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Anatomy and physiology of headache

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Summary – Headache is a vast field with many different varieties of headaches and classifications. However, all headaches have a common anatomy and physiology. All headaches are mediated by the trigeminocervical nucleus, and are initiated by noxious stimulation of the endings of the nerves that synapse on this nucleus, by irritation of the nerves themselves, or by disinhibition of the nucleus. A mastery of the relevant anatomy and physiology of the trigeminocervical nociceptive system serves to predict and summarise the many varieties of headache systematically and with reference to their mechanisms.

headache / migraine / mechanisms

INTRODUCTION

Headache is a common complaint that can stem from a multitude of sources and causes. Indeed, so large is the problem that there are international bodies dedicated to its study and management [24]. Ultimately, headache may require specialist investigation and management [30, 37] but because of its prevalence, headache intrudes into the practice of virtually every specialty. Consequently, every physician or surgeon has a responsibility to be able to assess headaches: either to identify varieties of headache that pertain to their own craft, or to recognise those headaches that they can manage themselves, or those that require referral.

Traditionally the approach to headache has been clinical, and taxonomies of headache have been based on catalogues of countless varieties with different distinguishing clinical features [24]. But there is another approach which avoids rote learning of case after case. It is a basic science approach which starts with anatomy and progresses through physiology and pathology to yield the differential diagnosis of headache. The end point is the same as that achieved by rote learning but it is achieved with a comprehension of the mechanisms involved, which themselves form the rational basis for investigation therapy.

NEUROANATOMY

In the brainstem, the grey matter constituting the pars caudalis of the spinal nucleus of the trigemi-

nal nerve extends caudally without interruption to become continuous with the grey matter of the dorsal horn of the spinal cord. Within this column of grey matter one can discern what is effectively a nucleus – the trigeminocervical nucleus (fig 1). This nucleus is not a nucleus in the classical sense for it does not have distinct rostral and caudal boundaries – it is directly continuous with the remainder of the spinal nucleus above and with the grey matter of the dorsal horn of the spinal cord below; nor does it have a unique cyto-architecture – the cells in the pars caudalis resemble those of the spinal grey matter and are arranged in laminae that correspond to laminae I to V of the dorsal horn [39]. Rather, the "nucleus" is defined by its afferent fibres.

The trigeminocervical nucleus is that region of grey matter that receives afferents from the trigeminal nerve and from the upper three cervical spinal nerves, together with additional fibres from the VII, IX and X cranial nerves. Trigeminal afferents ramify in the pars caudalis and as far caudally as the third cervical spinal cord segment, perhaps even as far as C4 [23, 45]. Afferents from the first three spinal cord segments ramify at the segment at which they enter the spinal cord and also send collateral branches to more rostral and caudal segments. In particular, afferents from C2 ramify within the C2 grey matter but also ascend to C1 and descend to C3, and afferents from C3 ascend as far as C1 and C2 [26].

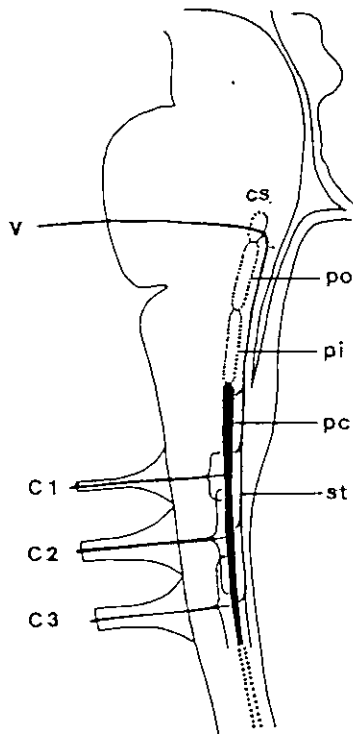


Fig 1. The trigeminocervical nucleus (depicted in black) is continuous rostrally with the pars interparialis of the trigeminal nucleus, and caudally with the grey matter of the spinal cord. It receives afferents from the spinal tract of the trigeminal nerve and from the C1-3 spinal nerves. v: trigeminal nerve; cs: chief sensory nucleus; po: pars oralis; pi: pars interparialis; pc: pars caudalis; st: spinal tract.

The significance of the trigeminocervical nucleus is that it is the essential nociceptive nucleus of the head, throat and upper neck. All nociceptive afferents from the trigeminal, facial, glossopharyngeal and vagus nerves and the C1-3 spinal nerves ramify in this single column of grey matter. Moreover, because of the overlapping pattern of ramification of primary afferent fibres, fibres from different peripheral nerves terminate on common, second-order neurones in the trigeminocervical nucleus. Although not formally demonstrated anatomically, this convergence has been demonstrated physiologically. Neurones in the C1 and C2 segments respond to stimulation of afferents in both the upper cervical spinal nerves and the trigeminal nerve [27].

This convergence constitutes the basis of referred pain in the head and upper neck. Stimula-

tion of cervical afferents to a second-order neurone that also receives a trigeminal input may result in the source of stimulation being interpreted as arising in the cervical receptive field, the trigeminal receptive field or both. By the same token, if a neurone receives afferents from two, different, cervical, receptive fields, stimulation of one may result in the perception of pain in the other cervical receptive field.

This mechanism underlies the variety of patterns of pain perceived in the head and their sources. Pain in the forehead can arise as a result of stimulation of trigeminal, forehead afferents (eg, in frontal sinusitis) but it can also arise as a result of stimulation by the cervical afferents of second-order neurones in the trigeminocervical nucleus that happen also to receive forehead afferents. Similarly, pain in the occipital region (innervated largely by C2) does not necessarily imply an origin in the occiput, but may arise as a result of stimulation of trigeminal or cervical afferents from other sites but which relay to second-order neurones that receive a convergent input from occipital afferents.

Referred pain following cervical stimulation is most commonly perceived in the occipital and fronto-orbital regions of the head; less commonly in fields innervated by the maxillary and mandibular divisions of the trigeminal nerve. This correlates with the fact that maxillary and mandibular afferents in the spinal tract of the trigeminal nerve do not extend as far caudally into cervical segments as do ophthalmic afferents, or at least, do so less densely. Consequently, cervical afferents are more likely to converge on second-order neurones that receive ophthalmic afferents than ones that receive maxillary or mandibular afferents.

On anatomical grounds, the differential diagnosis of headache can be summarised comprehensively as any primary cause of pain that activates the trigeminocervical nucleus. In turn, the possible locations of peripheral causes of headache are dictated by the receptive field of the trigeminocervical nucleus, namely, any of the structures innervated by the trigeminal, VII, IX, X cranial nerves and the upper three cervical spinal nerves. Given the appropriate stimulus and given the appropriate convergent connections in the central nervous system, any structure innervated by these nerves is capable of causing headache.

PERIPHERAL ANATOMY

A systematic classification of the causes of nociceptive headache can be elaborated by considering the distribution of the afferents to the trigeminocervical nucleus and the disorders that may affect them. These nerves have either a cranial distribution, a cervical distribution or both (fig 2). Each structure they innervate can be affected by a variety of possible disorders most of which are well-recognised causes of headache (table I). Others are somewhat controversial or unfamiliar because their diagnosis requires techniques not commonly used or available to many consultants in headache. These include disorders of the upper cervical synovial joints (table I).

Within the head, nociceptive fibres of the first division of the trigeminal nerve (V_1) innervate the orbit and eye, the frontal sinus, the dura mater of the anterior cranial fossa and the falx cerebri, and the great vessels associated with these sections of dura. The anterior end of the falx cerebri is supplied by meningeal branches of the anterior and posterior ethmoidal nerves, but most of the dural distribution of the first division is through its recurrent meningeal (or tentorial) branch [41]. This nerve arises from the ophthalmic nerve near its origin and passes backwards along the superior surface of the tentorium cerebelli. Branches are distributed to this surface of the tentorium but others turn upwards into the posterior end of the falx cerebri from which location they innervate the falx and the superior sagittal sinus [41].

The second division of the trigeminal nerve (V_2) innervates the nose, paranasal sinuses, upper teeth and the dura mater of the middle cranial fossa. The dura is innervated by the nervus meningeus medius which arises from the maxillary nerve at the foramen rotundum. The third division (V_3) innervates the dura mater of the middle cranial fossa, the lower jaw and teeth, the ear, the temporomandibular joint and the muscles of mastication. The dura is innervated by the nervus spinosus which accompanies the middle meningeal artery. The temporomandibular joint receives articular branches from the nerve to masseter and the auriculotemporal nerve. The external auditory meatus and tympanic membrane are innervated anteriorly by the auriculotemporal nerve, and posteriorly by branches of a plexus formed below the meatus by branches of the VII, IX and X cranial nerves. The middle ear cavity is innervated by the IX cranial nerve. Otherwise,

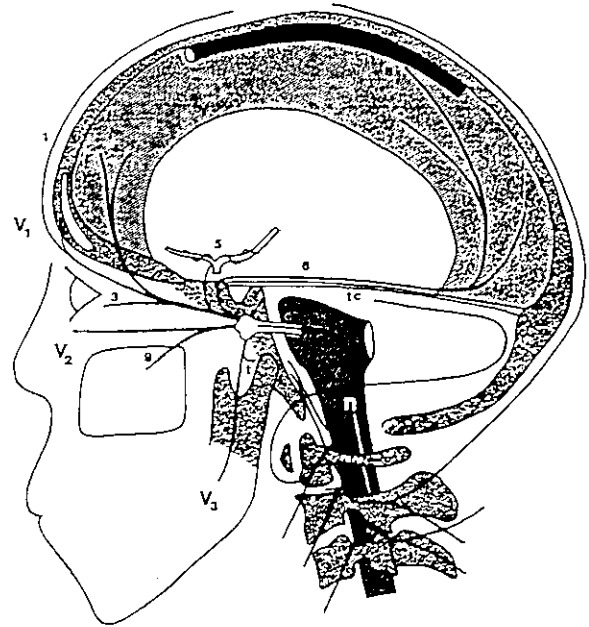


Fig 2. A graphic summary of the distribution of the afferents to the trigeminocervical nucleus (n). The first division of the trigeminal nerve (V_1) is distributed to the skin of the forehead[1], the frontal sinus[2], the orbit and eye[3], the anterior end of the falx cerebri[4] and the proximal ends of the anterior and middle cerebral arteries[5]; through its tentorial branch[6] it supplies the superior surface of the tentorium cerebelli (tc), the posterior end of the falx cerebri[7] and the superior sagittal sinus[8]. The second division (V_2) supplies the nose, maxillary sinus[9] and upper jaw. The third division (V_3) supplies the temporomandibular joint (t) and lower jaw. Within the skull, branches of the first three cervical nerves innervate the dura mater of the posterior cranial fossa and the inferior surface of the tentorium cerebelli. Outside the skull, cervical nerves supply the anterior and posterior muscles and joints of the first three cervical segments and the skin of the occiput.

the glossopharyngeal and vagus nerves are distributed to the pharynx and larynx.

The C1 and C2 spinal nerves are distinctive in that they do not emerge through intervertebral foramina. The C1 spinal nerve passes across the posterior arch of the atlas behind its superior articular process (fig 3C). The C2 spinal nerve crosses the posterior aspect of the lateral atlanto-axial joint (fig 3C), its ganglion lying opposite the radiologic midpoint of that joint [5]. Although the C1 spinal nerve lacks a cutaneous branch, it is nonetheless sensory to the suboccipital muscles. Its dorsal root ganglion, however, may be ectopic. When missing from the dorsal root of C1 it is typically found amongst the rootlets of

Table I. The causes of headache tabulated according to innervation, mechanism and pathology.

Nerve	Distribution	Pathology		Conditions
		Mechanical	Chemical	
Intra-cranial				
V ₁	Orbit, eye	Distension	Inflammation	Tumours, glaucoma, uveitis Painful ophthalmoplegia Tumour, mucocoele, sinusitis Space-occupying lesions, haemorrhage, inflammation Tumours, lumbar puncture, idiopathic Drugs Aneurysm Temporal arteritis Tumours, sinusitis Tumours, infections Otitis TMJ dysfunction
	Cavernous sinus	Distension	Granulomas	
	Frontal sinus	Distension	Inflammation	
	Dura mater	Tension	Chemical irritation	
	Tentorium cerebelli	Raised or lowered CSF pressure		
V ₂	Venous sinuses	Dilatation	Inflammation	
	Cerebral arteries	Dilatation	Inflammation	
V ₃	Temporal artery	Stretch	Inflammation	
	Nose, upper jaw	Distension	Inflammation	
V ₃	Lower jaw	Distension	Inflammation	
	Ear		Inflammation	
VII, IX, X	Temporomandibular joint	Unknown		
	Ear, throat	Disorders of the ear and throat		
C1, 2, 3	Dura mater	Tension	Chemical irritation	Space-occupying lesions, haemorrhage, inflammation Lumbar puncture, idiopathic Aneurysm
		Raised or lowered CSF pressure		
	Vertebral artery	Stretch		
Extra-cranial				
C1, 2, 3	Carotid arteries	Stretch	Inflammation	Aneurysm, carotidynia Arthropathy, arthritis
	Atlanto-occipital, Atlanto-axial joints, Alar and transverse ligaments, C2-3 zygapophysial joint, C2-3 intervertebral disc	Trauma, strain	Inflammation	
	Prevertebral post-vertebral muscles, trapezius, sternomastoid	Sprain	? spasm	Tender points Trigger points

the spinal accessory nerve [40]. The C3 spinal nerve is the first of the typical cervical spinal nerves, and lies in the C2-3 intervertebral foramen.

The C1-3 spinal nerves divide into ventral and dorsal rami. Their ventral rami join with that of C4 to form the cervical plexus from which muscular branches are distributed to the prevertebral muscles – longus capitis and cervicis, rectus capitis anterior and lateralis, and to the sternocleidomastoid and trapezius. At their origin, the C1-3 spinal nerves form recurrent meningeal branches – the sinuvertebral nerves. These nerves

supply the ventral surface of the dura mater of the upper cervical spinal cord before entering the skull *via* the foramen magnum to supply the dura mater over the clivus (fig 3D). En route, they furnish branches to the median atlanto-axial joint, the transverse ligament of the atlas and the alar ligaments [29]. In the posterior cranial fossa C1-3 sinuvertebral nerves are joined by meningeal branches of the X and XII cranial nerves. Although arising from cranial nerves these branches are cervical in origin having gained the cranial nerves outside the skull where they communicate with the cervical plexus [29]. Other branches of

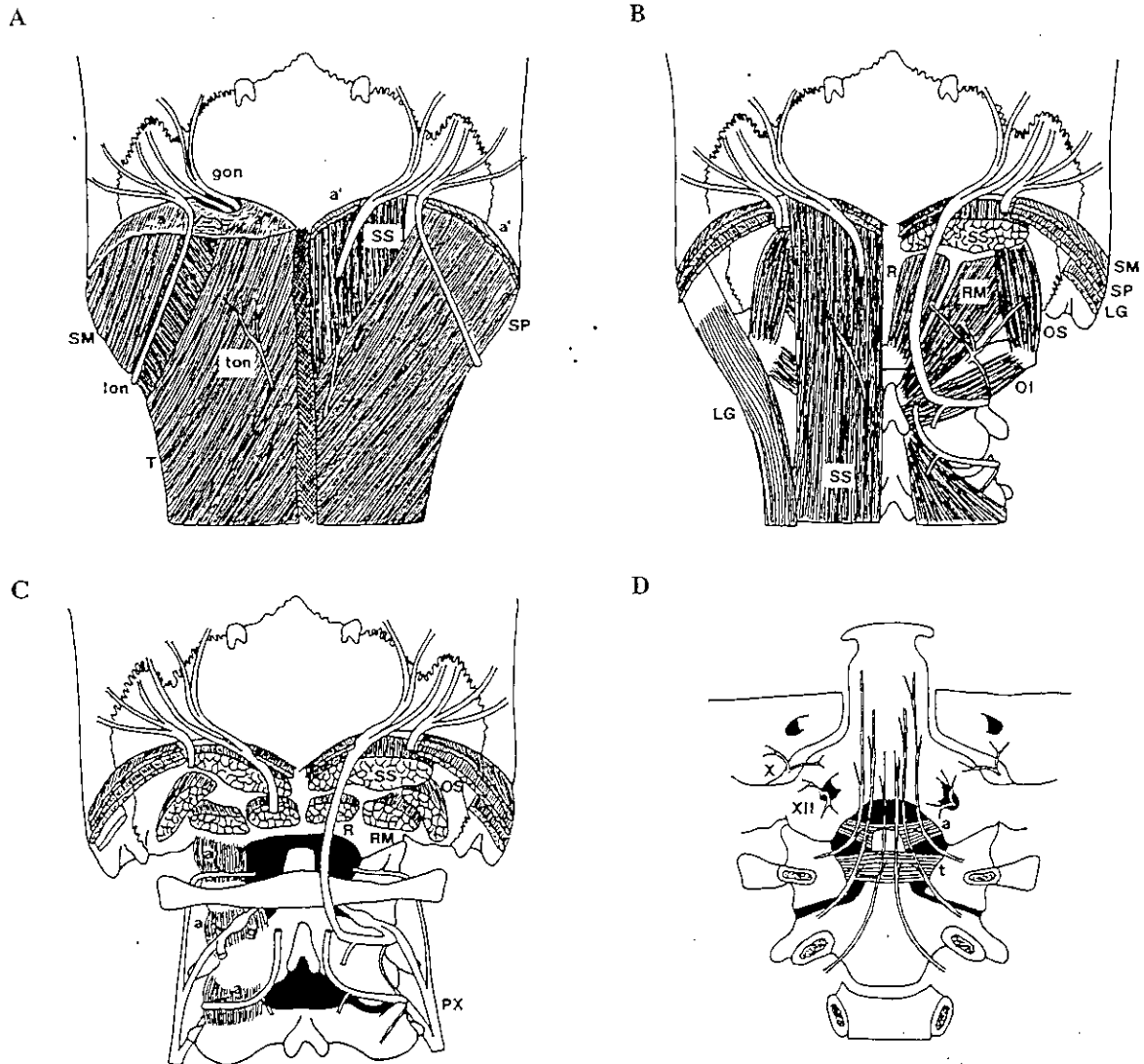


Fig 3. The anatomy of the suboccipital region, by layers. A: On the left, the most superficial muscle layer is shown, in which the sternocleidomastoid (SM) and trapezius (T) attach to the superior nuchal line by way of an aponeurosis (a) which connects the two muscles. The greater occipital nerve (gon) emerges through an aperture above the aponeurotic sling between these two muscles to become cutaneous. The lesser occipital nerve (lon) ascends parallel to sternocleidomastoid to reach the occiput. The third occipital nerve (ton) penetrates the trapezius to become cutaneous. On the right, the trapezius and sternocleidomastoid have been resected, leaving their aponeuroses (a') attached to the superior nuchal line, to reveal the splenius (SP) and the semispinalis capitis (SS) through which the greater occipital nerve passes. B: On the left, the splenius has been resected to reveal the longissimus capitis (LG) and the extent of semispinalis capitis. On the right, the semispinalis capitis (SS) has been resected to reveal the course of the greater occipital nerve across the suboccipital muscles: rectus capitis posterior minor (R), rectus capitis posterior major (RM), obliquus inferior (OI) and obliquus superior (OS). The attachments of sternocleidomastoid (SM), splenius (SP) and longissimus capitis (LG) to the mastoid process remain in situ. C: All posterior muscles have been resected, leaving only their occipital attachments, to show the entire course of the greater occipital nerve, and the course of the third occipital nerve (ton) across the C2-3 zygapophysial joint. The ganglion of the C2 spinal nerve (g) lies behind the lateral atlanto-axial joint. Articular branches (a) arise from the C1 ventral ramus to the atlanto-occipital joint, from the C2 ventral ramus to the lateral atlanto-axial joint, and from the third occipital nerve to the C2-3 zygapophysial joint. The C1-3 ventral rami enter the cervical plexus. D: Removal of the posterior elements of the occiput and the C1-3 vertebra reveals the C1-3 sinuvertebral nerves which supply the transverse (t) and alar (a) ligaments before passing through the foramen magnum to innervate the dura mater over the clivus. The meningeal branches of the vagus (X) nerve and hypoglossal nerve (XII) are found emerging from the jugular foramen and hypoglossal canal respectively. (Reproduced with permission from Bogduk [8]).

the C1-3 ventral rami join the vertebral nerve – the plexus accompanying the vertebral artery, and furnish sensory branches to the fourth part of the artery [9, 28].

The dorsal ramus of C1 innervates the muscles of the suboccipital triangle – obliquus superior, obliquus inferior and rectus capitis posterior major and minor (fig 3B). The C2 dorsal ramus has lateral branches directed to the superficial, posterior muscles of the neck – longissimus capitis and splenius, but its large, medial branch becomes the greater occipital nerve [6]. This nerve winds around the inferior border of obliquus inferior, turns upwards and backwards through semispinalis capitis, which it supplies, and enters the scalp through an aperture bounded by the superior nuchal line and the aponeurosis of trapezius [4, 6, 47] (fig 3). Over the occiput it is joined by the lesser occipital nerve which is a cutaneous branch of the cervical plexus and reaches the scalp by passing along the posterior border of sternocleidomastoid.

The C3 dorsal ramus furnishes lateral branches to the longissimus capitis and splenius. It forms two medial branches [6]. The deep medial branch crosses the waist of the C3 articular pillar to enter the multifidus muscle. The superficial medial branch is the third occipital nerve which winds around the lateral and posterior aspect of the C2-3 zygapophysial joint (fig 3). Over the joint this nerve communicates with the C2 dorsal ramus and furnishes articular branches to the joint. Distally the third occipital nerve penetrates the semispinalis capitis and trapezius to become cutaneous over the suboccipital region. En route it furnishes branches to the semispinalis capitis which join those from the greater occipital nerves to supply this muscle.

It is not clear what the sensory innervation of the carotid arteries is in the upper neck; whether nociceptive afferents travel with the special, autonomic afferents of the glossopharyngeal and vagus nerves to the carotid body and carotid sinus or whether afferents from the adventitia of these arteries return *via* the sympathetic nervous system and cervical plexus to reach upper cervical spinal nerves, like those of the vertebral artery.

Apart from having a similar segmental innervation, many of the muscles innervated by C1-3 share the feature that they attach to the skull and, therefore, underlie sites that are commonly tender in various forms of headache. Most superficially, the sternocleidomastoid and trapezius attach

along the superior nuchal line from the mastoid process to the external occipital protuberance (fig 3). Deep to these, the splenius capitis attaches to the mastoid process and outer half or so of the superior nuchal line (fig 3). In the next deeper layer, the bulky semispinalis capitis is anchored to the occiput below the medial half of the superior nuchal line, and the slender longissimus capitis reaches the mastoid process. Between them the obliquus superior attaches to the occiput, and deep to semispinalis capitis the rectus capitis posterior major and rectus capitis posterior minor attached to the occiput (fig 3).

These details are pertinent to the description and interpretation of tenderness in this region. There is a proclivity amongst some physicians to ascribe tenderness in the suboccipital region to entrapment or irritation of the greater occipital nerve or the lesser occipital nerve [22, 34, 36]. However, the attachment-sites of these various occipital muscles, notably semispinalis capitis and sternocleidomastoid are tender even in normal, asymptomatic individuals [24]. Their tenderness in patients with headaches needs to be distinguished from normal tenderness or decreased perceptual threshold in the course of headache before being arbitrarily ascribed to nerve entrapment [31, 33, 38].

PHYSIOLOGY

There are three basic mechanism by which pain may be generated. Nociceptive pain arises when the terminals of peripheral nociceptive afferents are stimulated. Neurogenic pain arises when the axons or cell bodies of a peripheral nerve are stimulated. Central pain does not involve peripheral nerves and is caused by activation of second or third order pathways within the central nervous system.

Nociceptive pain requires some form of pathology or disturbance in the periphery that can activate nerve endings. In this regard only two mechanisms obtain – mechanical or chemical stimulation. Archetypically, mechanical nociception involves distortion of a network of collagen. In the appendicular skeleton the classical example is ligament strain; in the context of headache the example is strain of the dura mater. Chemical nociception requires the liberation of an algogenic chemical; inflammation is one source but others include potassium ions liberated from injured cells, *eg* blood.

Neurogenic pain requires the ectopic generation of action potentials along the course of a peripheral nerve. The causative lesion does not lie in peripheral territory supplied by the nerve but may be as far proximal as the roots of that nerve. The pain produced, however, is perceived in the territory of that nerve. Hence the location of the pain belies the location of the lesion. This type of pain has to be recognised in order that its source be accurately explored.

Central pain is a mysterious phenomenon. It involves the activation of second or third order pathways by mechanisms other than stimulation by peripheral nerves. The pain evoked, however, is nonetheless perceived in the territory of the nerves that relay to the pathways involved; yet there is no pathology in the periphery to explain the pain. Archetypically, central pain occurs after peripheral nerve injury and involves de-afferentation supersensitivity of second order neurones of the spinal cord. Another model is dysmodulation, in which the descending inhibitory pathways that control pain perception are somehow themselves inhibited resulting effectively in an illusion of pain but pain that is nonetheless real in terms of the suffering it produces; the illusion pertains only to the lack of tissue damage in the territory in which the pain is perceived.

When each of these three basic mechanisms is matched to the anatomy of headache the differential diagnosis of headache systematically emerges.

NOCICEPTIVE HEADACHE

One can determine the sources of nociceptive headache by systematically reviewing the distribution of each of the nerves that relay to the trigeminocervical nucleus. In turn, each structure innervated by a given nerve can be considered with respect to the disorders that might affect it to give rise to pain (table I).

1st division trigeminal

A variety of disorders can affect the eye and the orbit to cause headache. Mechanical cause of pain include glaucoma and retrobulbar tumours. Chemical causes are the inflammatory diseases, optic neuritis and uveitis. The clinical action required is an examination of the eye itself for signs of inflammation or proptosis, eye movements and visual acuity, and fundoscopy. CT scanning may

be required if on clinical examination orbital lesions are suspected.

So-called "eye-strain" is a contentious issue. This rubric should not be applied unless there is evidence of hypermetropia, astigmatism or ocular muscle imbalance. It should not be used as a convenient explanation for inexplicable headaches ostensibly stemming from the eye, or as an excuse for not considering the problem more responsibly.

Lying behind the orbit is the cavernous sinus. Here a variety of disorders can produce headache associated with palsies of the cranial nerves passing through that sinus. The disorders include tumours of the pituitary and sphenoid bone, mucocoeles of the sphenoid sinus, aneurysms of the internal carotid artery, meningiomas, infections and granulomatous infiltrations of the cavernous sinus. Collectively these conditions are classified and present as painful ophthalmoplegia [7]. Thrombosis of the cavernous or other venous sinuses may also present as headache.

Pain from the frontal or ethmoid sinus, can be produced by mechanical processes such as tumours or mucocoeles, or by chemical processes as in inflammation. Pain from the ethmoid sinus tends to be focussed around the inner canthus of the eye; that from the frontal sinus is distinctly over the forehead and is associated with tenderness over the forehead and along the roof of the orbit [2]. Frontal sinusitis needs to be suspected on clinical grounds in the first instance because radiographic changes may not be apparent for several days after the onset of infection [2].

For mechanical pain from the dura mater all that is required is that the dura be stretched. This can arise from direct tension from an adjacent space-occupying lesion or as a result of changes in CSF pressure. Raised CSF pressure stretches the tentorium cerebelli but so do does lowered CSF pressure as the cerebrum sinks onto the tentorium.

The archetypical cause of raised CSF pressure is a space-occupying intracranial lesion; suspicion of such a lesion is enhanced if focal neurological signs are evident. However, in the condition of idiopathic intracranial hypertension, CSF pressure is raised by an intermittent obstruction of outflow through the arachnoid granulations [37]. Clinically the hallmark of raised CSF pressure is papilloedema. Acute obstruction of the cerebral aqueduct by a tumour or colloid cyst of the third ventricle may present with sudden severe headache and drop attacks.

The archetypical form of headache due to lowered CSF pressure is post-lumbar puncture headache but there is also a condition of primary intracranial hypotension [37].

Chemical irritation of the dura mater invites a consideration of the agent responsible: blood in the case of subarachnoid haemorrhage, pus in bacterial meningitis, or the inflammatory exudate of viral meningitis. Extension of the offending agent into the cervical subarachnoid space results in meningismus. Subarachnoid haemorrhage classically presents with a dramatic, sudden onset of very severe headache and photophobia; the patient may be vomiting and prostrate. CT scanning can identify the aneurysm and lumbar puncture confirms the presence of blood in the CSF. Patients may present with a sentinel headache presumably due to leakage of blood from an aneurysm that is about to burst.

Patients with infections of the CNS typically exhibit photophobia, nausea, drowsiness, fever and general malaise. Less florid presentations may be diagnosed only by lumbar puncture.

Vascular dilatation is a side effect of certain drugs such as alcohol, nitrates, nitrites and indomethacin. Caffeine and nicotine are vasoconstrictors but may be responsible for rebound vasodilatation. Vascular dilatation is presumed to be the mechanism of headache in toxæmia as a result of circulating pyrogens. The history of drug consumption or pyrexia are the distinctive features of vasodilatation headache.

Related to vasodilatation are the conditions of exertional headache, sex headache, and the headache of pheochromocytoma. Raised blood pressure is believed to be the underlying mechanism for these vascular headaches [30].

An aneurysm that has not ruptured presumably hurts as a result of distension of the adventitia of the artery. Headaches due to this mechanism cannot be diagnosed clinically; angiography, CT scan or MRI are the only definitive means. However, not all aneurysms are painful. Hence what appears on an angiogram or scan may not necessarily be the cause of the patient's pain.

Temporal arteritis is a threatening condition that presents with headache. It needs to be considered in any patient over the age of 50 who presents with an unaccustomed headache. The threat is progression of the condition to involve the ophthalmic artery resulting in blindness. An elevated ESR is the hallmark and biopsy of the temporal artery provides the definitive diagnosis. Ur-

gent therapy with steroids needs to be implemented once the ESR is to hand.

2nd division trigeminal

Disorders of the nose and maxilla do not as a rule give rise to mysterious headaches. The pain of maxillary sinusitis is characteristically felt over the cheek; headache, if present, is a secondary, associated feature. Similarly the pain of maxillary carcinoma is usually local; otherwise the disease presents with signs such as facial swelling, nasal obstruction, epiphora or epistaxis.

Diseases of the sphenoid sinus, such as sinusitis, mucocoeles and carcinoma may present with headache as the only manifestation; symptoms of nasal obstruction, rhinorrhœa or post nasal drip occur only in a minority of patients [2]. Radiography and CT scans are likely to be abnormal in the case of neoplastic disorders but may be false-negative in inflammatory disease [2].

3rd division trigeminal

Disorders of the lower jaw and its adnexae are most likely to present with local pain – pain over the parotid region, pain in the ear. Headache in the frontal or orbital regions, if it occurs, is usually additional to the local pain. The diagnosis of disorders of the temporomandibular joint is vexatious in its own right. Features that alert the physician to this possibility included clicking of the joint, difficulties chewing, and tenderness around the joint.

Glossopharyngeal and vagus nerves

Pain from the throat may be referred to the ear or even to the frontal region, but local features, such as hoarse voice, dysphagia or local pain, usually indicate the source of the pain.

Aneurysms of the internal carotid artery are a rare but documented cause of headache [21]. Carotidynia is an enigmatic condition believed to involve inflammation or weakening of the wall of the internal carotid artery. It is suggested by tenderness over the affected vessel in a patient with an otherwise unexplained headache [20].

Cervical nerves

The posterior cranial fossa and its contents are innervated by cervical nerves but the considerations are the same as for the first division of the trigeminal nerve. Space-occupying lesions may

distend the tentorium; the dura mater may be irritated by blood or inflammation. Vertebral artery disease, such as an aneurysm becomes an important differential diagnosis of what otherwise might seem to be neck pain with referred pain to the head.

The upper cervical synovial joints can be affected by overt arthritides like rheumatoid arthritis, and thereby become a source of neck pain and headache [3, 12, 42-44]. The lateral atlanto-axial joints can be affected by osteoarthritis, and anaesthetising these joints relieves a form of headache that can be mistaken for greater occipital neuralgia [18, 35]. Headaches can also arise from the C2-3 zygapophysial joints in patients who have suffered neck injuries. Blocking these joints or their nerve supply relieves the headache, indicating that the joint is the source of pain [10, 32]. Radiographically, however, the joints exhibit no obvious arthritic changes, and the actual cause of pain in such cases still remains a mystery.

Patients with seemingly obscure complaints of upper cervical pain and headache following injury may damage to an alar ligament [15-17]. The diagnosis becomes evident when functional CT scanning reveals a unilateral range of rotation of the head and atlas that is significantly greater than normal.

There is no firm evidence as to if and how posterior neck muscles might be a source of pain. Clinical studies have shown that experimental stimulation of muscles innervated by C1-3 can cause headache in normal volunteers [13, 14, 19], but the nature of pathological conditions that might affect these muscles to cause headache in patients remains elusive. Theoretically, acute tears near their myotendinous junctions could be a cause of acute headache after injury but such tears attract an inflammatory repair response [8] and should heal rapidly. Muscular tears, therefore, cannot be entertained as a cause of chronic headache. Muscle spasm is believed by some to be a source of pain but the evidence concerning this contention is mixed at best; nor is it clear how spasm if it does occur, actually results in pain.

Trigger point theory is fashionable amongst some medical and paramedical circles, and a variety of trigger point syndromes affecting the neck muscles are reportedly associated with headache. These are the syndromes of semispinalis capitis, splenius capitis, splenius cervicis, trapezius and sternocleidomastoid [46]. Con-

spicuously all these muscles are innervated by C1-3 which is consonant with their capacity to activate the trigeminocervical nucleus. Notably, in contrast, trigger point syndromes of muscles innervated by lower cervical nerves are not associated with headache but cause referred pain to the shoulder girdle. An important consideration, however, is the validity of certain, upper cervical trigger point syndromes. Several of the tender sites ascribed to trigger points overlie cervical zygapophysial joints. Consequently, trigger point syndromes need carefully to be distinguished from painful and tender cervical zygapophysial joints lest the source of pain be mistakenly ascribed to muscles rather than to a cervical joint [11].

NEUROGENIC HEADACHE

The archetypical neurogenic headache is trigeminal neuralgia. In this condition the sensory root of the trigeminal nerve is focal demyelinated, sometimes by a plaque of multiple sclerosis but most often as a result of irritation by an aberrant nearby vessel. The clinical features are absolutely characteristic; the patient suffers repeated stabs of lancinating pain in the face or forehead, typically triggered by touching a particular spot on the surface of the face or mouth. The lancinating quality of the pain is characteristic of neuralgia.

C2 neuralgia is less common. It is caused by irritation of the C2 ganglion by an angioma or a meningioma, perhaps by scar tissue following trauma to the lateral atlanto-axial joint [7]. Clinically it is characterised by sharp jabs of pain over the occiput. There may be associated, reflex parasympathetic features such as conjunctival injection, lacrimation, facial flushing and ipsilateral rhinorrhea.

An idiosyncratic head pain is the prodromal phase of herpes zoster which may affect the first division of the trigeminal nerve or the second cervical nerve to produce headache. The pain is perceived in the distribution of these nerves some two or three days before the appearance of the vesicular eruption characteristic of this disease.

CENTRAL PAIN

The classical models of migraine were framed in terms of dilatation of the cranial vasculature; the distended vessels were presumed to be the source of the pain. Modern research has found the fea-

tures of migraine to be inconsistent with such models. The contemporary model of migraine portrays it as a disorder of the central nervous system in which the vascular changes are an epiphenomenon [30].

The mechanism of migraine is believed to involve interactions between the dorsal raphe nucleus and locus coeruleus of the brainstem, the superior salivatory nucleus and the trigeminocervical nucleus. Discharges of the locus coeruleus and raphe nuclei first cause vasoconstriction of the cerebral microcirculation and dilatation of the extracranial arteries, the latter involving parasympathetic relays along the greater superficial petrosal nerve. Exhaustion of the locus coeruleus subsequently results in the loss of inhibition of the nociceptive synapses of the trigeminocervical nucleus, resulting in the perception of pain [30].

The diagnostic features of migraine are that it is an episodic, severe headache associated with gastrointestinal disturbances such as nausea or vomiting and hypersensitivity in the form of photophobia and phonophobia. The headache is episodic in that there are distinct periods when the patient is absolutely free of pain. The periodicity is typically one to 12 attacks per month, each attack lasting four to 72 hours.

Migraine may occur with transient neurological features such as teichopsia and photopsia, paresis and sensory disturbances. These may precede the pain as a prodrome, or follow the onset of headache. These variants are referred to as migraine with aura. The neurological features are produced by transient ischaemia of the cortex or brainstem.

There are no confirmatory tests of migraine; it is a clinical diagnosis. The severity of headache is similar to that of headache associated with subarachnoid haemorrhage and infections of the central nervous system. The distinction lies in the associated features of these latter conditions.

Tension headache is a common entity whose aetiology remains very controversial. There are contentions that the pain stems from contraction of scalp and neck muscles induced by stress, but the evidence for this is mixed and not compelling. More attractive is the notion that so-called tension headache lies at the more benign end of a spectrum with migraine. It constitutes a headache generated by dysmodulation of the central nociceptive system but lacks the overt, peripheral vasculature features of migraine. As such it presents solely with pain which is essentially pericranial.

HEADACHES UNCLASSIFIED

Certain distinctive forms of headache defy classification under the above scheme for it is unclear whether they involve a peripheral, nociceptive cause or a neurogenic cause.

Cluster headache is characterised by episodes of severe orbital pain lasting 15 minutes to three hours, occurring one or more times a day in bouts lasting weeks or months, followed by pain-free intervals. Distinctive associated features are ipsilateral lacrimation, conjunctival injection and nasal obstruction. The mechanism of cluster headache is unknown but may involve central dysmodulation of pain, triggered from the hypothalamus. In contrast, the mechanism may involve oedema of the cavernous portion of the internal carotid artery.

Resembling cluster headache is paroxysmal hemicrania which is characterised by attacks of sustained hemicranial pain lasting 15 minutes each, recurring six to 30 times a day for periods of three to six weeks. Like cluster headache, paroxysmal hemicrania is associated with parasympathetic features on the ipsilateral side. Its cause is unknown but may involve a source in the cervical spine. Diagnostic is the response of this form of headache to indomethacin.

CLINICAL APPLICATION

This approach to headache provides a matrix for a thorough consideration of the differential diagnosis. Rather than memorise an arbitrarily organised list of possible causes of headache, a physician can work systematically through the sources and mechanisms of pain prompted by a knowledge of the anatomy of the head and neck and the physiology of pain.

Meanwhile there is a clinical imperative. Some forms of headache require urgent identification and intervention, notably those associated with subarachnoid haemorrhage and CNS infections. For these and other conditions the distinction lies not with the location and distribution of pain or even its quality but with the associated features. Immediately serious headaches are characterised by systemic or focal neurological and other disturbances indicative of the patient's illness.

Other forms of headache are no less serious to the patient but they do not constitute medical emergencies. Investigations, and referrals if required, may be instituted under routine condi-

tions. Investigations such as CT scans are not urgently required unless neurological or intracranial conditions are seriously indicated by the presentation. Nevertheless, no complaint of headache can be trivialised, dismissed or ignored. Headache is a symptom that may herald many conditions, some of which may become fully expressed only with the passage of time.

REFERENCES

- 1 Behrens MM. Headache associated with disorders of the eye. *Med Clin N Am* 1978;62:507-21
- 2 Birt D. Headaches and head pains associated with diseases of the ear, nose and throat. *Med Clin N Am* 1978;62:523-531
- 3 Bland JH, Davis PH, London MG *et al*. Rheumatoid arthritis of the cervical spine. *Arch Int Med* 1963;112:892-8
- 4 Bogduk N. The anatomy of occipital neuralgia. *Clin Exp Neurol* 1980;17:167-84
- 5 Bogduk N. Local anaesthetic blocks of the second cervical ganglion: a technique with application in occipital headache. *Cephalalgia* 1981;1:41-50
- 6 Bogduk N. The clinical anatomy of the cervical dorsal rami. *Spine* 1982;7:319-30
- 7 Bogduk N. Pain of cranial nerve and cervical nerve origin other than primary neuralgias. In: Olesen J, Tfelt-Hansen P, Welch KMA, eds. *The Headaches*. New York: Raven Press, 1993:765-72
- 8 Bogduk N. Anatomy and Pathology. In: Olesen J, Tfelt-Hansen P, Welch KMA, eds. *The Headaches*. New York: Raven Press, 1993:445-54
- 9 Bogduk N, Lambert G, Duckworth JW. The anatomy and physiology of the vertebral nerve in relation to cervical migraine. *Cephalalgia* 1981;1:1-14
- 10 Bogduk N, Marsland A. On the concept of third occipital headache. *J Neurol Neurosurg Psychiatr* 1986;49:775-80
- 11 Bogduk N, Simons DG. Neck pain: joint pain or trigger points? In: Vaeroy H, Merskey H, eds. *Progress in Fibromyalgia and Myofascial Pain*. Amsterdam: Elsevier, 1993:267-73
- 12 Cabot A, Becker A. The cervical spine in rheumatoid arthritis. *Clin Orthop* 1978;131:130-40
- 13 Campbell DG, Parsons CM. Referred head pain and its concomitants. *J Nerv Ment Dis* 1944;99:544-51
- 14 Cyriax J. Rheumatic headache. *Br Med J* 1938;2:1367-8
- 15 Dvorak J, Panjabi MM. Functional anatomy of the alar ligaments. *Spine* 1987;12:183-9
- 16 Dvorak J, Panjabi MM, Greber M, Wichman W. CT-functional diagnostics of the rotatory instability of upper cervical spine. 1: an experimental study on cadavers. *Spine* 1987;12:197-205
- 17 Dvorak J, Hayek J, Zehnder R. CT-functional diagnostics of the rotatory instability of the upper cervical spine. Part 2: an evaluation on healthy adults and patients with suspected instability. *Spine* 1987;12:726-31
- 18 Ehní G, Benner B. Occipital neuralgia and the C1-2 arthrosis syndrome. *J Neurosurg* 1984;61:961-5
- 19 Feinstein B, Langton JBK, Jameson RM, Schiller F. Experiments on referred pain from deep somatic tissues. *J Bone Joint Surg* 1954;36A:981-97
- 20 Feit H. Further observations of the diagnosis and management of carotidynia. *Headache* 1982;22:86-8
- 21 Fisher CM. The headache and pain of spontaneous carotid dissection. *Headache* 1982;22:60-5
- 22 Hammond SR, Danta G. Occipital neuralgia. *Clin Exp Neurol* 1978;15:258-70
- 23 Humphrey T. The spinal tract of the trigeminal nerve in human embryos between 7 1/2 and 8 1/2 weeks of menstrual age and its relation to early fetal behaviour. *J Comp Neurol* 1952;97:143-209
- 24 Headache Classification Committee of the International Headache Society. Classification and Diagnostic Criteria for Headache Disorders, Cranial Neuralgias and Facial Pain. *Cephalalgia* 1988;3(suppl 7)
- 25 Jensen R, Rasmussen BK, Pedersen B, Lous I, Olesen J. Cephalic muscle tenderness and pressure pain threshold in a general population. *Pain* 1992;48:197-203
- 26 Kerr FWL. Structural relation of the trigeminal spinal tract to upper cervical roots and the solitary nucleus in the cat. *Exp Neurol* 1961;4:134-48
- 27 Kerr FWL, Olafson RA. Trigeminal and cervical volleys. *Arch Neurol* 1961;5:171-8
- 28 Kimmel DL. The cervical sympathetic rami and the vertebral plexus in the human foetus. *J Comp Neurol* 1959;112:141-61
- 29 Kimmel DL. Innervation of the spinal dura mater and dura mater of the posterior cranial fossa. *Neurology* 1960;10:800-9
- 30 Lance JW. *Mechanism and Management of Headache*, 5th ed. Oxford: Butterworth Heinemann, 1993
- 31 Langemark M, Olesen J. Pericranial tenderness in tension headache. *Cephalalgia* 1987;7:249-55
- 32 Lord S, Barnsley L, Wallis B, Bogduk N. Third occipital headache: a prevalence study. *J Neurol Neurosurg Psychiatry* 1994;57:1187-90
- 33 Lous I, Olesen J. Evaluation of pericranial tenderness and oral function in patients with common migraine, muscle contraction headache and combination headache. *Pain* 1982;12:385-93
- 34 Martin BC, Fagan PJ. The surgical therapy of certain occipital headaches. *Plast Recon Surg* 1964;33:266-8
- 35 McCormick CC. Arthrography of the atlanto-axial (C1-C2) joints: technique and results. *J Intervent Radiol* 1987;2:9-13
- 36 Murphy JP. Occipital neurectomy in the treatment of headache. *Md State Med J* 1969;18:62-6
- 37 Olesen J, Tfelt-Hansen P, Welch KMA. *The Headaches*. New York: Raven Press, 1993
- 38 Olesen J. Some clinical features of the acute migraine attack. An analysis of 750 patients. *Headache* 1978;18:268-71
- 39 Olszewski J. On the anatomical and functional organization of the spinal trigeminal nucleus. *J Comp Neurol* 1950;92:401-13
- 40 Ouaknine G, Nathan H. Anastomotic connections between the eleventh nerve and the posterior root of the first cervical nerve in humans. *J Neurosurg* 1973;38:189-97
- 41 Penfield W, McNaughton F. Dural headache and innervation of the dura mater. *Arch Neurol Psychiatr* 1940;44:43-75
- 42 Robinson HS. Rheumatoid arthritis: atlanto-axial subluxation and its clinical presentation. *Can Med Ass J* 1966;94: 470-7
- 43 Sharp J, Purser DW. Spontaneous atlanto-axial dislocation in ankylosing spondylitis and rheumatoid arthritis. *Ann Rheum Dis* 1961;20:47-77
- 44 Stevens JS, Cartlidge NEF, Saunders M, Appleby A, Hall M, Shaw DA. Atlanto-axial subluxation and cervical myelopathy in rheumatoid arthritis. *Quart J Med* 1971;159: 391-408
- 45 Torvik A. Afferent connections to the sensory trigeminal nuclei, the nucleus of the solitary tract and adjacent structures. *J Comp Neurol* 1956;106:51-141
- 46 Travell JG, Simons DG. *Myofascial Pain and Dysfunction. The Trigger Point Manual*. Baltimore: Williams & Wilkins, 1983
- 47 Vital JM, Grenier F, Dautheribes M, Baspeyre H, Lavignolle B, Senegas J. An anatomic and dynamic study of the greater occipital nerve (n of Arnold). *Surg Radiol Anat* 1989;11:205-10