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A SIMPLE AND PRACTICAL APPROACH TO UNDERSTANDING THE EXTRADURAL CAROTID SEGMENTS RELATED TO BOTH OPEN AND ENDOSCOPIC SKULL BASE

Background: *The understanding of the carotid anatomy is critical while operating within the cranial base. The internal carotid artery takes a complex course as it enters the cranium and travels a length extra-durally from inferio-lateral to superior-medial direction. Along its path, the carotid takes sharp turns and forms intimate relationships with bony and nervous structures, that serve as important landmarks in identifying the carotid segments. Many classifications have been proposed till date which have divided the carotid based on angiographic, cadaveric and endoscopic views. In this article, however, we proposed a simplified model to achieve a better understanding and correlation of the carotid segments to skull base structures.*
Methods: *This model is based on the cadaveric and intra-operative findings during skull base dissections, and serves important for both, open and endoscopic skull base views, with the later being commonly used in routine procedures as a minimally invasive intervention via endonasal approach.*
Results: *This model distinguishes the orientation of the carotid segments into horizontal and vertical planes, each corresponding to even and odd segments respectively. Based on the results of the observation, the nomenclature is retrograde to the carotid flow, that is, the C2 (intradural) segment is most superior, anterior and medial and C7 (para-pharyngeal) most inferior, posterior and lateral.*
Conclusion: *The understanding of carotid is very important in microsurgical and endoscopic skull base procedures. A simplified model serves important to correlate the relationship of the carotid throughout its extradural course in the skull base. It should be noted that variations among individuals occurs and this understanding will help preserve the carotid during complex open and endoscopic surgical procedures.*
Keywords: *Internal carotid artery, Microsurgery, Skull base anatomy, Endoscopic Surgery, Cerebrovascular surgery.*

Introduction

The study of the internal carotid artery is crucial to learning skull base surgery. Providing two-thirds of the cerebral circulation, the internal carotid artery follows a tortuous course as it ascends from the bifurcation of the common carotid in the neck, into the cranium, running extra-durally along the two sides of the cranial base, until it reaches the distal dural ring. From here, the internal carotid artery follows an intra-dural course. Throughout its course, the internal carotid artery takes sharp turns at almost right angles to its segments [1], illustrating a relationship to adjacent bony and neurovascular structures of the skull base. These anatomical landmarks help identify each segment, as well as its spatial position in the skull base.

Over the years, many classifications have been proposed by dividing the carotid in segments, some simpler than others depending on the utility they pursue. These classifications are based on angiography [2], cadaveric neuroanatomy [3,4], and vertical endoscopic views [5]. In this article, the authors propose a very simple model based on the fact that odd segments are vertical and even segments are horizontal - minor modification of the classification proposed by Professor Fukushima [6]. This learning model is based on the author's observations in more than 50 human cadaver skull base dissections.

The carotid segments – open skull base

In order to better understand the carotid anatomy, a two-dimensional model is used, assigning only vertical and horizontal orientations. Based on these orientations, we divide the internal carotid in 7 segments listed in the direction contrary to the blood flow, that is, starting from distal to proximal. Again the thing to remember would be that all vertical segments correspond to odd numbers and all horizontal segments correspond to even numbers. Each segment is named in accordance to its relationship with an adjacent structure as seen in Figure 1.

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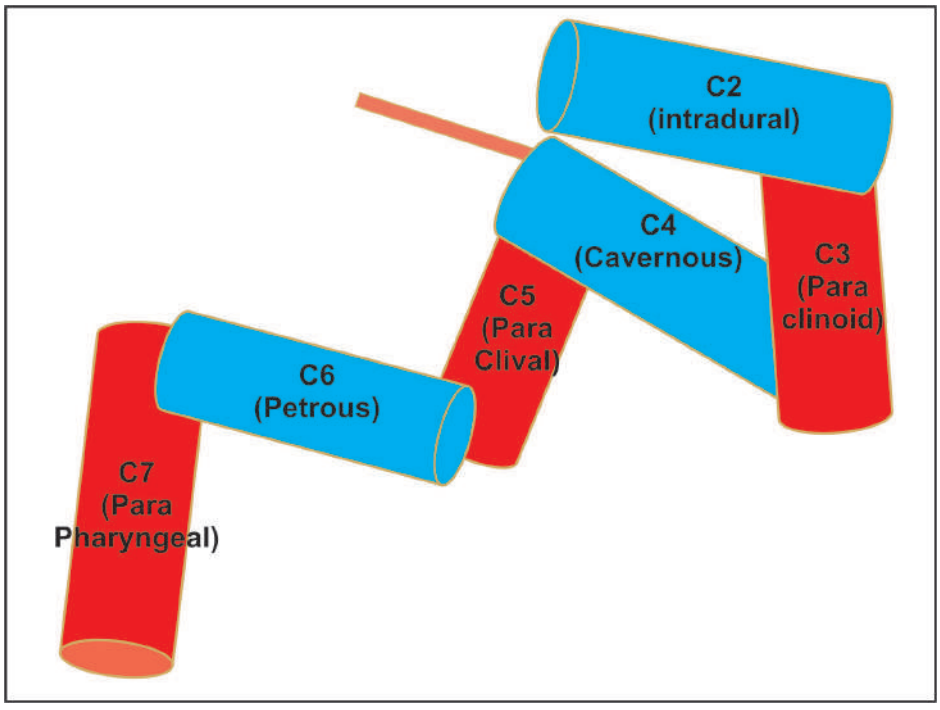

Figure 1 – Nomenclature of carotid segments with relation to adjacent structures.
The horizontal and vertical orientation of even and odd segments can be seen

The extradural internal carotid can be hence classified into the following segments:

C7: Cervical Segment or para-pharyngeal segment,
C6: Petrosal segment,
C5: Paraclival Segment,
C4: Cavernous horizontal segment,
C3: Paraclinoid or Parasellar segment and
C2: intradural segment.

C7 - Cervical or Para-phayryngeal Segment (Vertical):

The cervical segment ascends from the base of the neck up to the carotid canal. During this course, the majority of C7 runs extracranially, giving off no branches. Upon entering the carotid canal, the distal part of C7 makes a sharp 90° turn anteromedially to form the C6 or the intraosseous petrosal segment. The Cochlea serves as an important landmark to predict the location of the carotid curve from C7 to C6 (it is posterior and lateral to this curve) (Figure 2). However, care must be taken while exposing the cochlea during petrosectomy to avoid hearing loss [7].

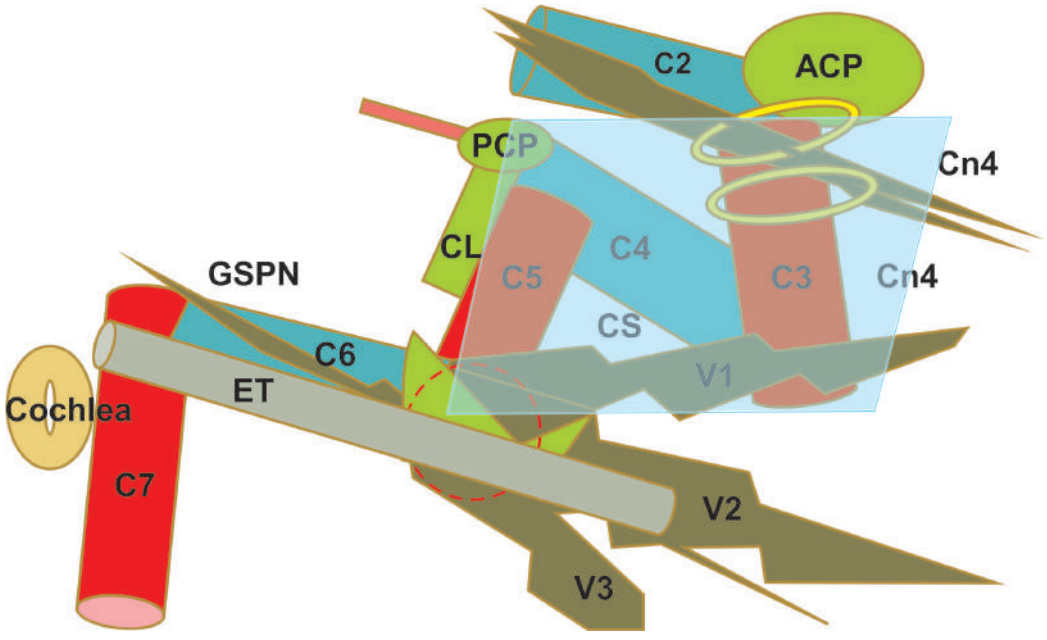

Figure 2 – The extradural course of Internal Carotid in relation to the adjacent structures. Note the close relationship of the Cochlea posterolateral to the Carotid Curve from C7 to C6.

ACP: Anterior Clinoid Process; CL: Clivus; CN 3: Occulomotor Nerve; CN 4: Trochlear Nerve; CS: Cavernous Sinus; ET: Eustachian Tube; GSPN: Greater Superior Petrosal Nerve; PCP: Posterior Clinoid Process; V1: Ophthalmic division of Trigeminal Nerve; V2: Maxillary division of Trigeminal Nerve; V3: Mandibular Division of Trigeminal Nerve

C6 - Petrosal Segment (Horizontal):

All of the C6 segment is intraosseous, within the petrosal bone. The greater superior petrosal nerve lies almost over the C6 carotid segment and can predict the course of the internal carotid at this level. Lateral to the C6 carotid if one drills into the temporal bone, the Eustachian tube is encountered.

The petrolingual ligament lies at the foramen lacerum, which marks the terminal part of the C6 segment and the proximal part of C5 segment which courses horizontally along the sides of the top third of clivus (Figure 3). Hence, the petrolingual ligament is an important landmark and is easy to identify as seen in Figure 3. The Gasserian ganglion lies lateral to petrolingual ligament and the proximal C5 segment and anterolateral to C6 segment. Throughout its course within the petrous bone, the C6 segment gives off the branch of the Vidian artery forming an ECA-ICA anastomosis within the Vidian canal [8]. The vidian canal and nerve are important landmarks during endoscopic surgery in accessing the anterior portion of the petrous carotid, anteromedial part of the cavernous sinus, and petrous apex [9].

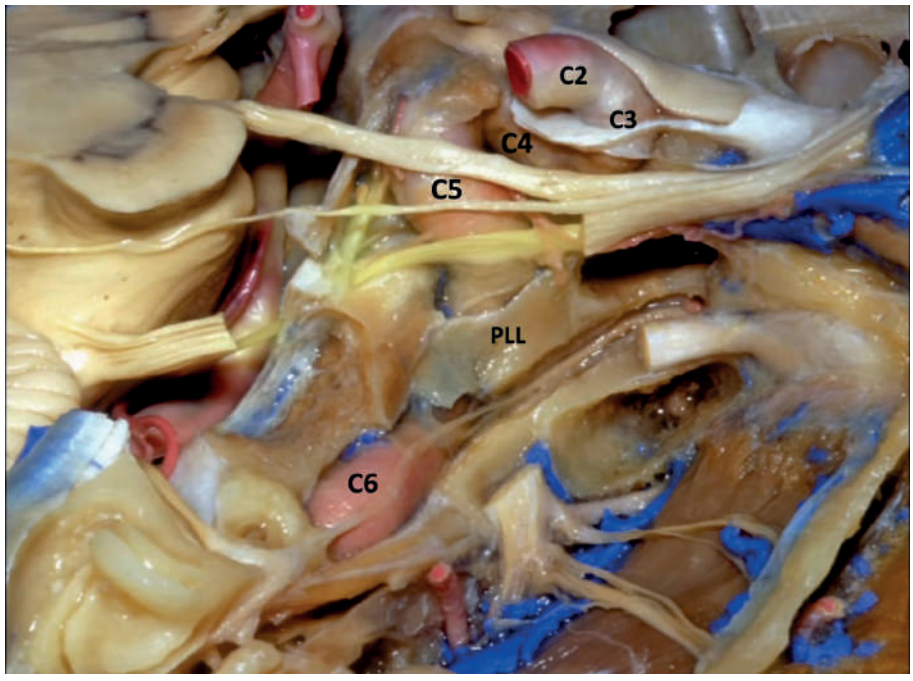

Figure 3 – The Petrolingual ligament in relation to C6 and C5 segments.
(Image Courtesy: The Rhoton Collection)

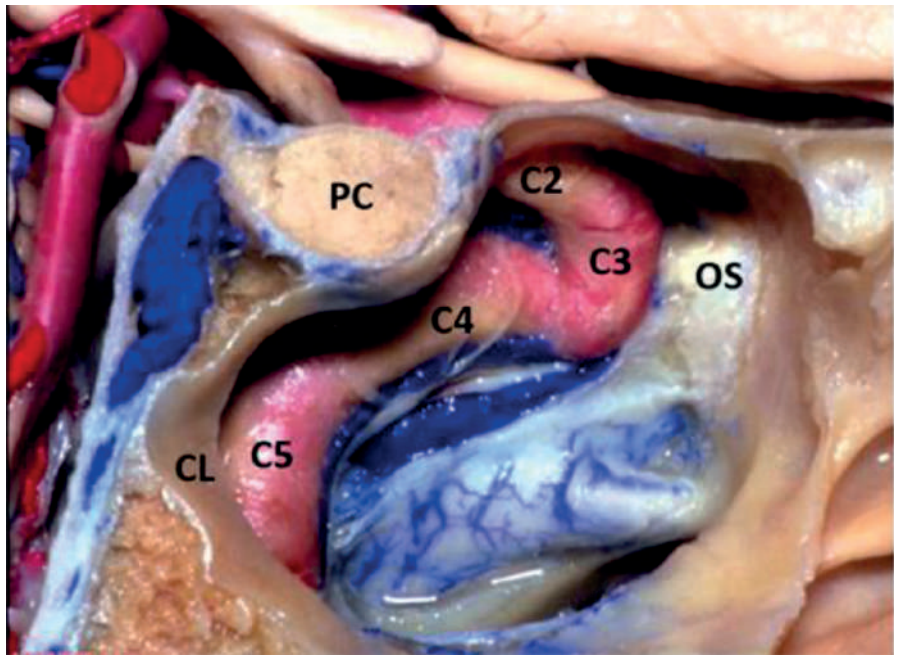

Figure 4 – The course of C5 along the clivus (CL), terminating at the Posterior Clinoid (PC) to continue as the C4 segment. The Optic Strut (OS) lies in close proximity to the C3 segment after which the extradural carotid ends its course and enters the intradural space forming C2 segment.
(Image Courtesy: The Rhoton Collection)

C5 - Para-clival Segment (Vertical):

The small proximal part of C5 segment is within the petrosal bone (more specifically in the foramen lacerum), however, it lies in a close relationship with the clivus and the dorsum sellae (Figure 4). This segment does not give off any branches and terminates at the Posterior clinoid process to take a horizontal turn forming the horizontal cavernous segment (C4).

C4 - Cavernous Segment (Horizontal):

The proximal part of C4 is related to the posterior clinoid process. The C4 segment travels horizontally

along the roof of the Cavernous sinus forming important relationships with adjacent structures and grooves the body of the sphenoid, where it is related laterally to the abducens nerve. The Cavernous Sinus completely covers the C4 segment, the distal part of C5 and the proximal part of C3 (Figure 5). Likewise, the cavernous sinus covers part of the cranial nerves III, IV, V1, V2 and part of the Gasserian ganglion [10,11].

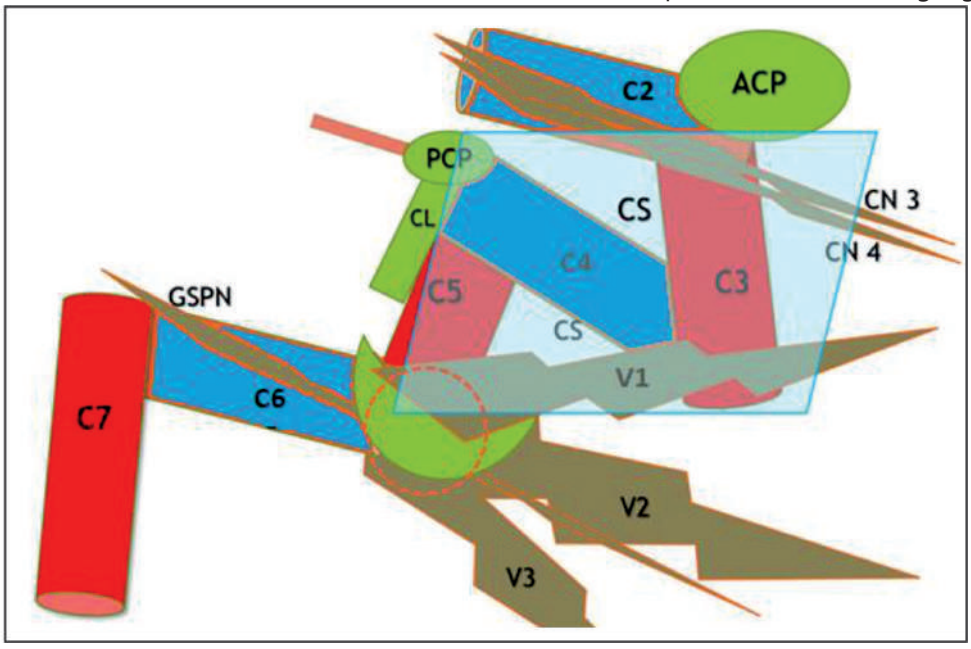

Figure 5 – Cavernous Sinus (CS) in relation to C5, C4 and C3 Segments.
ACP: Anterior Clinoid Process; CL: Clivus; CN 3: Occulomotor Nerve; CN 4: Trochlear Nerve; GSPN: Greater Superior Petrosal Nerve; PCP: Posterior Clinoid Process; V1: Ophthalmic division of Trigeminal Nerve; V2: Maxillary division of Trigeminal Nerve; V3: Mandibular Division of Trigeminal Nerve

C4 segment lies anterolateral to the first branch of the trigeminal nerve (V1). Together, they form the boundary of the Parkinson's triangle [12]. If one opens the space between the cranial 4 and V1, they can access the top of C5 and its junction with the C4 segment and the meningohypophyseal trunk which arises from the top of C5. Also if one laterally displaces the V1, one can visualize the sixth cranial nerve which runs in intimate relationship with the C4 segment. The most proximal part of C4 segment and the C3 segment is in relation to Cranial nerves III and IV. The C4 C5 junction usually contributes to the meningo-hypophyseal trunk.

C3 - Clinoidal or Para-sellar Segment (Vertical):

Closely related to the inferolateral parts of the anterior clinoid process, the clinoidal or para-selar segment; like the C4 segment, is covered completely by the cavernous sinus. Here, it forms important relations to the ophthalmic division of the trigeminal nerve at the proximal end and the third and fourth cranial nerves at the distal end. The C3 segment is practically delimited by the proximal and distal dural rings after which it enters the dura to form the intra-dural part (Figure 6). The carotid cave is an intradural pouch, found in the paraclinoid area between the distal and the proximal dural ring [13].

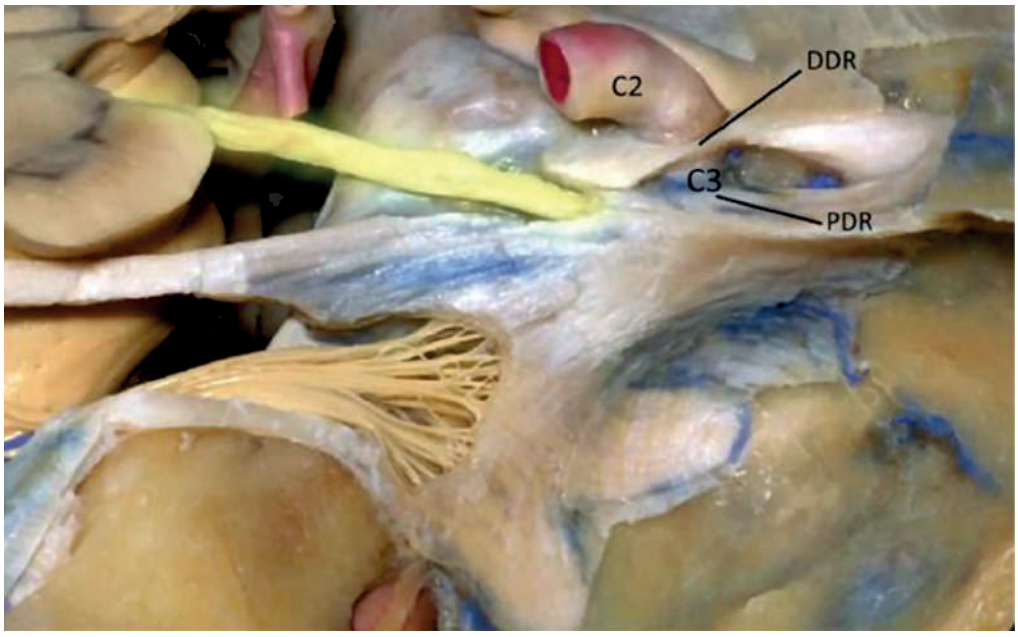

Figure 6 – Transition of Extradural Carotid (C3) into Intradural (C2). The Proximal dural ring (PDR) and the Distal Dural Ring (DDR) delimit the C3 segment.
(Image Courtesy: The Rhoton Collection)

C2 - intra-dural segment (Horizontal):

The terminal part of the extradural carotid is the C2 or the intradural segment. This is formed after the CS segment exits the distal dural ring, and the carotid takes a sharp horizontal turn to enter the dura. The C2 lies in close proximity to the optic nerve and forms an important window to reach the basal cisterns after the complete removal of the anterior clinoid process. The C2 then divides into anterior and middle cerebral arteries supplying the structures of the brain.

Once a true understanding of the carotid segments and their orientation is achieved, one can easily visualize the course of carotid on a microscopic field as shown in Figures 7 and 8:

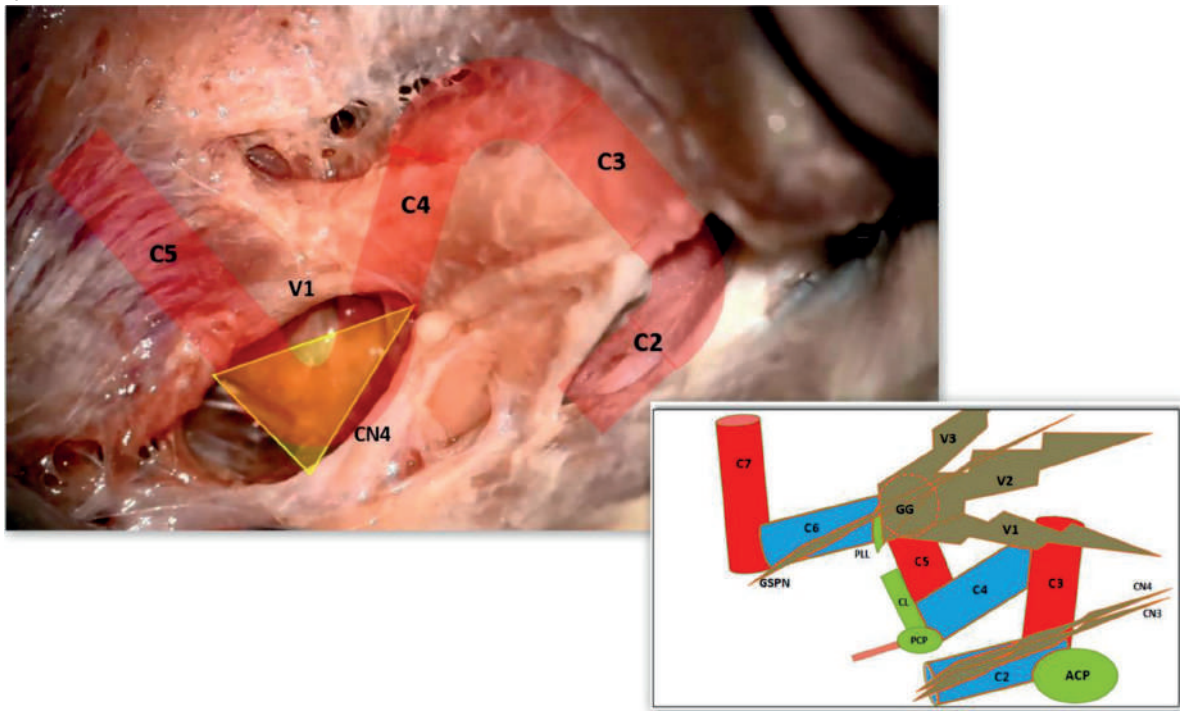

Figure 7 – Overview of the extradural carotid course. It is easy to map the schematic proposal (lower right image) onto the real dissection image (top). Notice the Infratrochlear (Parkinson's) triangle (yellow)

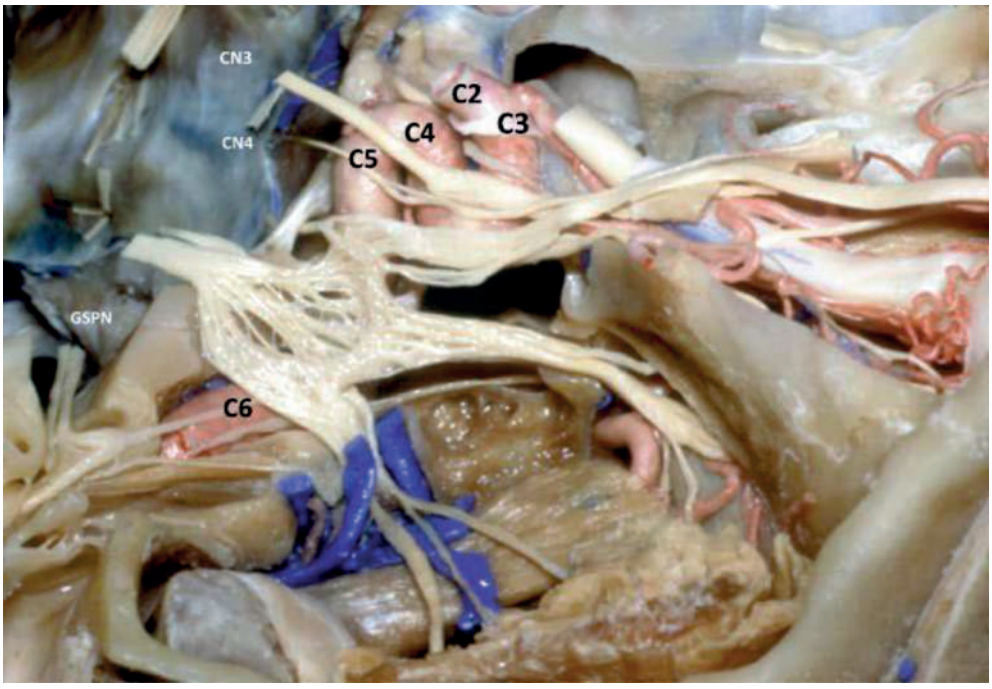

Figure 8 – Overview of the extradural carotid course (Image Courtesy: The Rhoton Collection)

Endoscopic skull base and the carotid artery

The frequent use of an Endoscopic Endonasal Approach (EEA) in skull base surgery warrants the study of the carotid segments. EEAs provide access to the ICA from its cavernous to the parapharyngeal segments [5,14]. An endoscopic view just turns the perspective to another 90 degrees from a lateral to the front. The carotid system is now looked at from the front.

Therefore, it is only common sense that the vertical segments would be more easily seen and these are actually the named segments in endoscopic anatomy (Figure 9).

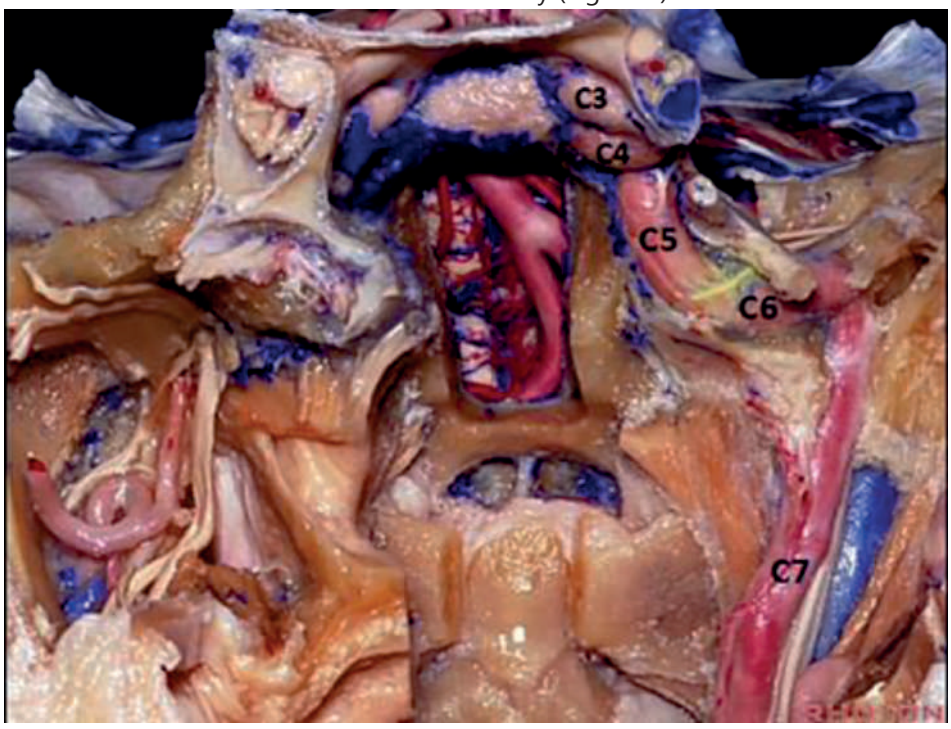

Figure 9 – Endoscopic view of the extradural carotid as seen through an endonasal approach. Note the orientation of the horizontal and vertical segments (Image Courtesy: The Rhoton Collection)

The most anterior and the superior one would be the vertical C3 which is the parasellar segment, the top of which is the paraclinoidal segment. Slightly posterior and inferior would be the C5 segment which is the paraclival segment and laterally one can find the vertical C7 segment with infra laceral drilling using a transpterygoid approach. The C4 and C6 segments are "end on view" for the endoscopic surgeon and they can be made out because both segments have a lateral curvature.

In another common view, the C3 (parasellar) and C5 (paraclival) carotid can be visualized related to the sella and the clivus as shown in Figure 10:

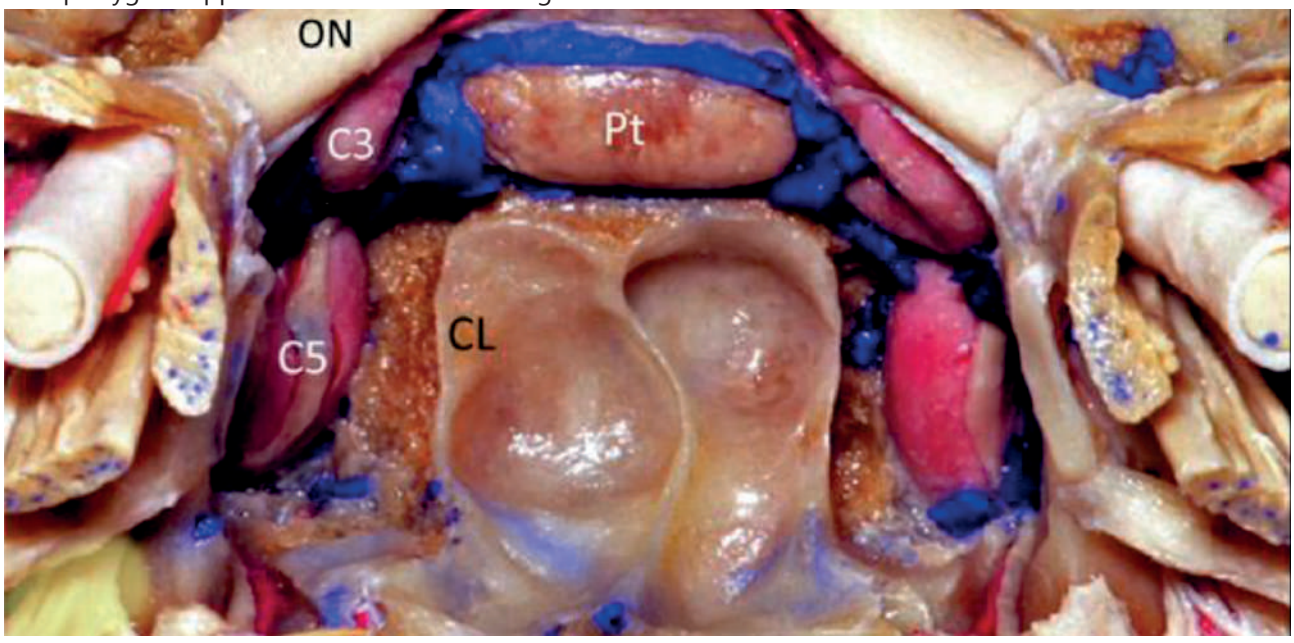

Figure 10 - C3 and C5 segments in relation to the sella and clivus respectively

Conclusion:

The tortuous course by the carotid artery and its intimate extradural relationship to the skull base structures makes it crucial to fully understand it. This simple method will help young neurosurgeons to identify the carotid segments with respect to horizontal and vertical planes and important landmarks, that will be helpful to perform complex microsurgical procedures preventing damage to the internal carotid artery. It should, however be noted that anatomical variants do exist between patients and care has to be taken to identify and respect the variant anatomy for best surgical results.

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БАССҮЙЕК НЕГІЗІНДЕГІ АШЫҚ ЖӘНЕ ЭНДОСКОПИЯЛЫҚ ХИРУРГИЯ КЕЗІНДЕГІ ЭКСТРАДУРАЛДЫҚ КҮРЕТАМЫР СЕГМЕНТТЕРІН ТҮСІНУ ҮШІН ОҢАЙ ӘРІ ҚОЛАЙЛЫ ТӘСІЛ

Кіріспе: Ұйқы күретамырының анатомиясын түсіну бассүйек негізіне хирургия жасау кезінде шешуші мәнге ие. Ішкі ұйқы күретамыры күрделі жолдардан өтеді, себебі бассүйек қорабынан кіріп, сырттай төменгі-бүйір жақтан жоғарғы-медиалдық бағытқа қарай созылады. Өз жолында ұйқы күретамыры кілт бұрылыстар жасайды және ұйқы күретамырының сегменттерін айқындауда маңызды белгілер болып табылатын сүйек және жүйке құрылымдарымен тығыз қарым-қатынасқа түседі. Осы уақытқа дейін ұйқы күретамырын ангиографиялық, мәйіттік және эндоскопиялық кескіндер негізінде қарастыратын көптеген жіктемелер ұсынылды. Алайда бұл мақалада біз ұйқы күретамыры сегменттерінің бассүйек негізімен корреляциясын жақсырақ түсіну үшін қарапайым үлгіні ұсынамыз.

Әдістер: Бұл үлгі бассүйек негізінің мәйіттік және интраоперациялық материалдарына негізделеді және бассүйек негізінің ашық және эндоскопиялық хирургиясында қолданылады. Бұл ретте, эндоскопиялық әдіс эндоназалдық жолмен жасалатын минималды инвазиялық хирургия ретінде күнделікті қолданылады.

Нәтижелер: Бұл үлгі ұйқы сегменттерінің көлденең және тік жазықтықтарда бағдарлануын көрсетеді, олардың әрқайсысы тиісінше жұп және тақ сегменттерге сай келеді. Бақылау нәтижелеріне сәйкес номенклатура ұйқы күретамырына қатысты кері мәнге ие, яғни C2 (интрадуралды) сегмент ең жоғарғы, алдыңғы және медиалдық, ал C7 (парафарингеалды) ең төменгі, артқы және бүйірлік болып табылады.

Қорытынды: Ұйқы күретамырының анатомиясын білу бассүйек негізіне микрохирургиялық және эндоскопиялық процедуралар жасау кезінде аса маңызды. Бұл қарапайым үлгі ұйқы күретамырының бассүйек негізіндегі сырттай жолының барлық бойындағы байланыстарының корреляциясында маңызды рөлге ие. Адамдарда айрмашылықтар кездесетіндігін атап өткен жөн және мұны түсіну күрделі ашық және эндоскопиялық хирургиялық процедуралар кезінде ұйқы күретамырына зақым келтірудің алдын алуға көмектеседі.

Негізгі сөздер: ішкі ұйқы күретамыры, микрохирургия, бассүйек негізі анатомиясы, эндоскопиялық хирургия, цереброваскулярлық хирургия.

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ПРОСТОЙ И ПРАКТИЧНЫЙ СПОСОБ ДЛЯ ОРИЕНТИРОВАНИЯ В ЭКСТРАДУРАЛЬНОМ СЕГМЕНТЕ СОННЫХ АРТЕРИЙ ПРИ ОТКРЫТОЙ И ЭНДОСКОПИЧЕСКОЙ ХИРУРГИИ ОСНОВАНИЯ ЧЕРЕПА

Введение: Понимание анатомии сонной артерии имеет решающее значение при хирургии основания черепа. Внутренняя сонная артерия проходит сложный путь, поскольку она входит в черепную коробку и перемещается экстрадурально от нижне-бокового к верхне-медиальному направлению. На своем пути сонная артерия совершает крутые повороты и образует тесные связи с костными и нервными структурами, которые служат важными ориентирами при выявлении сегментов сонной артерии. До настоящего времени было предложено много классификаций, которые выделяли сонную артерию на основе ангиографического, трупного и эндоскопического изображений. Однако в этой статье мы предложили упрощенную модель для лучшего понимания и корреляции сегментов сонной артерии с основанием черепа.

Методы: Эта модель основана на трупных и интраоперационных материалах основания черепа и применима как для открытого, так и для эндоскопического доступов. Эндоскопический метод обычно используется рутинно в качестве минимально инвазивного вмешательства при эндоназальном доступе.

Результаты: Предложенная модель отображает ориентацию сонных сегментов в горизонтальной и вертикальной плоскостях, каждая из которых соответствует четным и нечетным сегментам соответственно. Согласно результатам наблюдения, номенклатура ретроградна по отношению к сонной артерии, то есть C2 (интрадуральный) сегмент является наиболее верхним, передним и медиальным, а C7 (парафарингеальный) наиболее нижним, задним и боковым.

Вывод: Знание анатомии сонной артерии очень важно при микрохирургических и эндоскопических процедурах на основании черепа. Упрощенная модель играет важную роль в корреляции взаимосвязей сонной артерии на всем протяжении ее экстрадурального хода в основании черепа. Следует отметить, что различия у людей встречаются, и это понимание поможет избежать повреждения сонной артерии во время сложных открытых и эндоскопических хирургических процедурах.

Ключевые слова: Внутренняя сонная артерия, микрохирургии, анатомия основания черепа, эндоскопическая хирургия, цереброваскулярная хирургия.