Nota HISTÓRICA

Binswanger and the carotid sinus

Binswanger e o seio carotídeo

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ABSTRACT

The 'carotid sinus' is an arterial dilatation placed usually at the beginning of the internal carotid artery. The medial wall of this dilatation appears modified, with a reduction of the media, and an increase of the adventitia, besides containing nervous terminations, forming thus a sensorial structure. This dilatation was possibly first observed by John Bell (1808), and clearly described and named by Cruveilhier (1834). However, many authors credited the initial finding to Burns (1811), followed by a number of researchers, as Luschka (1862), Manson (1866), Meyer (1876), Schäfer (1878), most with a view related to aneurysm formation, but some seeing the formation as a normal trait. Finally, Binswanger (1879) reaffirmed that the dilatation meant a normal feature of the region, based on his own observations, and on the opinion of some forerunners. Besides, he was the first to classify this dilatation regarding the variability of its localization. The thinning of this region was initially identified by Meyer (1876) and detailed by Binswanger (1879), at bare eye visual inspection and on microscopic examination, observing there an important reduction of the width of the tunica media. Despite Meyer's effort, and mostly Binswanger's, the microscopic findings are incipient, what can be explained by the limitations of the histological techniques at the time. However, there is no doubt that Binswanger and his forerunners provided important information for the upcoming research, comprising the structure, innervation, and function of this formation.

Keywords: internal carotid artery, carotid sinus, sinus wall, gross structure, microscopic structure

RESUMO

O 'seio carotídeo' é uma dilatação arterial situada geralmente no início da artéria carótida interna. A parede medial dessa dilatação apresenta-se modificada, com redução da média e aumento da adventícia, além de conter terminações nervosas, constituindo assim uma estrutura sensorial. Essa dilatação foi possivelmente observada primeiro por John Bell (1808) e claramente descrita e denominada por Cruveilhier (1834). Entretanto, muitos autores creditam o achado inicial a Burns (1811), seguido por numerosos pesquisadores, como Luschka (1862), Manson (1866), Meyer (1876), Schäfer (1878), a maioria com olhar relacionada à formação de aneurisma, mas alguns vendo a formação como uma característica normal. Finalmente, Binswanger (1879) reafirmou que a dilatação representava um aspecto normal da região, baseado em observações próprias e na opinião de alguns de seus antecessores. Além disso, foi o primeiro a classificar essa dilatação quanto a variabilidade de sua localização. O adelgaçamento dessa região foi identificado inicialmente por Meyer (1876) e detalhado por Binswanger (1879), à inspeção visual a olho nu e ao exame microscópico, observando lá uma importante redução da espessura da túnica média. Apesar do esforço de Meyer e sobretudo de Binswanger, os achados microscópicos são incipientes, o que pode ser explicado pelas limitações das técnicas histológicas daquele tempo. Todavia, não há dúvida que Binswanger e seus precursores proveram importante informação para as pesquisas que se sucederam, compreendendo a estrutura, inervação e função dessa formação.

Palavras-chave: artéria carótida interna, seio carotídeo, parede sinusal, estrutura macroscópica, estrutura microscópica

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INTRODUCTION

The 'carotid bulb' or 'carotid sinus' (*sinus caroticus*) is a somewhat dilated segment localized, more frequently, at the proximal part of the 'internal carotid artery'. The sinus is usually fusiform or triangular in shape but bulges more on its dorsolateral aspect. This region is supplied by a rich innervation originated from several sources, and functions as a baroreceptor.[1,2,3,4]

There are variations regarding the seat of the carotid sinus (bulb) region. The commonest site of the sinus is the origin of the 'internal carotid artery' (74.3%), being also found in the distal part of the 'common carotid artery' (17.1%), at the bifurcation involving the distal 'common carotid artery' and origins of its primary branches (7.32%), and at the origin of the 'external carotid artery' (1.22%). In individual cases, the sinus was located at the origin of the 'internal carotid artery' (97.6%) on at least one side. The sites of the sinus may be also asymmetrical (34.1%).[5]

The 'carotid sinus' region has a differentiated microstructure in relation to other segments of the carotid artery. The 'common carotid artery' is of an elastic conducting type, with a thick tunica media containing many elastic laminae running roughly parallel with one another, tightly packed smooth muscle fibres, and few small elastic and collagen fibres. The sinus region, in contrast, presents an abrupt and marked thinning of the media, restricted to the medial wall of the vessel, meaning, the side facing the angle of the bifurcation, where the 'carotid body' lays. The tunica media contains a number of elastic fibre layers, and alternating (single) smooth muscle layers, with a predominant circumferential arrangement with respect to the long axis of the artery, constituting the 'elastic segment'. Distally to the 'carotid sinus' the media of the internal carotid artery recovers its typical structure. The tunica adventitia of the sinus is much thicker than that of the adjacent arterial segments, the inner zone containing mainly collagen fibres which appear as separate lamellae interspersed with a few irregular elastic fibres, many cells, and smooth muscle, most arranged circumferentially, and nerve fibres, while the outermost zone contains numerous thick elastic fibres with a defined arrangement into regularly spaced layers, with numerous interstices through which collagen fibres pass, besides vasa vasorum. The tunica intima at the medial wall of the 'internal carotid artery' facing the bifurcation angle is formed by an endothelial lining and an underlying basement membrane, and appears normal according to most authors.[2,4,6,7,8,9,10,11,12,13]

HISTORICAL PERSPECTIVE

The carotid system is being studied since antiquity, and the carotid artery and its bifurcation were described, initially by Galenus, in animals,[14,15] and much later, in humans, by Vesalius.[16] However, the dilated sinus region was apparently identified, for the first time, by the brothers Bell, John Bell (1763-1820) and Charles Bell (1774-1842), Scottish surgeons, and anatomists, who described and depicted the arterial system. Regarding the carotid anatomy, John described in volume II of his "The Anatomy and Physiology of the Human Body" (1808): "The internal carotid artery leaves the external carotid at the angle of the jaw: it is so inclined to contortions, that at this point it even bulges...". Charles depicted this region in his 'Engravings of the Arteries' (Plate V) (1824) a right-sided view of a dissected head and neck displaying the 'common carotid artery' and its bifurcation, showing a possible fusiform bulge of the beginning of the 'internal carotid artery'.[17,18]

However, many authors credit to Allan Burns (1781-1813), Scottish surgeon and anatomist, the initial description of a slight bulbous dilatation found at the beginning of the 'internal carotid artery', at its origin from the common carotid, first regarded as an aneurysmatic formation, in his book "Observations on the surgical anatomy of the head and neck" (1811) as follows: "The carotid artery becomes frequently cartilaginous [atheromatous], or earthy matter is deposited in its structure. This weakens the artery, and paves the way for rupture of the internal coat and 'tissu arteriel', followed by dilatation of the membranous coat and external covering. It lays the foundation of aneurism, which is generally seated at the bifurcation of the carotid. I have repeatedly, in the dead subject, met with a dilatation of the common carotid and root of the internal carotid, forming a cyst nearly as large as a filbert nut; and I have twice felt a similar state of the vessel in the living body. In some of the former cases, the texture of the artery was altered, but in most of them the dilatation had taken place, independently of any organic disease of the coats. In the two instances in which the artery was enlarged in the living subject, the patients experienced no inconvenience, nor for some months, during which I had an opportunity of seeing them, did the dilatation seem to advance".[19,20,21]

Later, Jean Cruveilhier (1791-1874), French anatomist and pathologist, who provided a detailed description of the carotid arteries, remarks in his book "Descriptive Anatomy" (*Anatomie Descriptive*) (1834): "The site of this bifurcation is furthermore remarkable by a kind of bulb (ampulla) or bulge presented by the common carotid" (*Le lieu de cette bifurcation est encore remarquable par une sorte d'ampoule ou de renflement que présente le carotid primitive*).[22] Thus, he described in a clear way a dilatated segment of the carotid artery, illustrated only later (1867) - the dissected specimen, a right-sided view of the bifurcation of the common carotid artery, shows, what was described as the 'ampulla' [bulb] of the common carotid artery, and although in an indistinct way, a slight fusiform dilatation of the beginning of the internal carotid artery is shown.[22,23]

Next, came Hubert von Luschka (1820-1875), German anatomist, who in his book "The Anatomy of Man in Relation to the Needs of Practical Medicine" (*Die*

Anatomie des Menschen in Rücksicht auf die Bedürfnisse der praktischen Heilkunde 1.1) (1862), describes the 'internal carotid artery' and comments about its calibre, as follows: "... The thickness in adult humans, however, is usually not uniform over the entire course, but the artery usually has a slight spindle-shaped widening at the beginning... This dilation, to some extent [is] representative of the normal prototype of a fusiform aneurysm..." (*...Die dicke ist jedoch beim erwachsenen Menschen in der Regel nicht im ganzen Verlauf gleichörmig, sondern es besitzt die Ader an ihren Anfang gewöhnlich eine leichte spindelförmige Aufbreitung... Diese, gewissermaassen den normalen Prototyp eines Aneurysma fusiforme repräsentirende...*).[24]

Luschka was followed by Patrick Manson (1844-1922), Scottish physician, who performed post-mortem examination of mentally sick and other kind of cases (n=17), and dissecting the large arteries of the neck, found what he called a "...a peculiar dilatation of the 'internal carotid artery'...invariably involved the first part of the vessel, the remaining portion of the artery being of normal appearance...In some cases the shape of this small aneurism...I do not regard this lesion as confined to the insane...". He published his observations as "Peculiar affection of the internal carotid artery in connexion with disease of the brain" (1866).[25]

This period of research on the theme was closed by Meyer, of the Provincial Institute and Psychiatric Clinic in Goettingen, and Binswanger, who joined the institution, both working together for a time.[26] Both, as well as Schäfer, performed microscopic examination of the region.

Ludwig Meyer (1827-1900), German psychiatrist, studied the internal carotid artery of autopsied mentally ill persons, published as "On aneurysmal changes in the internal carotid of mentally ill" (*Ueber aneurysmatische Veränderungen der Carotis interna Geisteskranker*) (1876). There, he describes the results of the examination of a large number of cases (n=31), where he observed circumscribed ring-shaped (annular) changes of the arterial wall, mostly starting at the origin of the internal carotid artery, and extending upward for a short distance (8-10 mm), sometimes extending slightly downward to the common carotid, beginning and ending sharply and suddenly. His bare eye observation revealed that "on opening the carotid artery and holding the thinned part up to the light, it let the luminosity shine through easily, and when laid on the table-top, the thin region showing depressions that when blown-up appear as small bulges (ectasias)". This thinning appears sharply, localized at the origin of the 'internal carotid artery', extending to the 'external carotid artery', close to the spur-like projection formed internally by the junction of the two arteries. Such "circumscribed thinning of the arterial wall", according to him, was revealed for the first time. The observation of sections of the arterial wall hardened with 'chromic acid' reveals that the intima is histologically intact, and the media extraordinarily thinned(Figure 1 of Meyer's paper)(Figure 1). There, the internal carotid shows a dilatation, and in eight of the cases reached a state of a "complete aneurysm" (*vollständigen Aneurysmen*). The dilatation, regarding the form, is fusiform, frequently half-fusiform, or bottle-shaped.[27]

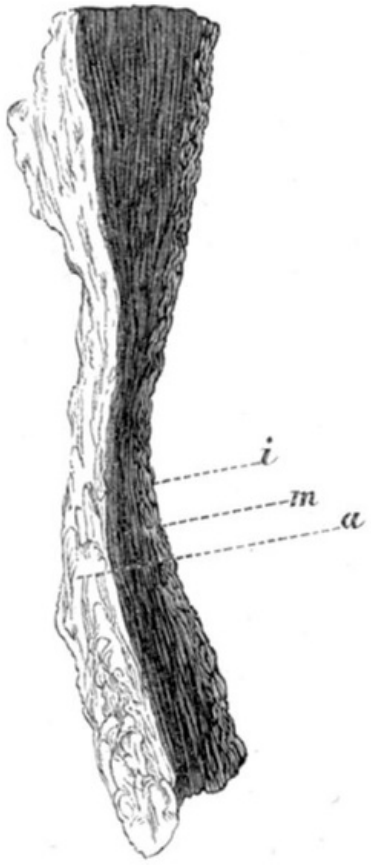

Figure 1. "Section through a very thinned and bulged place of the vessel wall of the internal carotid" [a=adventitia, m=media, i=intima].[28]

Interposed between the studies of Meyer and Binswanger, appeared that of E.A. Schäfer who identifies the 'bulb' (*bulbus*) of the 'internal carotid artery', and discusses the possible aneurysmatic nature of this formation. He examined post-mortems of mentally sick and mentally sound cases (n=60), and observes that the initial segment of the internal carotid artery is usually somewhat more dilated than the common carotid, and possesses a peculiar shape. He stated: "It is striking that the dilatation of the internal carotid at its beginning exceeds so rarely the limits within which it is of no meaning at all for the life or for the health". He found that the intima, at this level was thicker, and the segment was opaquer to transillumination. The microscopic examination revealed there an increase of the streaky layers [elastic fibres?] together with an increase of the cellular elements on the side of the media. Circumscribed thinning of the wall, as emphasized by Meyer (see above), was found only a few times. His study was published as "On the aneurysmatic dilatation of the internal carotid at its origin" (*Ueber die aneurysmatische*

Erweiterung der Carotis interna an ihrem Ursprung) (1878).[28]

After a short time, Binswanger took over Meyer's research, expanding and detailing the knowledge on the subject.

Otto Ludwig Binswanger (1852-1929) (Figure 2), a Swiss psychiatrist and neurologist, while working under Meyer's lead, seemingly continued one of his studies. He examined in cadavers the way the 'common carotid artery' bifurcates, and the aspect of the beginning of the 'internal carotid artery', published as "Anatomical studies of the place of origin and of the initial part of the internal carotid artery" (*Anatomische Untersuchungen über die Ursprungsstelle und den Anfangsteil der Carotis interna*) (1879), one of his first scientific studies.

Figure 2. Otto Binswanger Source: Berger H. Otto Binswanger (obituary), 1930 [05-11-2022] https://commons.wikimedia.org/wiki/File:Otto_Binswanger.jpg

Regarding macroscopic features he observes that the beginning segment of the internal carotid artery among adults, with very few exceptions, presents always a 'bulbar dilatation' (*bulbäre Erweiterung*). Such dilatation, in almost half of the cases, was restricted to the 'internal carotid artery', extending to the common carotid bifurcation level. He also observed, on naked eye inspection, the presence of a thinned region on the medial wall of the dilatation, turned to the bifurcation angle, which at transillumination reveals a sieve-like appearance, alternating sclerotic thicker and bulging thinner sites. He observed that the manner of bifurcation of the common carotid artery, and the seat of the bulbar dilatation, presented diverse locations. Regarding the variability of the latter, he classified the cases into 3 groups, as those [1] restricted to the beginning of the internal carotid artery, [2] pertaining to the bifurcation level, i.e., at the common carotid, and extending slightly to the beginning of its ramifications, and [3] beginning at the bifurcation level and extending to the internal carotid. Such findings corresponded to almost all cases he has observed, and the examined cases (n=182) revealed 81 pertaining to group [1], 42 to group [2], and 59 to group [3] (Figure 3).[29]

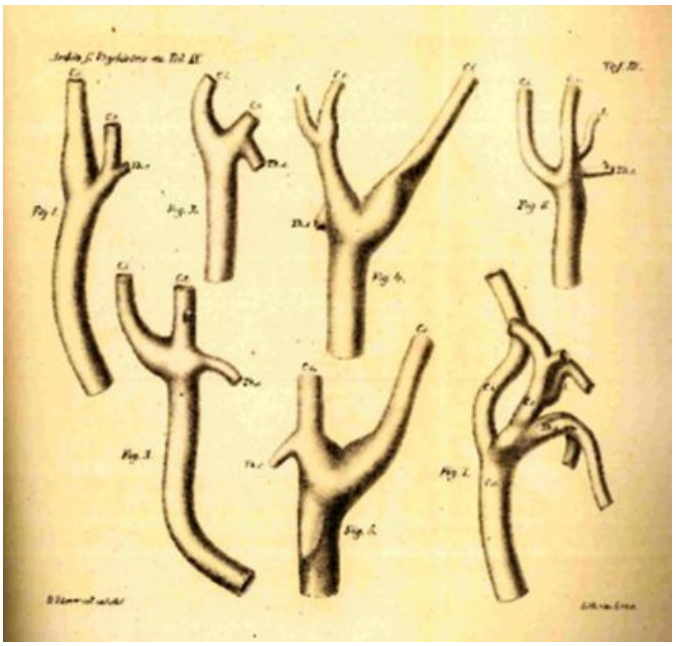

Figure 3. Carotid bifurcation and sinus location.[29]
A. Variability of the common carotid bifurcation: acute or forked (Figure 1 and 4), arcuate or candelabrum-like (Figure 2, 3, and 5); **B.** Variation of the place of the bulging [sinus]: group 1– beginning at the bifurcation and larger at the beginning of the internal carotid (Figure 1), group 2 – bifurcation level and mildly the internal and external carotids (Figure 2 and 3), group 3 – bifurcation level and mostly the internal carotid (Figure 4 and 5); **C.** Atypical forms (Figure 6 and 7)
cc=common carotid artery, ce=external carotid artery, ci=internal carotid artery

The observations of the microscopic changes of the wall of the vessel permitted him to state that there was little to add to Meyer's post-mortem description of the region (1876), and confirms such changes observing his large sample. The examination of serial transversal and longitudinal sections obtained using a sliding microtome (Weigert-Leyser's) comprised the segment beginning below

the bifurcation level of the common carotid up to over the bifurcation angle. This permitted him to see that the arterial wall is much thinner at the level where the 'internal carotid artery' emerges. The thinning begins quiet suddenly at the bifurcation level, the higher segment of the carotid artery showing the usual wall thickness. However, such thinning is not uniform around the wall of the internal carotid artery, being more pronounced near the division spur, the inward projection of the arterial wall, which corresponds to the peak of the bifurcation angle. The intima at the bifurcation site, small in comparison to the expanded other places of the arterial tubing, is not thinner in comparison to other places of the artery. The reduction of the wall thickness seen at this section sites attains exclusively the media. In a constant way such thinning is found on the inner surface of the vessel wall, facing the level of the angle of the bifurcation, where the 'carotid body' is placed. Finally, he ponders at what extent the thinning of this region might influence an aneurysmatic formation. In this regard, he cites Schäfer (1878), who has written about the 'bulb' at the beginning of the internal carotid artery, which he interpreted as "...usually very harmless feature of a normal anatomical disposition" (see also above).[29]

COMMENTS

The 'carotid sinus' is an important structure related to the control of arterial pressure and heart rhythm, considering that a baroreceptor system is there located.[2,9] The commonest site of the sinus is the origin of the 'internal carotid artery', less frequently in the distal part of the 'common carotid artery', at the bifurcation involving the distal 'common carotid artery' and origins of its two branches, and more rarely at the origin of the 'external carotid artery'.[5]

The initial anatomic description of the bifurcation of the human common carotid artery may be credited to Vesalius (1543),[16] without report of a dilated region. The first possible description of a dilatation may be credited to the John Bell (1808), as follows: "...the internal carotid artery ...it is so inclined to contortions, that at this point it even bulges...".[17] Cruveilhier's description (1834), purely anatomical, identified "a kind of 'bulb' [ampulla] or bulge (*d'ampoule ou de renflement*) presented by the common carotid artery" [one of the possible variations (according to West, 2018)[5]], without further comments.[22] This description is certainly a clear account of the 'carotid sinus', without mentioning aneurysmatic features.

Next, appeared a description provided by Burns (1811) that saw such dilatations as related to an aneurysmatic structure, sometimes with an asymptomatic course, meaning possibly a normal dilatation.[19] He is credited by authors as the first to identify the formation as the 'sinus'. Burns was followed by a number of researchers, as Luschka (1862), Manson (1866), Meyer (1876), Schäfer (1878), most with a view of aneurysm formation, but some seeing the dilatation as a normal trait.

Binswanger (1879) cited the studies of the authors that preceded him, and analysing his large sample of cases was able to classify, for the first time, the way the common carotid artery bifurcates, as well as the location of the 'bulbar dilatation'. He reaffirmed that the dilatation meant a normal feature of the region, based on his own observations, and interpreting Schäfer's concluding statement.[29]

The microscopic structure of the sinus begun to be studied by Meyer (1876), and followed by Binswanger (1879), working under the lead of the former, interposed by Schäfer's study (1878), whose description is unclear.

Meyer found there a 'circumscribed thinning of the arterial wall' that permitted the passage of light when transilluminated. He performed the first histological examination of the region, describing an intact intima, and a marked reduction of the media, without mentioning the state of the adventitia.[27]

Apparently, this was the first observation of the differentiated part of the internal carotid artery, the dilated region [sinus], and some of its histological features regarding the intima and media layers, while changes of the adventitia were not mentioned in the text, but depicted in his illustration (his Figure 1) as [erroneously] a thinned region (Figure 1).[27] The only histological technique reported was the hardening of the tissue with 'chromic acid' before sectioning.

Binswanger (1879) provided a detailed macroscopic description and classification of his 'bulbar dilatation'. He detected, as Meyer has done, a marked thinning of the region, but localizing it with precision on the inner side of the vessel wall, facing the 'carotid body'. The microscopic examination of serial sections of the region, obtained with a microtome, revealed that the marked reduction of the arterial wall attained exclusively the media of the differentiated region of the dilatation. He also did not describe the adventitia, in the same way as Meyer.[29]

Apparently, Binswanger regarded the dilatation as a normal anatomical formation of the parent artery, based on his own observations, and on some of his forerunners. He confirmed the histological changes of the differentiated seat described by Meyer, localizing it with more precision, mentions the normality of the intima, the thinning of the media, and overlooks the changes of the adventitia. It is important to mention that there is no description of use of fixatives and staining techniques, a fact reflected by the incipient account on the fine structure of the region.

CONCLUSION

The initial study of the 'carotid sinus' (or bulb) occurred in a relatively short period (1808-1879), when the macroscopic features were provided, as identification of this formerly unknown structure, distinguishing it from an aneurysmatic formation, as considered by some, classifying

its main possible localizations, and its naming.

Further steps comprising the identification of a thinned region, by bare eye observation, and by the description of its microscopic characteristic, which appeared at a later point of this period, provided by two researchers working in the same Institution, initially by Meyer (1876), and next perfected by Binswanger (1879). The microscopic description may be regarded as poor, considering that basic histological techniques were missing, mainly fixative and staining methods, only recently introduced in some laboratories,[30] which would permit to identify the tissue components constituting the structure, and their changes.

Nevertheless, despite incipient, the initial knowledge was laid, and the studies that followed with the upcoming techniques provided the lacked information on the microscopic features, including the innervation, and the important function of this structure.[6,31,32]

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