What is consciousness and what does it mean for the persistent vegetative state?

Consciousness: wakefulness or awareness?

Consciousness is an ambiguous term. Two senses are of particular relevance to clinical neurology[1,2]:

(i) Wakefulness, alertness: when someone asks whether a patient in the A + E Department is conscious, the question generally refers to the patient's *conscious state*. Is the patient 'conscious' – that is to say awake or alert - as opposed to comatose, anasthetised, drunk or just fast asleep? Three principle states of consciousness are recognised in health - wakefulness, slow wave sleep (SWS) and rapid eye movement (REM or dreaming) sleep - alongside a miscellany of states of pathologically altered consciousness, from coma to brain death (Table 1). Consciousness in this first sense can vary in degree as well as in kind: we can be drowsy, half-asleep or wide awake. Objective criteria, like those of the Glasgow Coma Scale (Table 2), are usually a reliable guide to a patient's conscious state, enabling us to 'operationalise' our clinical assessment. This approach fails, once in a while, when paralysis blocks the usual manifestations of consciousness, for example when wakefulness recovers during anaesthesia with paralysing agents.

(ii) Awareness: while we are wakeful or dreaming, we are always conscious *of* something. The contents of consciousness can be drawn from any part of our psychological armoury: we can be conscious of sensations, perceptions, thoughts, memories, emotions, desires or intentions. This second, more 'inward', sense of consciousness is sometimes picked out by the word 'awareness'. While this term tends to be used to underline the subjective dimension of human experience, we can only ever infer awareness in others on the basis of objective evidence (which of course includes others' reports of their experience). The nature of consciousness in this second sense is a philosophical battlefield. There is a strong philosophical temptation to simplify our world picture by analysing the contents of experience in terms of the behaviour they give rise to, the functions they enable or the neural states which they express. Several philosophers have taken this approach enthusiastically[3], but others can still see no way around the postulate of a 'Cartesian', subjective, mental realm[4].

One pathology of consciousness, the vegetative state (VS)[5,6,7] has been described aptly as a state of 'wakefulness without awareness': this puzzling condition can occur because the brain systems which underlie wakefulness are substantially distinct from those which mediate awareness.

The biology of consciousness

(i) Wakefulness: the cycling of wakefulness, SWS and REM is controlled by a network of structures in the pons, midbrain, thalamus, hypothalamus and basal forebrain which regulate the activation of more rostral parts of the cerebral hemipsheres[8,9]. This arousal network incorporates nuclei transmitting noradrenaline (locus coeruleus), serotonin (dorsal raphe nuclei), histamine (hypothalamus), acetylcholine (nuclei at pons/midbrain junction and in basal forebrain) and hypocretin (hypothalamus). Neurons throughout this network become quiescent in SWS; REM is characterised by selective reactivation of the cholinergic subsystem (Figure 1); REM episodes are terminated by increasing noradrenergic and serotonergic tone. The timing of sleep is normally influenced both by circadian (the light-dark cycle) and homeostatic (fatigue related) factors.

(ii) Awareness: although there is continuing debate about the neural mechanisms of awareness, there is a broad consensus on the following (rather unsurprising) points: the contents of consciousness depend upon shifting coalitions of cortical neurons ('networks' or 'assemblies'), which are often interlinked via the thalamus, are usually distributed around the brain, and incorporate regions concerned with attention and action as well as with perceptual processing[1,2,10,11]. Importantly, cortical activity does not always give rise to awareness[1,2,10,11]. The idea that neurons subserving current awareness may be bound by rapid synchronised oscillations in the gamma frequency range is topical[12].

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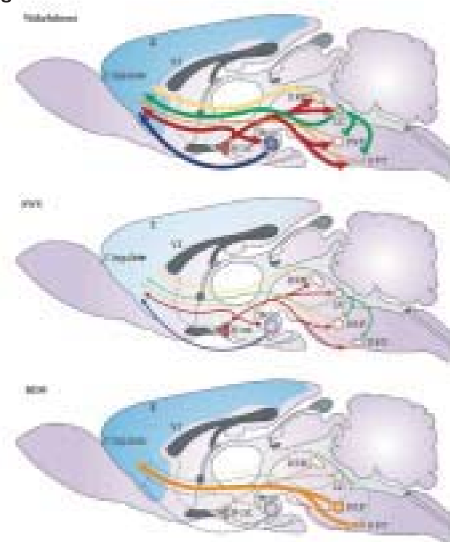
The vegetative state: wakefulness without awareness

The VS, first described in 1972 in the Lancet by Jennett and Plum[5] is an occasional outcome of severe brain injuries, usually traumatic or hypoxic-ischaemic. The clinical picture is somewhat eery. A patient in the VS appears to be awake: his eyes are open, he breathes spontaneously, he may turn fleetingly towards a prominent stimulus, or move spontaneously – grind his teeth, turn his head from side to side, grunt or moan. Yet despite this repertoire of behaviours, there is no evidence of 'a functioning mind': no evidence of discrimination between events or of purposeful behaviour, no sign of understanding or any attempt to communicate.

There is no doubt that such a condition occurs, but it has given rise to confusion. This has had two main sources: terminological and diagnostic. The terminology is explained in Table 3. The condition has sometimes been misdiagnosed for reasons including uncertainty about the nature of the syndrome, inadequate observation, failure to consult those who see most of the patient and the inherent difficulty of detecting signs of awareness in patients with major perceptual and motor impairments.

Studies of the pathophysiology of the VS indicate that it does indeed result from severe damage to the stuctures subserving awareness with relative preservation of the brain stem mechanisms of wakefulness. Autopsies reveal damage to the cortical mantle, cerebral white matter, thalamus or

Figure 1

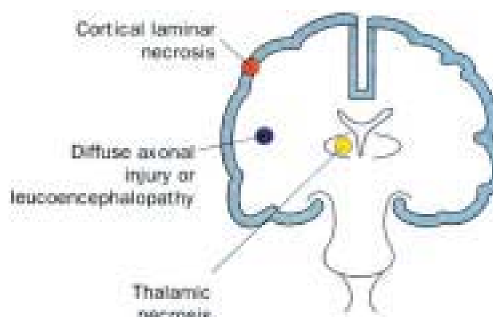


The figure indicates the levels of activity in the brain stem neurotransmitter systems which regulate sleep and waking in the rat (SWS = slow wave sleep, REM = rapid eye movement sleep) Hypocretin is shown in red, noradrenaline in green, acetylcholine in dark brown, serotonin in light brown and histamine in blue. *Reprinted by permission from Nature Reviews Neuroscience (*Vol 3: Congenital myasthenic syndrome (CMS) mutations in the acetylcholine receptor binding site*) copyright (2002) Macmillan Magazines Ltd.*

any combination of these (Figure 2). Functional imaging demonstrates reduction of global cerebral metabolic rates by 40-60%, down to or below the levels occurring during anaesthesia[13]. The metabolism of the upper brain stem is relatively spared. Where evoked cortical activity can be detected, it is fragmentary, with failure to recruit the distributed networks on which awareness is thought to depend. If the VS remits, as awareness recovers so too do previously silent long-range cortical connections[13].

Although the VS always indicates a severe brain injury, recovery can occur[7]. After one month in the VS following a traumatic insult there is a slightly better than even chance of recovering awareness: the chances are considerably less good in non-traumatic cases. But once one year has passed in the VS after trauma, or six months in non-traumatic cases, awareness is very unlikely indeed to recover, and in these exceptional cases, recovery is to a state of extremely severe disability. In these circumstances British courts tend to look favourably on applications for permission to withdraw treatment, reflecting the fundamental importance of awareness to the value we place upon our lives.

Figure 2



This figure indicates the three principal pathologies which give rise to the vegetative state.

Table 1: Some states of impaired consciousness

Condition	Vegetative state	Minimally conscious state	Locked-in syndrome	Coma	Death confirmed by brain stem tests
Awareness	Absent	Present	Present	Absent	Absent
Sleep-wake cycle	Present	Present	Present	Absent	Absent
Response to noxious stimuli	+/-	Present	Present (in eyes only)	+/-	Absent
Glasgow Coma score	E4, M1-4,V1-2	E4, M1-5,V1-4	E4, M1,V1	E1,M1-4,V1-2	E1, M1-3,V1
Motor function	No purposeful movement	Some consistent or inconsistent verbal or purposeful motor behaviour	Volitional vertical eye movements or eyeblink preserved	No purposeful movement	None or only reflex spinal movement
Respiratory function	Typically Preserved	Typically Preserved	Typically Preserved	Variable	Absent
EEG activity	Typically slow wave activity	Insufficient data	Typically normal	Typically slow wave activity	Typically absent
Cerebral metabolism (positron emission tomography)	Severely reduced	Insufficient data	Mildly reduced	Moderately-severely reduced	Severely reduced or absent
Prognosis	Variable: if permanent, continued vegetative state or death	Variable	Depends on cause but full recovery unlikely	Recovery, vegetative state or death within weeks	Already dead

Table adapted from: Royal College of Physicians. The vegetative state: guidance on diagnosis and management. Clin Med 2003: 3(3); 249-254.

Table 2: Glasgow Coma Scale (GCS):

E	Eye Opening	M	Motor function	V	Verbal
1	None	1	None	1	None
2	To pain	2	Extends to pain	2	Grunts
3	To sound	3	Abn flexion to pain	3	Inapprop. words
4	Spontaneously	4	Normal flex to pain	4	Confused
		5	Localises pain	5	Oriented
		6	Normal		

Table 3: Terminology of the vegetative state

Vegetative state (VS):	A state of intermittent wakefulness without awareness, as described in the text.
Persistent VS:	Any VS which has persisted for more than 1 month (arbitrarily).
Permanent VS:	A VS which has persisted for over 1 year following trauma, or for over 6 months following a non-traumatic cause, and which is therefore highly likely to be permanent.

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