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Anatomical and Morphological Variations of Carotid Sinus and Its Pathophysiological Relevance in Medicine - A Review

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Abstract*—Carotid sinus is situated at the bifurcation of the common carotid artery which performs vital role in regulation of blood pressure through stimulation of baroreceptors. Carotid sinus is unique structure in carotid system, and it is crucial for a surgeon to perform any interventions such as carotid stenting and carotid endarterectomy. incidental stimulating of carotid body may lead to acute hypotension, bradycardia and infrequently cardiac arrest. These variations of carotid sinus include alterations in the size, shape and location. Existing such kind of variations may impact the sensitivity of baroreceptor reflexes and may altering the cardiovascular physiology leads to abnormal blood pressure. The aim and objectives of the present review is to collect literature of different anatomical and morphological and physiological variations and to establish its clinical significance. Knowledge of various anatomical, morphological and physiological variations is necessary for cardiothoracic surgeons to improve advanced diagnostic and interventions procedures*.

***Keywords*—** *Carotid sinus; Common carotid artery; Blood pressure; Morphology*.

I. Introduction

Carotid sinus (CS) is a notable distension of arterial wall which behaves like a neurovascular structure located in the proximal part of internal carotid artery (ICA), occasionally CS may be seen in common carotid artery (CCA) or external carotid artery also [1]. Baroreceptors are type of stretch receptors which are seen on the wall of CS, which carries afferent fibres through glossopharyngeal nerve and carotid sinus nerve to nucleus tractus solitarius of brain stem and efferent fibres are conveyed by the autonomic nervous system which influence the heart rhythm as baroreflex. The principal nerve supply of CS is the carotid sinus nerve (CSN), which forms inter carotid plexus along with cranial nerves like glossopharyngeal nerve, vagus and cervical sympathetic trunk and pharyngeal plexus [2]. During elevation in the blood pressure, stimulation of baroreceptors can produce reflex brady cardia leads to reflex vasomotor dilatation to reduce the pressure. Location of carotid sinus may highly variates depends upon the level of common carotid artery bifurcation, and it plays a significant role by providing safe and effectiveness of surgical interventions related to this area.

II. Methods

A comprehensive review of the literature was conducted, focusing on studies that discuss anatomical and morphological variations of carotid sinus and its physiological and clinical relevance. Google Scholar, ScienceDirect, Web of Science, PubMed/Medline and Research Gate were used to collect data as evidence from already published literature.

III. Discussion

Carotid sinus (CS) is an influential structure which is closely situated at common carotid artery bifurcation and the anatomical variations of CS may altered the blood pressure to head and neck region. Identification of the exact location of CS during cervical lymph node palpation is essential due to possibility of syncope during clinical examination [3]. A cadaveric study reported the variability of carotid sinus location in 64.28% at common carotid bifurcation level, 25% extend to internal carotid artery and 10.7% in both internal carotid artery and common carotid bifurcation level [4] as mentioned in Table 1. A cadaveric study conducted on eighty-two carotid arteries and the locations of the CS were observed in four different potential sites. The first site was the most prevalent, with CS extending into the proximal ICA (61 out of 82, with 30 on the left and 31 on the right). The second site was at the distal CCA, with CS extending into both the proximal ECA and proximal ICA (6 out of 82, 4 left/2 right), third site was found at the distal CCA, but proximal to its bifurcation with no extension into either the ICA or ECA (14 out of 82, 7 left/7 right) and fourth was the least common site which CS began in the terminal part of the CCA extending into the proximal ECA (1 in 82 with only on right side). When compared with cadavers individually, 97.6% (37 in 41), the CS in Site 1 on at least one side was noticed. The CS sites were asymmetrical found in 34.1% (14 in 41) [5] (Table 1).

A recent study demonstrated the significant morphological variations of carotid sinus location in 43 patients by approaching through the computed tomography angiography (CTA). This study results showed that, out of 86 carotid bifurcations, the typical position and dilatation of carotid sinus was noticed in 80% (n = 69) of cases, 12% (n = 10) of cases

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did not detect any typical dilation on either of the terminal branches of the CCA and in 8% (n = 7) of cases a bulbar dilation was observed on both ICA and ECA [6] as mentioned in Table 1. The specific CS position and the carotid level of bifurcation is clinically important during neck vascular surgical interventions, a retrospective study was conducted on conventional digital angiography images of 100 (68 males, 32 females) and results showed that the CA location could range at the site of C2 to the C6 or C7 intervertebral disc [7] (Table 1). Angiographic study was performed to find interindividual and intraindividual variability of bifurcation and CS anatomy in European based Carotid Surgery Trial, in this study results showed that, the CS did not have the same position as its contralateral counterpart in 34.1% bilateral systems. However, the CS were noticed in the ICA, one side of the neck at least in 97.6% of cases [8] as mentioned in Table 1. Carotid sinus calcification due to calcium deposits, was noticed in previous studies and various degree of calcification can cause stenotic changes in the carotid vessels that may leads to impairment of cerebral function. A radiological study was conducted on 270 patient's roentgenograms over fifty years of age and found that, 18% of cases noticed with carotid sinus calcification [9]. the development of the CS is not understood well yet. Earlier research done on age dependent morphology of the human carotid bifurcation showed that, the carotid bulb does not exist at childhood and develops only during teen age years [10].

TABLE 1: The Percentage of locations of the CS variations in both Cadaveric and Radiological study. (CS: Coronary sinus, CCA: Comon Carotid Artery, ICA: Internal Carotid Artery, ECA: External Carotid Artery, CTA: Computed tomography angiography, CDA: conventional digital angiography) [4,5,6,7,8].

Author	Year	Number of Cases	Location of Carotid sinus	Percentage (%)	Reference Number
West et al., (Cadaveric study)	2018	(N=82)	**Site 1:** starts in the distal CCA and extends to the proximal ICA, which is the most common location. **Site 2:** starts in the distal CCA and extends to both the proximal ICA and proximal ECA. **Site 3:** starts in the distal CCA with no extension after bifurcation. **Site 4:** starts in the distal CCA and extends to the proximal ECA, which is the least common location.	74.3% 7.3% 17.1% 1.22%	[5]
Sinha et al., (Cadaveric study)	2016	(N=28)	CCA ICA Both ICA, CCA bifurcation	64.28% 25% 10.7%	[4]
Baz et al., (CTA)	2022	(N=86)	Typical position and dilation of the CS in CCA No Typical position and dilation of the CS in CCA Bulbar dilation of CS on both ICA and ECA	80% (n =69) 12% (n =10) 8% (n = 7)	[6]
Kurkcuoglu et al., (CDA)	2015	(N=100)	CS Range from C2 to the C6–C7 intervertebral disc	68= Males 32= Females	[7]
Schulz and Rothwell, (Angiography)	2001	(N=5395)	CS present at ICA Asymmetrical position	97.6% 34.1%	[8]

The carotid sinus nerve (CSN) is the principal innervation of the carotid sinus, it is usually originating from the glossopharyngeal nerve, which relays baroreceptive information to the nucleus tractus solitarius [11]. An unusual origin of the CSN was noticed in one case which arose from two small rami extending from the external laryngeal nerve in one Caucasian female cadaver [12]. A Previous study published about variations of location, relation, communications and distribution of CSN in 12 specimens. The CSN was commonly located on anterior portions of the internal carotid artery, either laterally (5/12) or medially (6/12). Separate connections to pharyngeal branches of the vagus (X) nerve (6/12), vagus nerve itself (3/12), sympathetic trunk (2/12), as well as the superior cervical ganglion (2/12) were commonly observed. The CSN constantly ended in a network of small independent branches innervating both carotid sinus and carotid body [13].

The clinical condition known as carotid sinus syndrome (CSS) causes dizziness, syncope, and falls, particularly in older adults. It may result from an erratic heartbeat or blood pressure, perhaps as a result of aging and the resulting instability of the carotid sinus baroreceptors. Prevalence of CSS may be up to 45% in elderly populations [14]. CSS demonstrates with irregular activation of baroceptors reflexes at CS that, leading to abrupt fall in arterial pressure and cardiac rhythm and possibly to loss of consciousness. Physiology of carotid sinus syndrome is not explained well yet, but it is assumed that improper activation begins at baroceptors at carotid sinus. A study revealed this Improper activation is usually unilateral on right side (55%) and 21% on the left) [15].

IV. Conclusion

Information and knowledge of numerous anatomical, morphological and physiological differences and variations are essential for cardiothoracic surgeons to improve advanced diagnostic and interventions practices in cardiovascular medicine.

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