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An anatomic and dynamic study of the greater occipital nerve (n. of Arnold)

Applications to the treatment of Arnold's neuralgia

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Summary. This study concerns the posterior ramus of the second cervical spinal n., or greater occipital of Arnold. By means of dissections in formalin embalmed cadavers, an attempt was made to define its winding course and to locate it in relation to clinical or radiographic landmarks, so as to provide a guide for infiltration of the nerve with local anesthetic. At the same time a dynamic study was made to elucidate the relations of the nerve to adjacent structures during the different movements of the neck. This allowed us to propose clinical tests of nerve involvement and to reveal the zones where the nerve is anatomically vulnerable.

Etude anatomique et dynamique du nerf grand occipital (n. d'Arnold) — Applications au traitement des névralgies d'Arnold

Résumé. Cette étude porte sur le rameau dorsal du deuxième n. spinal cervical (ou grand n. occipital d'Arnold); nous avons voulu préciser, par des dissections sur cadavres formolés, le trajet sinueux de ce nerf, en essayant de le situer par rapport à des repères cliniques ou radiographiques, ceci afin de guider au mieux des infiltrations de ce nerf. De façon concomitante, il a été réalisé une étude dynamique pour reconnaître les rapports du nerf avec les éléments l'entourant lors des divers mouvements du cou, ce qui peut conduire à proposer des manœuvres cliniques sensibilisant les conflits et faisant apparaître les zones de vulnérabilité du nerf.

Key words : N. of Arnold — Arnold's neuralgia

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The greater occipital n., or posterior ramus of the second cervical n., has a winding course comprising a series of portions and angles as described in the classic works of Tillaux [21], Hovelacque [10], Villemin [23], de Ribet [20] and Guerrier [8]. Juskiewenski [11] and particularly Lazorthes [13, 14, 15, 16] who has made a specific study of this nerve and its exposure to compression at different points in its course. The symptomatology of such compressions has been clearly described by Pobeau [19] and Ehni [6]. Technical details of infiltration have been described by Arnold [1], Bogduk [3, 4] and Baret [2], of thermolysis by Horst [9] and of surgical release by Ody [18], Lang [12] and Mijares Grau [17]. One of the present authors [7] recently studied the changes in relations of the different parts of the nerve during movements of the neck, and the results allow us to suggest clinical tests to locate the zone of nerve compression.

Material and method

Material

This study was based on the dissection of 18 posterior rami of the second cervical n. in 9 formalin embalmed adult cadavers: 5 women and 4 men.

Two further cadavers were used to make frontal and transverse sections, by means of the cryomicrotome after paraffin embedding and freezing.

The nerve travelled in a space bounded by the capsule of the joint

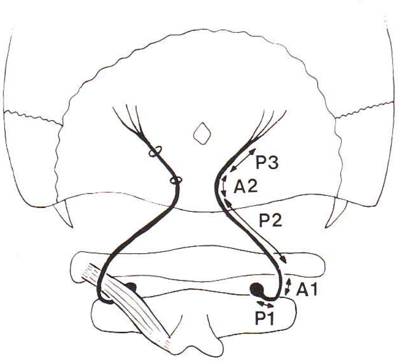


Fig. 1
The different portions of the greater occipital n. *P1* First portion, *P2* second portion, *P3* third portion, *A1* first bend, *A2* second bend

Les différentes portions du n. grand occipital. *P1* Première portion, *P2* deuxième portion, *P3* troisième portion, *A1* premier coude, *A2* deuxième coude

between C1-C2 in front and the lateral margin of the atlanto-axial membrane behind; it never crossed this membrane.

Its course seemed fairly constant: there were 3 portions and 2 bends (Fig. 1).

- The first portion (P1) runs obliquely downwards, outwards and backwards to reach the lower border of the inferior obliquus capitis muscle. The first bend (A1) turns more or less transversely round this muscle with its concavity directed upwards, forwards and inwards;
- The second portion (P2) now travels upwards and inwards to approach the ligamentum nuchae and is situated between 2 muscular layers: a superficial layer represented by the semispinalis capitis and a deep layer where the nerve successively crosses the dorsal aspect of the inferior obliquus capitis, rectus capitis posterior and rectus capitus anterior muscles. The second bend (A2) is where the nerve crosses the semispinalis capitis muscle, passing between its fibers to emerge at the surface near the midline. In none of our dissections was the nerve cramped in this muscular channel;
- The third portion (P3) travels upwards and outwards between the dorsal aspect of the semispinalis capitis and the deep aspect of the trapezius, where it is always flattened. In all our dissections the last part of this portion of the nerve perforated the trapezius at its tendinous area to become subcutaneous. The aperture in the trapezius was always narrow and rigid. In 13 cases the nerve traversed the trapezius before dividing into its terminal subcutaneous branches. In 5 cases it had already divided into its terminal branches, but these traversed the trapezius through the same orifice. In 1 case the medial branch was already separate and left by an independent opening.

Method

Three aspects of the nerve were studied: its topography, with special reference to the relations of its bends to the external occipital protuberance and the auricle; the projection of the nerve in anteroposterior and lateral cranio-cervical radiographs; variations of its course and relations during movements of flexion-extension and rotation of the head.

Topographic landmarks

Two points on the nerve were located: where it crossed the semispinalis capitis and where it perforated the trapezius to become subcutaneous.

These points were located by reference to the external occipital protuberance and to the auricle. To avoid error, the head was always placed in the reference position we have previously described [24], with the line between the nasion and opisthion horizontal.

The crossing of the semispinalis was located on average 11.5 mm lateral to the midline and 37.3 mm below a horizontal line through the external occipital protuberance.

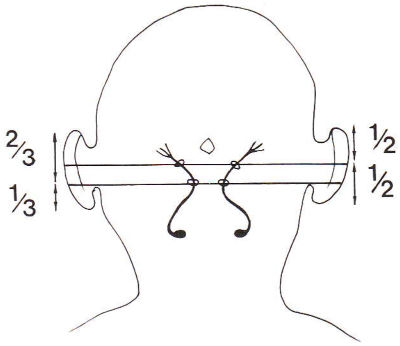


Fig. 2
Location by reference to the auricle. *Lower line:* passage through semispinalis m.; *upper line:* passage through trapezius m.

Mesure par rapport au pavillon de l'oreille. *Ligne inférieure :* traversée du m. semi-épineux; *ligne supérieure :* traversée du m. trapèze

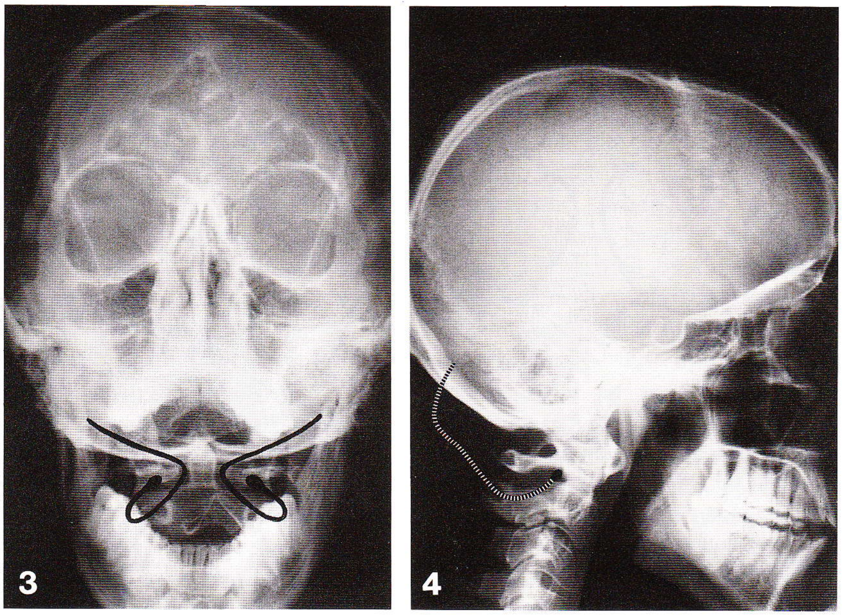
The crossing of the trapezius was located on average 31.8 mm from the midline and 22.2 mm below the external occipital protuberance. In 16 of the 18 cases, the crossing of the semispinalis was situated on a horizontal line through the junction of the middle and lower thirds of both auricles (Fig. 2), while the crossing of the trapezius was located on a horizontal line through the middle of the auricles. These measurements did not vary with head movement.

Radiologic location of the nerve and the ganglion of C2

A copper thread was fixed along the nerve from the ganglion to its termination in each dissected subject. Radiographs were then made using the following views: frontal, frontal with open mouth, frontal with petrous projection in the orbits, and lateral. Of these, the most useful were the open-mouth frontal and the lateral views.

The open-mouth frontal view (Fig. 3)

It shows the different portions and bends of the nerve. The most useful



Figs. 3, 4
3 Radiologic location of greater occipital n. (open-mouth view) **4** Radiologic location (lateral view)

3 Repérage radiologique du n. grand occipital (cliché de face, bouche ouverte) **4** Repérage radiologique (cliché de profil)

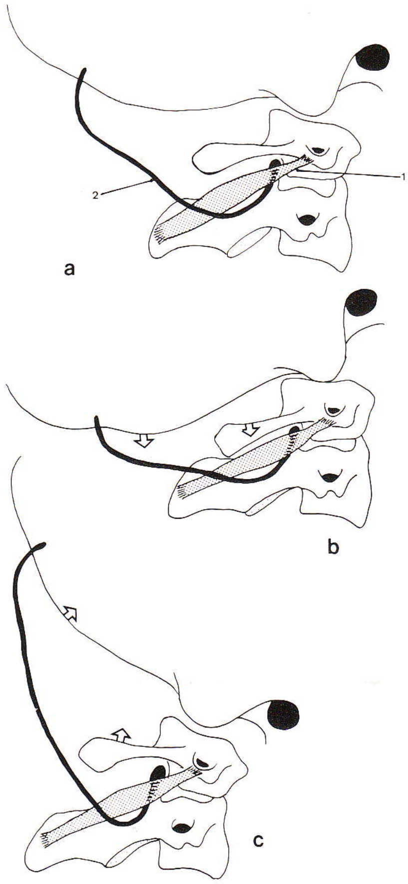


Fig. 5 a-c
Dynamics of nerve during flexion-extension movements of head (lateral view) **a** Rest position: *1* inferior obliquus capitis m. *2* greater occipital n. **b** extension **c** flexion: the inferior oblique capitis m. does not shift during this movement

Etude dynamique du n. grand occipital au cours des mouvements de flexion/extension de la tête (vue latérale) **a** Position de repos : *1* m. oblique inférieur de la tête *2* n. grand occipital **b** aspect en extension **c** aspect en flexion : au cours de ce mouvement le m. oblique inférieur de la tête ne bouge pas

landmark is the projection of the ganglion of the second cervical nerve, which lies regularly opposite the inferior articular process of the lateral mass of the atlas and extends laterally over the atlantoaxial joint. The point where the nerve crosses the semispinalis capitis is located between 0 and 15 mm below the line connecting the mastoid processes. The point where it traverses the trapezius is situated between 5 and 25 mm above the inter-mastoid line. However, these last two references are not very reliable as they vary considerably with a slight change of tilt.

The lateral film (Fig. 4)

The nerve describes a smooth curve with its concavity forward and upward. The ganglion of the nerve is projected just behind the inferior articular process of the lateral mass of the atlas, below the posterior arch. The nerve travels downwards and backwards to cross the upper border of the posterior part of the lamina and spinous process of the axis. At the level of the spinous process it runs upwards and backwards, becoming nearly vertical after reaching the semispinalis.

Behavior of the nerve during movements of the head
(Figs. 5, 6)

The bends A1 and A2 act as hinges where changes in direction occur. A1 separates P1 and P2 which have opposite directions and is displaced during movements. A2 separates P2 and P3 and forms an angle of 80-100° open outwards which opens or closes during movements of the head.

Behaviour of the nerve during flexion-extension movements of the head

Extension decreases the height of the posterior atlanto-occipital and atlanto-axial spaces. This approximates the 2 bends A1 and A2, while P2 becomes more horizontal in the frontal and sagittal planes. Extension opens the angle A1 (80-95°) in the sagittal plane and

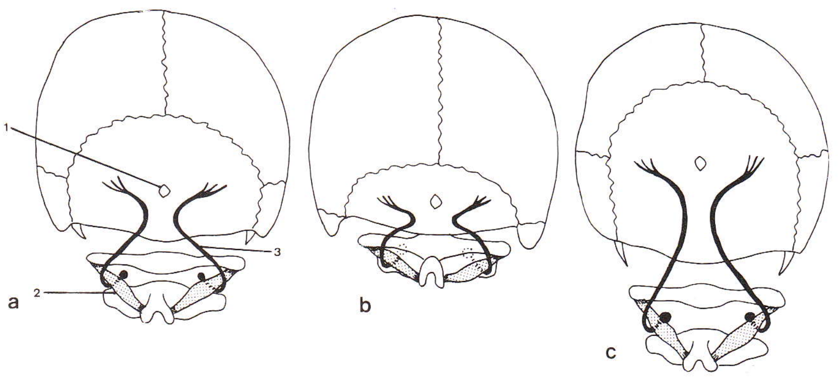


Fig. 6 a-c
Anatomic study of greater occipital nerve during flexion-extension movements of head, posterior view. **a** Rest position: *1* external occipital protuberance *2* inferior obliquus capitis m. *3* greater occipital n. **b** In extension: **c** In flexion. The angle A2 closes in extension and opens in flexion

Etude anatomique du n. grand occipital au cours des mouvements de flexion/extension de la tête, vue postérieure. **a** Position de repos : *1* protubérance occipitale externe *2* m. oblique inférieure de la tête *3* n. grand occipital **b** Aspect en extenstion **c** Aspect en flexion. L'angle A2 se ferme en extension et s'ouvre en flexion

closes the angle A2 in the frontal plane. The P2 portion is relaxed.

Flexion of the head increases the posterior atlanto-occipital and atlanto-axial intervals, separating A1 and A2 and making P2 more vertical. Angle A1 closes in the sagittal plane and angle A2 opens in the frontal plane.

In sum, during flexion-extension movements only P2 is mobile and flexion tends to stretch this portion. The inferior obliquus capitis muscle does not move and keeps the angle A1 fixed. If this muscle is divided, the angle A1 tends to move upwards and slightly inwards during flexion, eliminating the stretching of P2. P2 becomes more vertical and P1 more horizontal. Thus this muscle seems to play an important part in the stretching of the nerve in forced flexion movements.

Behavior of the nerve during rotational movements of the head (Fig. 7)

Here, the 2 nerves behave differently but movement and stretching of the nerve are less.

On the side of the rotation the lateral mass of the atlas, the ganglion of C2 as well as A1 and P1 are drawn backwards, causing closure of angle A1 and opening of angle A2. On the opposite side the converse is the case, the inferior obliquus m. being stretched.

It seems useful now to specify which segments of the nerve are stretched or compressed during the different movements.

- *Extension* does not appear to threaten any part of the nerve;

- *Flexion* stretches the posterior roots of C2 over the denticulate ligament and also stretches the P2 portion of the greater occipital nerve between A1 and A2;

- *Rotation* stretches the posterior root of C2 on the side opposite to the rotation;
- *Extension combined with contralateral rotation* narrows the space containing the ganglion of C2.

P3, which comprises the passage through the trapezius, is not affected during these movements.

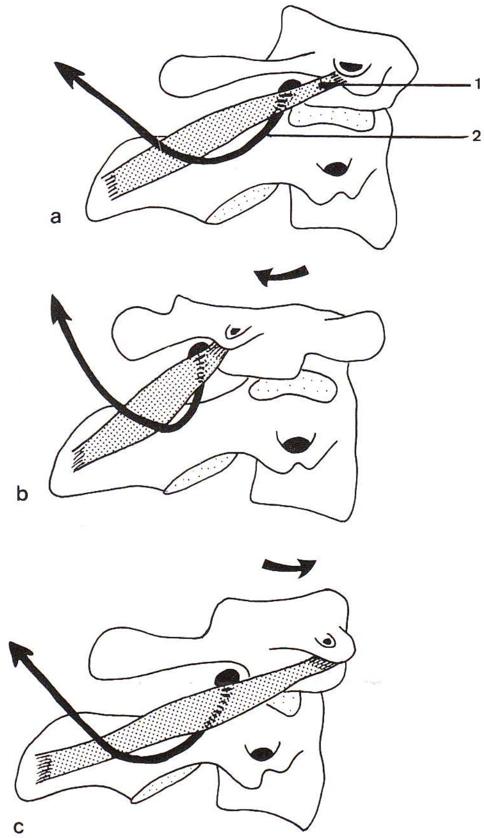


Fig. 7 a-c
Dynamic study of greater occipital n. during rotational movements of head. **a** Rest position: *1* inferior obliquus capitis m. *2* greater occipital n. **b** Lateral atlanto-axial joint on side of rotation: retraction of lateral mass of C1 and closure of angle A1 **c** Lateral atlanto-axial joint of side opposite rotation: the inferior obliquus m. is stretched on the side opposite the rotation

Etude dynamique du n. grand occipital au cours des mouvements de rotation de la tête. **a** Position de repos : *1* m. oblique inférieur de la tête *2* n. grand occipital **b** Articulation atlo-axoïdienne latérale du côté de la rotation : recul de la masse latérale de C1 et fermeture de l'angle A1 **c** Articulation atlo-axoïdienne latérale du côté opposé à la rotation : le m. oblique inférieur est étiré du côté opposé à la rotation

Discussion

There are 2 main points: the vulnerability of the nerve, mainly due to its muscular relationship, which may indicate surgical procedures; the localization of certain points on the nerve which can be easily identified for the performance of infiltration with local anesthetic.

Vulnerable points

The course of the greater occipital n. in the nuchal m. before entering the scalp accounts for the different mechanisms of nerve compression suggested by many authors. Our manipulations showed a surprising degree of mobility of the nerve during movements of the head. This may be analysed as follows:

Around the inferior oblique capitis (P1, A1, P2). Sturniolo, quoted by Lang [12] drew attention to possible compression of the nerve by the inferior obliquus m. He proposed an operation to divide the attachment of the muscle to the spinous process of the axis; having lost its inferior attachment, the muscle is drawn upwards and relaxes A1, P1 and P2. Lang performed this operation in 19 cases, but always combined with another procedure (laminectomy of the atlas with neurotomy, posterior arthrodesis or neurotomy), though in 1 case the operation was done without any additional procedure and with a good result. Sturniolo's concept is attractive and his simple treatment undeniably relaxes P1, A1 and P2. However, it is difficult to assess the efficacy of the method since the improvement obtained by Lang may have been due to the other procedures performed simultaneously.

Here, the nerve seems to be stretched rather than compressed as in entrapment syndrome. As we have seen, this stretching is exacerbated during flexion movement. Hence, if an occipital neuralgia is due to stretching of the nerve over the inferior obliquus m., flexion of the head should increase or reproduce the pain, as also deep pressure 2 cm lateral to and 1 cm below the spinous process of the axis.

During passage through the semispinalis capitis m. (A2). In our dissections, the nerve always traversed this muscle from deep to superficial aspects 1 cm lateral to the ligamentum nuchae. It passes between the muscle fibers and, as Bogduk suggests [3, 4], may be compressed when the muscle contracts. However, this hypothesis cannot be verified by dissection.

When perforating the trapezius. Bogduk states that the nerve does not perforate the trapezius but passes under an aponeurotic band stretched between the trapezius and sternocleidomastoideus m. He concludes that the nerve cannot be compressed by spasm of the trapezius since such spasm would draw the aponevrotic band downwards and away from the nerve. We have never encountered this band in our series, and if the nerve is dissected from within outwards it is easy to find the opening in the muscle.

However, the attachments of the trapezius and sternocleidomastoideus m. are joined over 2-3 cm, which may account for our disagreement with Bogduk. The trapezial orifice that we constantly found was always in the tendinous zone, where the nerve was always flattened.

We agree with Bogduk that contraction cannot compress the nerve here as the orifice is devoid of muscle fibers. On the other hand, a tendinitis at the trapezius insertion could irritate the nerve and the existence of an entrapment syndrome here is also possible.

Mijares Grau [17] attributes this canalicular entrapment syndrome to contracture of the trapezius, producing segmental ischemia of the nerve. He performed section of the trapezius combined with neurolysis in 42 patients with Arnold's neuralgia and obtained 88% of good results at 10-years follow-up.

Location of different points for nerve infiltration

The literature has little to say regarding infiltration of different segments of the nerve. Those techniques that have been reported involve the nerve at its emergence from the trapezius and, more recently, the ganglion of C2.

Infiltration of the nerve at its emergence and at its termination. Different authors give different sites of injection. Baret [2] injects the nerve 2 finger-breadths (3 cm) lateral to and slightly above the external occipital protuberance. Arnold [1] gives 2 points: one 5 cm lateral to the protuberance, one 6 cm lateral to and 3 cm above the protuberance. Horst [9] uses thermolysis of the nerve and inserts his needle 2 cm lateral to and 3 cm below the protuberance. The needle is perpendicular to the occipital squama and he skirts the squama when changing its direction. He obtained 78.1% of excellent results in 114 patients with Arnold's neuralgia.

In our study, the point of emergence from the trapezius was situated on average 3 cm lateral at and 2 cm below the occipital protuberance, with a range of 23-38 mm lateral to and 15-32 mm below the protuberance.

These variations are therefore considerable, but it seems that an injection above a horizontal line through the protuberance affects only the terminal branches of the nerve.

As Horst [9] has shown in his series, thermolysis gives good results, probably due to the sweep of the needle over the occipital squama.

Infiltration and thermolysis of the ganglion of C2. Bogduk [4], in 1981, proposed infiltration of the ganglion. He sited the point of entry of the needle at the middle of a line drawn between the transverse process of the atlas and the spinous process of the axis. The needle is passed from this point to contact the middle of the lateral atlanto-axial joint, successively traversing the trapezius, splenius capitis, semispinalis capitis and inferior obliquus capitis m. We agree with Bogduk, since in our study the C2 ganglion was always situated behind the lateral atlanto-axial joint.

However, there are 2 dangers. In front and laterally there is the vertebral a. (situated 6-12 mm in front of and lateral to the ganglion in our series), while the dural sac, which is very wide at this level, may be close in contact with the ganglion. Bogduk minimizes these risks by aspirating before injection and injecting only small amounts (3 ml). If the anesthetic block of the ganglion is effective, he proposes thermolysis of the ganglion for Arnold's neuralgia.

In conclusion, we specify certain clinical tests for compression of the nerve and the relevant therapeutic measures at each site:
- if a patient with Arnold's neuralgia has the pain provoked or exacerbated by extension and contralateral rotation of the head, this suggests compression of the ganglion. It is then logical to suggest anesthetic blocks of the ganglion and, if this is effective, thermolysis of the ganglion, postganglionic radiculotomy or extradural section seem the most suitable treatments;
- if pain is produced or increased by flexion of the head and/or pressure 2 cm lateral to and 1 cm above the spinous process of the axis, this rather suggests a syndrome of stretching of the second portion of the nerve, especially if there is a previous history of flexion injury. Here, Sturniolo's operation after assessment by infiltration seems the appropriate technique;
- neuralgia due to a canalicular entrapment syndrome at the level of the semispinalis should be improved by injection of the nerve where it traverses this muscle without residual cervical pain. Pressure 3-4 cm below and 1 cm lateral to the occipital protuberance should reproduce or exacerbate the pain;
- neuralgia with pain where the nerve emerges from the trapezius, unaffected by movements of the head, is in favor of a canalicular syndrome where it traverses the trapezius. Here, infiltration may be made at this point, but also more proximally where the nerve traverses the semispinalis as above.

If surgery seems indicated, the most logical procedure is to divide the trapezius where the nerve passes through the orifice in the muscle, with neurolysis of the P2 segment of the nerve.

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