

Cheyne Stokes: hemisphere  
 Central neurogenic hyperventilation:  
 rapid/midbrain  
 Apneustic: Rapid with pauses/lower  
 pontine

SAH, subarachnoid haemorrhage.

hypoglycaemic coma where urgent correction of the metabolic disorder is paramount and any delay—for example, waiting for a scan—is unacceptable.

Understanding the pathophysiological basis for coma directs the neurological examination and properly determines the selection of neurological investigations. The approach to clinical evaluation is used to categorise coma into:

- ▶ Coma without focal signs or meningism. This is the most common form of coma and results from anoxic-ischaemic, metabolic, toxic, and drug induced insults, infections, and post ictal states.
- ▶ Coma without focal signs with meningism. This results from subarachnoid haemorrhage, meningitis, and meningoencephalitis.
- ▶ Coma with focal signs. This results from intracranial haemorrhage, infarction, tumour or abscess.

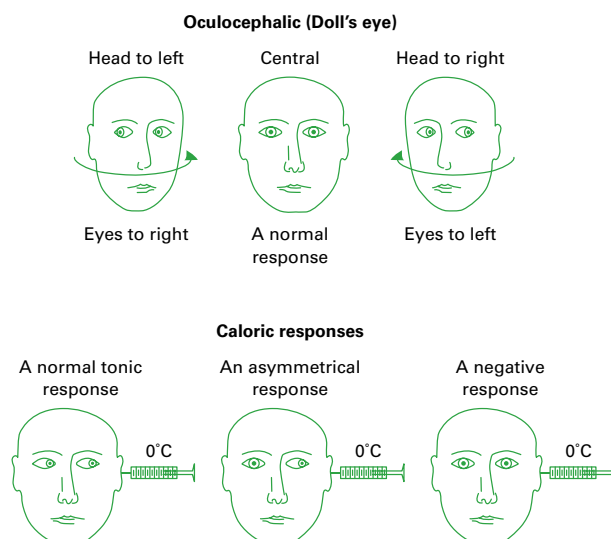
Monitoring the subsequent course of coma with serial GCS assessment and formal neurological examination is essential, especially in the case of mass lesions where management of raised intracranial pressure either pharmacologically or by surgery may be necessary.

Multifocal structural pathology, such as venous sinus thrombosis, bilateral subdural haematomas, vasculitis or meningitis, can present with coma without focal signs or meningism and so mimic toxic or metabolic pathologies. Conversely, any toxic/metabolic cause for coma may be associated with focal findings—for example, hypoglycaemic or hepatic encephalopathy. Also focal signs may be the consequence of pre-existing structural disease; in the septicaemic patient with a previous lacunar infarct, for example, the focal neurology may be mistakenly accepted as signs of the current illness.

The adjacent box summarises the salient relevant signs in relation to localisation and diagnosis.

### Neurological examination: specific features

The stimulus and response used in examination should be specified in the notes. Voice, visual menace, and painful stimuli are used to arouse the patient. All patients should be asked to open their eyes and look up, down, and from side to side. Patients with a “locked-in” syndrome will be able to open their eyes and look up and down, but are unable to make any other purposeful response. Painful stimuli should

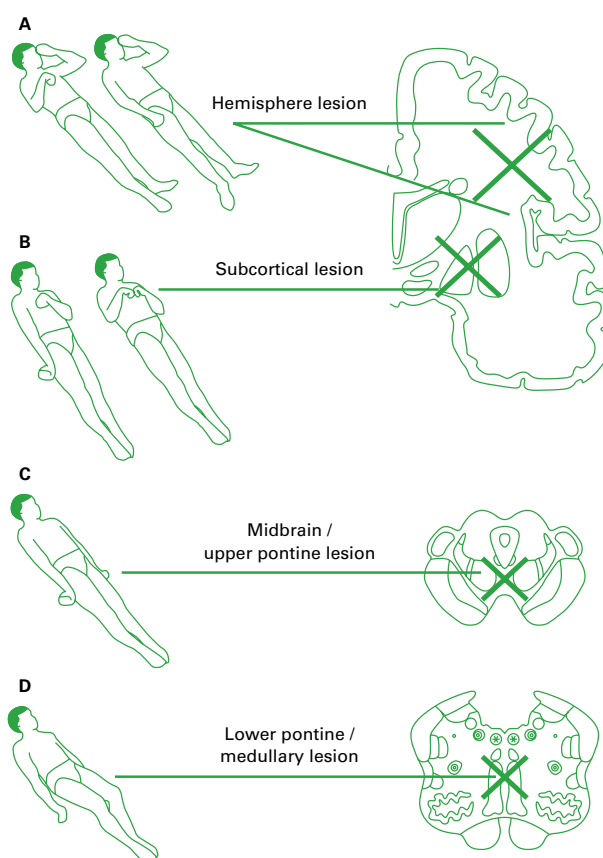


**Figure 2** Oculocephalic and caloric response. Oculocephalic (doll's eyes) response: move head passively and observe motion of the eyes. The eyes should move conjugately in the direction opposite to the movement. An abnormal response (absent or asymmetric) implies brain stem disease. Do not perform when neck instability is suspected. Caloric response: if doll's eye movements are absent proceed to calorics. Ice cold water applied to the tympanic membrane normally elicits a slow conjugate deviation to the irrigated side. Absence indicates brain stem disease. Caloric testing is more sensitive than the oculocephalic response. Check the tympanic membrane is intact before testing.

be administered without injury. This is done by pressure over the notch of the supraorbital nerve to induce a facial grimace, which will be present in the absence of limb responses with afferent peripheral lesions affecting the pain pathways. Limb response can also be assessed by pressing down on the nail bed with a tendon hammer or pinching the Achilles tendon. Asymmetry of response should be looked for as should the nature of the response, since this helps localise the site of structural damage (fig 3).

#### Clinico-anatomical correlation in coma

- ▶ Bilateral hemisphere damage/dysfunction
  - symmetrical signs (tone and flexor or extensor response to pain)
  - may have fits or myoclonus
  - normal brain stem reflexes
  - normal oculocephalic response (OCR): normal calorics (fig 2)
  - normal pupils
- ▶ Supratentorial mass lesion with secondary brain stem compression
  - ipsilateral third nerve palsy
  - contralateral hemiplegia
- ▶ Brain stem lesion
  - early eye movement disorder: abnormal OCR or calorics
  - asymmetrical motor responses
- ▶ Toxic/metabolic
  - normal pupils: single most important criterion (except opiate poisoning)
  - ocular motility: rove randomly in mild coma and come to rest in primary position with deepening coma
  - absent OCR and calorics
  - decorticate and decerebrate rigidity or flaccidity
  - multifocal myoclonus



**Figure 3** Motor response to pain. The symmetry or asymmetry of the motor response can assist localisation. (A) Left hemisphere lesion. The two figures illustrate localisation of pain with the left hand and flexion (left hand figure) or extension (right hand figure) on the right. (B) Subcortical: unilateral left sided lesion exerting a variable contralateral effect. The figures illustrate flexion to pain with the left hand with either extension (right hand figure) or flexion with the right and hyperextension in both lower limbs. (C) Midbrain upper pontine: a bilateral upper and lower limb extension response. (D) Lower pontine/medullary: a bilateral extensor upper limb posture with either flaccidity or minimal diminished flexor response in lower limbs.

#### Pupillary responses

Assuming the visual pathways to the lateral geniculate body are intact, assessment of the pupillary responses is important in localising the site of coma and separating structural from toxic/metabolic causes, as pupillary responses in the latter are generally intact (fig 4). Lesions above the thalamus and below the pons preserve pupillary reactions. A third nerve lesion can be differentiated from a Horner's syndrome on the contralateral side, by the position of the eye and the degree of ptosis.

Proper assessment of the pupillary responses requires a bright light and if needed magnification that can be provided by using an otoscope. Preceding ocular injury impairs responses and relatives should be asked about this. Use of mydriatics can confuse matters by causing an asymmetrical response as the effect may wear off asymmetrically. Drugs such as atropine or dopamine that can be used in resuscitation from cardiac arrest have effects on pupillary reactions that may be misleading.<sup>4</sup>

#### Ocular motility

Centres for eye movement control are adjacent to the brain stem areas responsible for arousal; thus, evaluation is a valuable guide to the presence and level of brain stem disease

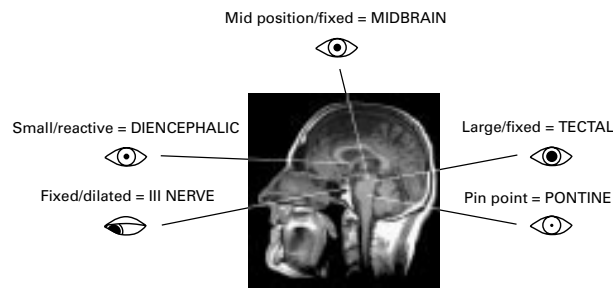


Figure 4 Pupillary findings in comatose patients

causing coma. Ocular pathways run from the mid brain to the pons, thus normal reflex eye movements imply that the pontomedullary junction to the level of the ocular motor nucleus in the mid brain is intact. In addition the oculomotor nerve is susceptible to compression in tentorial herniation.

The following observations should be made:

- ▶ resting position
- ▶ spontaneous eye movements
- ▶ on lifting the lids and releasing them, observe tone and closure
- ▶ if blinking is present, either spontaneously or to bright light, sound or menace, this implies an intact pontine reticular formation
- ▶ when carrying out corneal reflexes, observe the movement of the eyelid and globe of the eye; with an intact pons eye closure will occur and with integrity of both pons and mid-brain, Bell's phenomenon will be present.
- ▶ reflex eye movements should be performed (fig 2).

### Eye deviation

This can be conjugate or disconjugate. Lateral deviation of the eyes is commonly caused by a lesion in the ipsilateral frontal eye fields, but can result from lesions anywhere in the pathway from frontal eye fields to the parapontine reticular formation (PPRF). Disconjugate eye movements imply sixth or third nerve or intrinsic brainstem lesions. Downward deviation of the eyes below the horizontal meridian is a sign of poor localising value, occurring in brain stem, bilateral thalamic, and subthalamic lesions and can occur in some metabolic encephalopathies. Upward deviation is also a poor localising sign being described both in sleep and seizures as well as with brain stem lesions. Skew deviation occurs with posterior fossa lesions.

#### Case history 1

A 63 year old man is admitted for carcinoma of the colon. He has a history of high alcohol intake. The day after admission he has a tonic-clonic seizure and is treated with thiamine and chlordiazepoxide. Surgery is performed the next day. Because of poor conditions post surgery, he is admitted to the intensive therapy unit and put on a ventilator for two days. As he is weaned and sedation reduced, he is thought to be in a coma and there is no limb response to pain. However, when you assess him there is a brief eye opening to verbal response. The eye movements are difficult to assess because of blepharospasm. He appears to have lateral but not vertical doll's eyes and normal pupils. The facial grimace is symmetrical. There is no voluntary jaw opening and a poor gag. Limb tone is normal with minimal response to painful stimuli, normal reflexes and flexor plantars.

- ▶ What is the cause of the patient's neurological condition?
- ▶ What investigations would you perform?

#### Case history 2

You are called to the HDU to see a 78 year old patient in a coma 24 hours after undergoing knee replacement surgery. There is a history of progressive memory failure and deterioration in other cognitive function over the past few years. Preoperatively the patient was taking digoxin and a diuretic. During the operation the patient's blood pressure dropped a little, but not substantially. She woke up after the operation, but her oxygen saturation was slightly reduced and she remained hypotensive. Her conscious level then deteriorated together with a rise in her pulse rate and a further fall in her blood pressure. The patient had a transfusion and may have had mild left ventricular failure. Since then her oxygen saturation has remained a little poor and she has been hypotensive. There has been no improvement in her conscious level. Examination now shows that the patient is apyrexial. There is no neck stiffness. The pupils and discs are normal. The doll's eye movements are normal in the vertical plain. On lateral gaze there is failure of abduction bilaterally. There is no facial grimace or corneal. She has a gag and is breathing normally. She has a flaccid triplegia. Her right leg is in plaster. The tendon reflexes are present, but not exaggerated. The left plantar is probably extensor. A CT scan is normal. The anaesthetist suggests that she has had a postoperative stroke.

- ▶ What is the problem with the patient?
- ▶ What further tests would you do?

Please email answers to: [david.bateman@ruh-bath.swest.nhs.uk](mailto:david.bateman@ruh-bath.swest.nhs.uk)

### Spontaneous eye movements

If purposeful eye movements are present in an otherwise unresponsive patient, states confused with coma such as locked-in syndrome, catatonia, and pseudo coma should be considered.

Roving eye movements are slow, conjugate, lateral, to and fro excursions. These occur when third nerve nuclei and connections are intact and often indicate a toxic, metabolic or alternatively bilateral hemisphere cause for coma.

Irritative or epileptic foci cause contralateral conjugate eye deviation. This can occur with or without other obvious manifestations of seizures, though sometimes these are simply subtle movements of eyelids, tongue, jaw or face. The presence of such an eye movement disorder should raise the possibility of some form of complex partial status that should be confirmed by EEG.

Ocular bobbing describes a rapid downward jerk of both eyes with slow return to the mid-position. This eye movement disorder is specific for acute pontine lesions.

### Motor examination

Resting position and spontaneous movements should be documented. If the eyes and head are deviated to the side opposite hemiparesis, this implies a hemisphere lesion whereas deviation to the side of hemiparesis is indicative of a pontine lesion.

- ▶ *Decerebrate rigidity*—This refers to bilateral upper and lower limb extensor posture, usually the consequence of bilateral mid-brain or pontine lesions.
- ▶ *Decorticate posture*—This refers to bilateral flexion of the upper limbs and extension of the lower limbs, usually the consequence of an upper brain stem lesion.

Unilateral decerebrate or decorticate postures can be seen and are an indication of a unilateral lesion. This asymmetry has some localising value (fig 3).



Movement disorders such as myoclonus, epilepsy partialis continua, and tonic-clonic seizures may all occur in coma. They are important to identify since seizures require urgent treatment. Myoclonic jerking is seen commonly in patients with anoxic/ischaemic encephalopathy and other toxic or metabolic disorders. Patients with brain stem herniation can have flexor or extensor posturing triggered by respiration or external stimuli. These should not be confused with seizures.

Asymmetry of the plantar response, tendon jerks, and muscle tone may all be valuable in localisation of structural lesions and differentiation from metabolic conditions. Acute structural damage above the brain stem results in a flaccidity of muscle tone and is asymmetric in comparison to metabolic disorders where such findings are usually symmetrical.

### Fundal examination

Subhyaloid haemorrhages, hypertensive retinopathy, and papilloedema should be looked for. Subhyaloid haemorrhages occur in conditions that cause a sudden increase in intracranial pressure. Papilloedema can occur when raised intracranial pressure is established for some time, but its absence does not exclude raised intracranial pressure.

### Respiratory pattern

Respiration can be affected in coma. This can be a generalised effect relating to the level of consciousness, be preferentially affected by certain drugs or metabolic states, and it may have some limited localising value (table 2).

### Role of neurological investigations

CT imaging is the most readily available investigation that gives immediate information on the presence of gross structural intracranial disease. This will confirm the presence of mass lesions showing displacement or shift of intracranial compartments—for example, subfalcine or uncus herniation. Raised intracranial pressure is suggested by narrowing of the third ventricle and loss of the quadrigeminal and suprasellar

cisterns. Magnetic resonance imaging provides better visualisation of the brain stem and cerebellar structures, venous sinuses, compartment shifts and diffuse disorders—for example, laminar necrosis of hypoxic encephalopathy—but in the acutely unwell or those who are ventilator dependent it is logistically difficult. Neurologists should be aware of conditions where the CT brain scan is normal—for example, metabolic encephalopathies but also disorders such as fat embolism. The electroencephalogram (EEG) is helpful in the diagnosis of acute toxic or metabolic encephalopathies showing diffuse slow wave change (4–6 Hz). Rapid (> 12 Hz) activity occurs with sedative overdose and slow wave changes of a focal nature are found in herpes simplex encephalitis.  $\alpha$  Coma—where the normal cortically generated  $\alpha$  rhythm is retained—occurs in hypoxic ischaemic or drug induced states. The  $\alpha$  activity is uninfluenced by stimulation or eye opening (in alert awake patients  $\alpha$  rhythm disappears with eye opening) and this suggests a better prognosis. Apart from this the EEG is not as good a predictor of clinical outcome when compared with clinical assessment. However, the EEG is of particular value in confirming complex partial status, a condition that should always be considered in the intensive care setting in patients with an ischaemic hypoxic insult and low coma score.

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