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Original Article

Anatomy Section

A Study on the Anatomical Organization of the Aortic Arch Anomalies

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ABSTRACT

Background: The day to day advances in the fields of cardiac and vascular surgeries need to revive interest in the developmental and the adult anatomies of the Aortic Arch (AA) and its great vessels. A variant aortic arch branching pattern may occur with different embryological mechanisms. The variations in the branching pattern of the aortic arch may range from differences in the distance between the origins of the different branches to the number of branches. The present study was undertaken to study the variations in the branching pattern of the arch of the aorta and their surgical applications.

Aim: In the present study, the anatomical characteristics of the aortic arch and its branches were evaluated by doing a macroscopic examination which has diagnostic and surgical importance.

Methods: This study was conducted on 35 cadavers from the Anatomy Department, 100 aortic angiographic studies were done at the Care Hospital, Visakhapatnam and 300 CT angiographic studies were done at Vijaya Medical Centre, Visakhapatnam. This study was carried out by the conventional dissection method and by doing angiograms.

Results: The normal branching pattern was observed in 26 specimens out of the 35 cadavers. The common trunk for both the brachiocephalic and the left common carotid arteries was present in 5 specimens. The left vertebral artery arose from the aortic arch between the left common carotid and the left subclavian artery in 4 specimens. Among these 4 cases, in 1 cadaver, the cervical segment of the left vertebral artery was very long and it entered through the foramen transversarium of the 3rd cervical vertebra. Whereas, in 1 cadaver, there were three branches which arose from the aortic arch, (1) the common trunk of the brachiocephalic and the left common carotid arteries (2) the left vertebral artery and (3) the left subclavian artery.

Conclusions: Knowledge on the variations in the classical branches of the aortic arch is important in the diagnosis of intracranial aneurysms which occur after a subarachnoid haemorrhage. Clinicians and surgeons should be aware of the aortic arch variations. Prior identification of these vascular anomalies through diagnostic interventions is crucial, in order to avoid complications during heart and vascular surgeries.

Key Words: Variation, Common trunk, Aortic arch, Aortic angiogram, CT angiogram

INTRODUCTION

The frequency of the congenital aortic arch abnormalities is less than 1% of the congenital cardiovascular defects. The aortic arch is a continuation of the ascending aorta, as it is located in the superior mediastinum. 3 classical branches spring from the convex aspect of the aortic arch, the Brachiocephalic Trunk (BCT), the Left Common Carotid artery (LCC) and the Left Subclavian Artery (LSA) [1]. These branches may arise from the beginning of the aortic arch or from the convex part of the aortic arch with varying distances between them. The approximation of the left common carotid artery to the brachio cephalic trunk is an important observation in invasive surgeries, which helps in preventing injuries to these branches [2]. Bernardi et al., [3] hypothesized that the anomalous origins and the distribution of the large aortic arch vessels could cause changes in the cerebral haemodynamics that could lead to cerebro vascular catastrophies. The detection of the anomalous origins of the great vessels prior to surgery has great diagnostic importance, as well as importance in the critical analysis of the further treatment. Intensive care patients should be screened before the long term placement of a nasogastric tube, in order to avoid fistulization and fatal haemorrhage [4]. Momma et al., [5] described that aortic arch anomalies were also associated with the chromosome 22q11 deletion. The common brachiocephalic trunk may be a marker for the presence of accompanying congenital cardiac defects and coronary arterial abnormalities [6]. The anatomical and the morphological variations of the vertebral artery are of great importance in surgery, angiography and in all non-invasive procedures [7].

The present study has described the branching pattern of the aortic arch in Indian subjects, as the literature on the Indian population is meagre.

MATERIALS AND METHODS

This study was conducted on 435 specimens of both sexes by the routine dissection method and the angiographic method. The radio graphical imaging of the arch of the aorta and its branches were obtained by doing an angiogram which combined the use of cineangiography and aortography. The variant specimens were injected with glass sealant silicone gel and the models were preserved in the museum.

Type of study	Sample size
Cadaveric study.	35
Aortic angiography.	100
CT angiography.	300

Cadaveric Study

During the routine dissection which was conducted over 35 cadavers of both sexes who were aged 50-70 years, at the Maharajah's Institute of Medical Sciences, Nellimarla, the origins and the diameters of all branches at the sites of their origins from the aortic arch were recorded as morphological parameters with the help of vernier calipers and the variations in the branching pattern of the aortic arch were also noted.

The variant specimens were injected with silicon glass sealant gel with the help of a pumping gun and they were allowed to dry for 48 hours in air. Then, the models were secured by cutting along the inferior margin of the aortic arch.

Angiogaphic Study

Aortic angiograms which were done in 100 patients in the year 2010 at the Care hospital, Visakhapatnam and 3OO CT angiographic studies which were done at the Vijaya Medical Centre, Visakhapatnam were studied for the clinical implications of the aortic arch anomalies [Table/Fig-1].

RESULTS

Type of study	Sample size	Normal	variations
Cadaveric study	35	26 (74.28%)	9
Aortic angiography	100	98 (98%)	2
CT angiography	300	290 (96.6%)	10

[Table/Fig-1]: Morphological

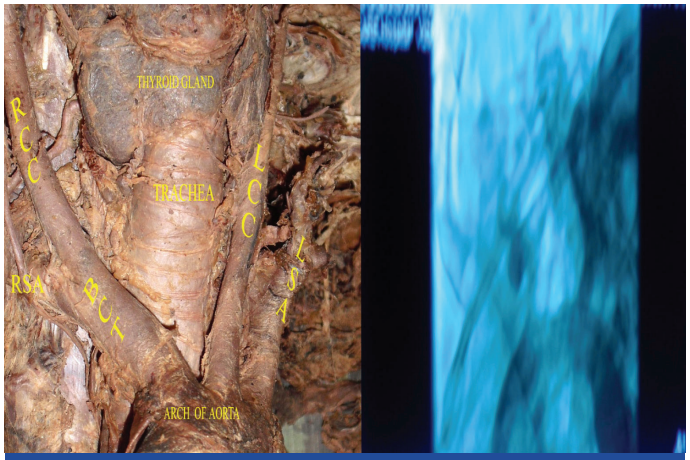
Cadaveric Study

In the present study, the aorta commenced from the upper part of the left ventricle, ascended for a short distance and arched backwards and downwards along the left side of the vertebral column, after arching over the root of the left lung in all the specimens.

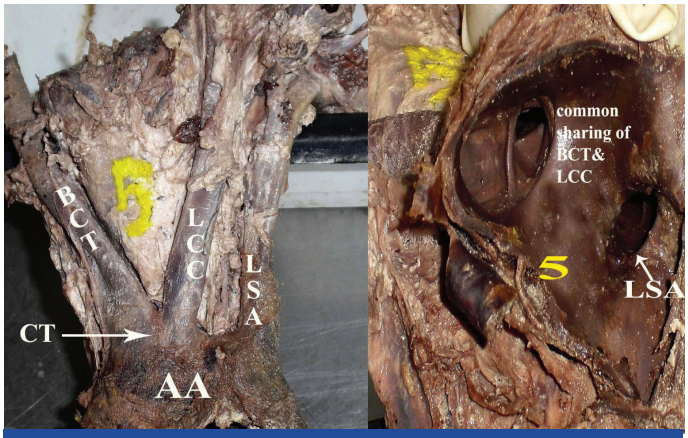
The most common aortic arch branching pattern was found in 26 (74.28%) of the 35 specimens. In this pattern, the 3 major branches, the BCT, LCC and the LSA originated independently from the arch of the aorta [Table/Fig-2].

The most common variant branching pattern i.e., common Sharing (CT) for both the BCT and the LCC was found to be present in 14.2% of the cases (in 5 cases out of the 35 specimens) [Table/Fig-3].

In 11.4% of the cases (4 out of 35 specimens), the Left Vertebral Artery (LVA) originated directly from the aortic arch [Table/Fig -4]. Except in 1 specimen, where the cervical segment of the LVA was



[Table/Fig-2]: Showing typical branching pattern of Aortic arch



[Table/Fig-3]: Showing common sharing of BCT & LCC

[Table/Fig-4]: Showing origin of LVA directly from aortic arch

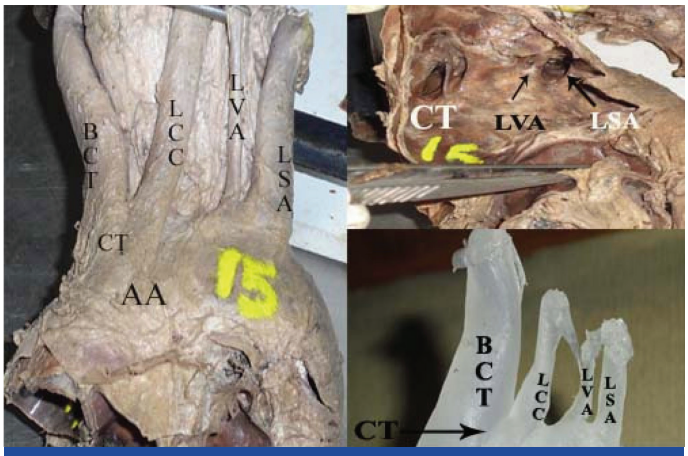
[Table/Fig-5]: Showing long cervical segment of LVA

very long [Table/Fig-5] and where it entered the foramen transversarium of the 3rd cervical vertebra, the course of the cervical segment of the LVA was normal. In 3 specimens, the 4 branches, the BCT, LCC, LVA and the LSA originated from the aortic arch, whereas in 1 specimen, the LVA arose in between the common sharing of the BCT with the LCC and the LSA [Table/Fig-6].

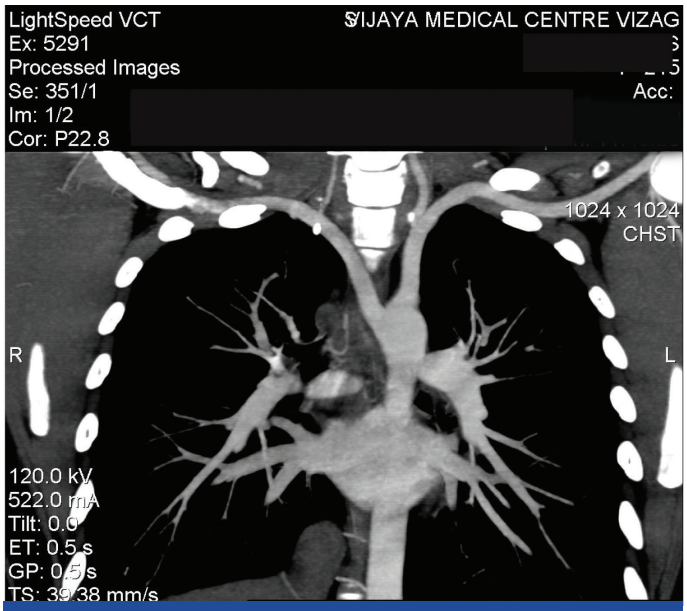
Angiographic Study

In the aortic angiographic study, coarctation of the aorta was noticed in 2 out of 100 cases. So, the normal aortic arch pattern was noted in 98% of the cases.

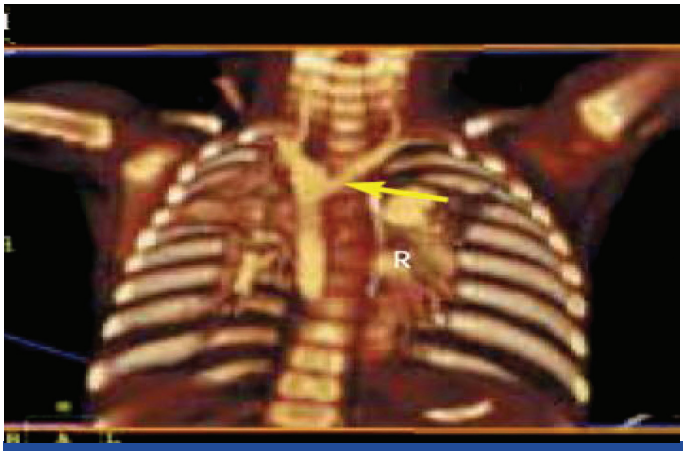
10 variant presentations of the aortic arch were noted among the 300 cases by the CT angiographic study; the types of variants included(a) the aberrant subclavian artery in 1 case [Table/Fig-7], (b) the right sided aortic arch in 2 cases [Table/Fig-8], (c) the Bi carotid trunk in 1 case [Table/Fig-9], (d) the double aortic arch in 2 cases [Table/Fig-10] and (e) co-arctation of the aorta in 4 cases [Table/Fig-11]. Hence, the typical branching pattern was found in 96.6% of the cases.



[Table/Fig-6]: Showing origin of LVA between CT & LSA



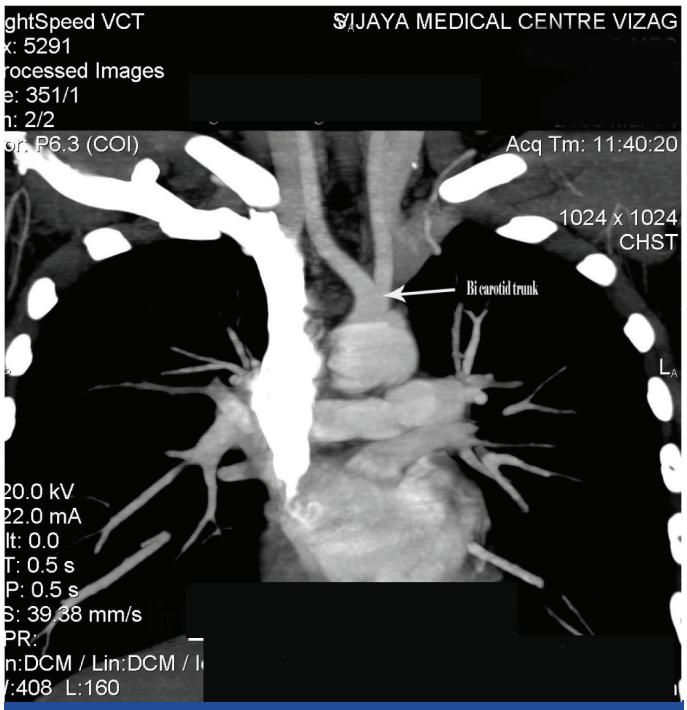
[Table/Fig-7]: Showing aberrant right subclavian artery



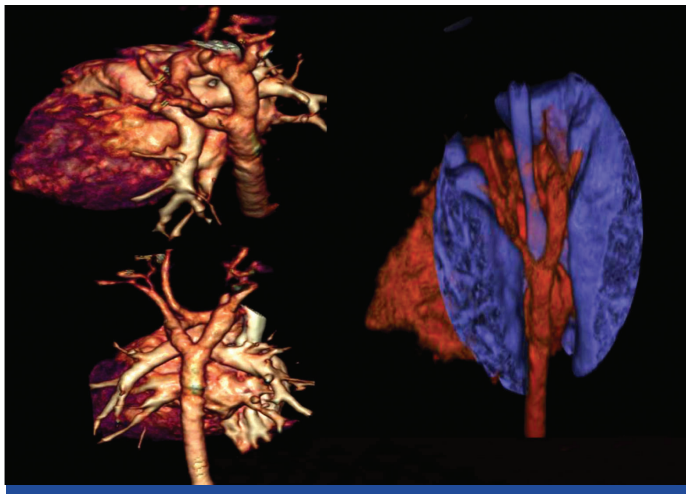
[Table/Fig-8]: Showing right sided aortic arch

DISCUSSION

The developmental anomalies in the aortic arch's branching pattern arise from the unusual patterns of development of the embryonic aortic arch system of the pharyngeal arches, so that there may be persistence of the aortic arches that normally disappear or



[Table/Fig-9]: Showing Bi carotid trunk



[Table/Fig-10]: Double aortic arch

[Table/Fig-11]: Showing the Co-arctation of aorta

Type of presentation	Adachi [15] 516 Japanese cadavers	Thomson [17] 500 English cadavers	Nayak et al., [13] 62 Indian cadavers	Natsis et al., [18] 633 angiographies	Present study North coastal Andhra Pradesh		
					35 cadavers	100 aortic angiographies	300 CT angiographies
Normal	83.3%	82.4%	91.4%	83%	74.28%	98%	96.6%
Common trunk (BCT & LCC)	10.9%	10.2%	4.8%	15%	14.2%	_	_
LVA directly from aortic arch	4.3%	5.4%	1.6%	0.79%	11.4%	_	_
Aberrant right SC	0.2%	_	_	0.16%	_	_	0.33%
Right sided AA	_	_	_	_	_	_	0.66%
Bi carotid trunk	0.2%	0.8%	1.6%	0.16%	_	_	0.33%
Double AA	_	_	_	_	_	_	0.66%
Co-arctation of Aorta	_	_	_	_	_	2%	1.3%

[Table/Fig-12]: Showing Incidence of the types of aortic arch branches variations [17,18]

disappearence of the parts that normally persist. The proximal part of the third aortic arch normally gets extended and absorbed into the left horn of the aortic sac. If it gets absorbed into the right horn of the aortic sac, it can lead to anomalies where the left common carotid artery arises from the brachiocephalic trunk. A variation in the distance between the origin of these vessels has also been reported, the most frequent one being the approximation of the left common carotid artery to the brachiocephalic trunk [8].

The origin of the vertebral arteries from the aorta suggests that a part of aortic arch arose from the left 7th inter-segmental artery or that there was an increased absorption of the embryonic tissue of the left subclavian artery between the origin of the aortic arch and the vertrebral artery [8]. According to Satti SR [9], the possible cause for the origin of the left vertebral artery from the aortic arch is the persistence of the dorsal intersegmental arteries more cranial than the 7th intersegmental artery, which is the typical site of anastomosis. Albayaram et al., [10] suggested that the aberrant origin of the LVA directly from the aortic arch was due to the persistence of the 8th intersegmental artery.

Koenisberg RA [11] reported that the left vertebral artery arose from the arch of the aorta, usually between the left common carotid and the left sub clavian artery in 6% of the population. According to the studies which were done by Hong Jae Taek MD [12], the vertebral artery entered the foramen transversarium of the C6 vertebra in 94.9% of the specimens (in 664 out of 700 cases) with an incidence of 5.1%, with an incidence of 1.6% through C4, with an incidence of 3.3% through C5 and with an incidence of 0.3% through the C7 foramen.

A study which was done by Nayak et al., [13] reported the classical branching pattern of the aortic arch in 91.4% cases, and the arising of the LVA from the AA in 1.6% of the cases. Bergman et al., [14] reported a case of the RVA directly arising from the aortic arch. The frequency of the BCT which provided an origin to the LCCA was 11%, with the LSA arising independently from the arch.

The common carotid arteries were the derivatives of the 3rd aortic arch and the left limb of the aortic sac normally formed the part of the arch that intervened between the origin of the BCT and the LCC arteries. If the aortic sac failed to bifurcate into the right and left limbs, then, the LCC artery would connect to the aortic sac directly, resulting in a common origin of the carotid trunk. In the present study, the bicarotid trunk was found in 1 case out of 300 CT angiograms.

The persistence of the right dorsal aorta distal to the origin of the right 7th intersegmental artery resulted in the formation of a double aortic arch, which was noted in 2 CT angiograms. The right dorsal aorta persisted below the 7th intersegmental artery and the disappearance of the corresponding portion of the left dorsal aorta resulted in the right sided aortic arch. This variant was noted in 2 cases out of 300 angiograms.

When the right 4th aortic arch degenerated, the right 7th inter-segmental artery and the distal part of the right dorsal aorta continued as the right aberrant subclavian artery, which was noted in 1 case out of 300 CT angiograms. In a study which was done on the aortic arches of 516 Japanese cadavers, Adachi [15] found an aberrant right subclavian artery in 0.2% of the cases. 1% of the cases showed this anomaly in a study which was done by Williams GD and Edmonds HW [16] on 407 American cadavers.

The congenital narrowing of the arch of the aorta distal to the origin of the left subclavian artery is co arctation of the aorta. This is of 2 types (a) pre-ductal and (b) post-ductal. In the pre-ductal type, the ductus arteriosus remains patent, whereas in the latter type, it is obliterated. In the present study, 4 CT angiograms and 2 aortic angiograms showed the post-ductal type of the co-arctation of the aorta.

CONCLUSIONS

The present study revealed a significant rise in the anomalies like the aberrant right subclavian artery, the right sided aortic arch, the Bi carotid trunk, the double aortic arch and the co arctation of the aorta.

The aortic arch anomalies are associated with the anomalies of the heart. An irregular and imperfect development of the septum between the aorta and the pulmonary trunk may produce variations, as it develops from the conus arteriosus [14].

Knowledge on the variations in the classical branches of the aortic arch is important in the diagnosis of intracranial aneurysms which occur after a subarachnoid haemorrhage [19]. Keeping abreast with the latest tendencies of the variations of the aortic arch is utmost essential for clinicians and CT surgeons, as the prior identification of these vascular anomalies through diagnostic interventions is crucial, in order to avoid complications during heart and vascular surgeries.

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REFERENCES

[1] Williams PL, Waewick R, Dyson M, Bannister LH: Gray's Anatomy. 37thed, Edinburg*:* Churchill Livingstone*:* 1989;733-34.
[2] Bhatia K, Ghabriel MN, Henneberg M. Anatomical variations in the branches of the human aortic arch: a recent study on a south Australian population.
[3] Bernardi L, Deton P. Angiographic study of a rare anomalous origin of the vertebral artery. *Neuroradiology.* 1975;9:43-47.
[4] FazanVPS, Ribeiro RA, Ribeiro JAS, Rodrigues Filho OA. The right retroesophageal subclavian artery. *Acta Cir Bras.* 2003;18:54-56.
[5] Momma K, Matsuoka R, Takao A. Aortic arch anomalies which are associated with the chromosome 22q11 deletion (CATCH 22). *Pediatr Cardiol.* 1999;20:97-102.
[6] Moskowitz WB, Topaz O. The implications of the common brachio-cephalic trunk on the associated congenital cardiovascular defects and their management. *Cardiol Young.* 2003;13:537-43.
[7] Matula C, Trattnig S, Tschabitscher M, Day JD, Koos WT. The course of the prevertebral segment of the vertebral artery and its anatomy and clinical significance. *Surg Neurol.* 1997;48(2):125-31.
[8] Moore K, Persaud TVN. The Developing Human: Clinically Oriented Embryology. 7th ed, Philadelphia*:* Elsevier Science*.* 2003; 364-66.
[9] Satti SR, Cerniglia CA, Koenisberg RA. Cervical vertebral artery variations: An anatomic study.
[10] Albayram S, Gailloud P, Wasserman B. The bilateral arch origin of the vertebral arteries. *AJNR*. 2002; 23:455-58.
[11] Koenisberg RA, Pereira L, Nair B, Mc Cormick D, Schwartzman R. Unusual vertebral artery origins: examples and the related pathology. *Catheter Cardiovasc Inter* . 2003; 59:244-50.
[12] Taek HJ, Park DK, Lee MJ, Woo KS, Howard AS. *Spine*: 15th Oct 2008; 33 (22): 2422-26.
[13] Nayak SR, Pai MM, Prabhu LV, D'Costa S, Shetty P. Anatomical organization of the aortic arch variations in India: embryological basis and review. *J Vasc Bras.* 2006; 5: 95-100
[14] Bergmann RA, Afifi AK, Miyauchi R. The aorta: the arch and the thoracic part of the descending aorta.Available at:anatomyatlases.Org/Anatomic variants/Cardiovascular/Text/Arteries/Aorta.shtml. Accessed Nov 15, 2009.
[15] Adachi B. Das arteriensystem der Japaner, 1st ed, vol 1, Verlag der Kaiserlich-Japanischen Universität, Kenyusha Press, Kyoto, 1928; 29-41.
[16] Williams GD, Edmonds HW. Variations in the arrangement of the branches which arise from the aortic arch in American whites and negroes. *(a second study)*, *Anat Rec*. 1935;62(2):139-46.
[17] Thomson A.The third annual report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland for the year, 1891-1892. *J Anat Physiol* 1893;27: 183-94.
[18] Natsis I, et al. Anatomical variations in the branches of the human aortic arch in 633 angiographies: clinical significance and literature review: *Surg Radiol Anat.* 2009; 31: 319-23.
[19] Paraskevas G , Agios P, Stavrakas M, Stoltidou A, Tzaveas A. The left common carotid artery arising from the brachiocephalic trunk: a case report. *Cases J* .2008; 1:83.

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