Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anatomy and Physiology

Journal homepage: https://www.ijcap.org/

Original Research Article

Cadaveric and ultrasonographic morphometry of cervicothoracic ganglion (Stellate ganglion)

Savita Mhetre[1], Saurabh Kulkarni[1]*, Archana Kalyankar[1], Shivaji Sukre[1]

[1] Dept. of Anatomy, Government Medical College, Aurangabad, Maharashtra, India

A R T I C L E I N F O

Article history:
Received 21-05-2024
Accepted 01-06-2024
Available online 20-07-2024

Keywords:
Arrhythmias
Stellate ganglion
Ultrsonographic anatomy

A B S T R A C T

Background: Stellate ganglion block (SGB) inhibits sympathetic innervation and is a common treatment for reflex sympathetic dystrophy. During the positioning of the needle, there is a risk of injury to the adjacent structures. Cardiac sympathetic denervation (CSD) to treat ventricular arrhythmias (VAs) requires transection at the middle or lower third of stellate (cervicothoracic) ganglia (SG). However, the morphological appearance of the adult SG and its distribution are not well described.

Objective: To determine the morphology of left and right SG (LSG and RSG) and their relations with adjacent structures.

Materials and Methods: 1. Cadaveric: LSG and RSG (n=30) from 15 embalmed adult cadavers were dissected intact. Weights, volume, height, morphologic appearance, relationship between C8 and T1 ganglia (which form the SG) were determined. 2. Ultra-sonographic: Fifty adult patients enrolled for other than neck pathology evaluation were included. The size, shape, the relationship between the superior pole of SG and the transverse process of C7, the relationship between the superior pole of SG and the inferior thyroid artery, and the relationships between SG and other surrounding tissues were evaluated.

Results: 1. Cadaveric part: Three distinct morphologies of SG were identified: fusiform-rounded; fusiform-elongated; and bi-lobed. RSG and LSG did not differ in weight or volume. RSG were longer than LSG. Bi-lobed morphology was most common in RSGs while fused, elongated was most common in LSG 2. Ultra-sonographic part: it was difficult to visualize SG No significant differences found in thickness and cress-sectional area on right and left side. In fact, 60% of SGs were located in the C7 transverse process level, 75% of SGs were located under the inferior thyroid artery, and all of these SGs were located lateral to the thyroid gland and medial to the anterior scalene muscle and the vagus nerve.

Conclusion: Knowledge of the stellate ganglia's morphology may help for greater precision and accuracy in the transection of the lower half to distal third of the SG during stellate ganglionectomy to treat cardiac arrhythmias. Ultra-sonographic guided SGB may improve safety and allows the visualization of the local anesthetic injection site. Studying the local anesthetic spread might allow the avoidance of side effects as well as typical complications of SGB. Thus, potentially improving both the safety and efficacy of the procedure.

1. Introduction

The stellate ganglion (SG) in sympathetic chain is the result of fusion of the 8th cervical and first thoracic ganglia.[1] The first rib and subclavian artery serve as important anatomical landmarks to locate the SG.[2] It is a particularly attractive nexus point for targeting sympathetic outflow to the heart given that preganglionic to postganglionic neurotransmission occurs predominantly here.[3] The correlation between the sympathetic nervous

* *Corresponding author*.
E-mail address: dfdgmcj@gmail.com (S. Kulkarni).

https://doi.org/10.18231/j.ijcap.2024.018

system (SNS) and arrhythmogenesis has long been studied in animal models[4] and in humans.[5] For arrhythmia control Cardiac sympathetic denervation, involving removal of lower half of the stellate ganglion, and the 2nd through 4th segment (T2-T4) of the sympathetic chain was used as treatment modality for almost a century; however, its efficacy was challenged time to time and still requires further investigation.[6,7]

In clinical practice Stellate ganglion block (SGB) is frequently used for the treatment of various medical conditions by injecting a local anesthetic around stellate ganglion (SG). It influences both the central and peripheral nervous system. In central nervous system it influences the hypothalamus, known for regulating the systemic autonomic nervous, immune, and endocrine systems and to maintain homeostasis and normal cardiovascular function.[8] Physiologically Peripheral nervous system regulates vascular dilatation and constriction, muscular movement, bronchial smooth muscle relaxation and contraction, and pain conduction.[9] Clinically this procedure is adopted for modulating sympathetically mediated pain affecting the head, neck and upper limbs as a routine protocol.[10,11] Stellate ganglion block (SGB) has inhibitory control over sympathetic innervation and can be used for treatment of reflex sympathetic dystrophy as well.

Ultra-sonography (US) guided procedures are advocated for their safety and efficacy by direct visualization of the soft tissues, bony surfaces, and dynamic tracing of the needle path and the spread/ absorption of drugs. SGB under US guidance is considered more accurate and greatly reduces complications than the blind technique.[12,13]

As Stellate (cervicothoracic) ganglion block (SGB) can be associated with serious complications, such as esophageal and vascular injury, the sonological anatomy of the neck and relevant structures for the SGB at the sixth (C6) and seventh (C7) cervical vertebral levels is crucial. Therefore, for determining the intervening course of blood vessels and esophagus in the simulated path of needle insertion ultrasound-guided approaches can be preferred over in the conventional to perform a SGB.[14]

Anterior cervical surgery for the treatment of cervical vertebral body lesions, including tumor infection and trauma is complex, which increases surgical difficulty and risk. Sympathetic nerve injury, a complication of the surgery, has been studied and commonly associated with Horner's syndrome.[15,16]

2. Materials and Methods

2.1. Cadaveric part

Both the right and left stellate ganglia were identified in 15 formaldehyde embalmed adult cadavers (Male-9, Female - 6) lying anterior to the C7 transverse process or neck of the first rib on each side, and identification of the course of subclavian artery, vertebral artery was done meticulously. Ganglia were dissected and removed completely.

After cleaning Ganglia were a placed on a towel for examination. The measured morphologic details include weight, the length of the ganglia in the superior-inferior axis and Volume (in milliliter, mL) which was measured by water displacement.

2.2. Ultra-sonographic (US) part

After approval By Ethical Committee study was conducted on total 50 adult patients (14 men and 36 women), with an average age of 25.22 ± 5.46 years (range 21–46 years). The inclusion criteria were age ≥18 years, with no history of neck irradiation and neck surgery or trauma.

All US examinations were performed by a trained sonologist using an 18 MHz linear-array transducer (Toshiba Aplio 500, Japan). Examination performed in the supine position with slightly turned their necks to the opposite side. The participants were asked to lie while relaxing their necks. Initially, the ultrasound transducer was placed on the neck in transverse plane and scanned from up to down, up to the C7 transverse process, and down to the supraclavicular fossa. SG was located between the carotid sheath and the Longus Coli Muscle.

Thus under US guidance Length, shape, echogenicity, margin, the inferior pole of SG, the relationship between the superior pole of SG and the transverse process of C7, and the relationship between the superior pole of SG and the inferior thyroid artery were evaluated. In addition, the relationships between SG and other surrounding tissues, such as thyroid gland, scalenus anterior muscle, and vagus nerve, were also evaluated.

The degree of deviation of the esophagus relative to the larynx/trachea as well as the likelihood of encountering a vessel in the simulated path of needle insertion in C7 approach to SGB; the incidence of the vertebral artery being situated outside the foramen transversarium at the C6 level; and the distance of the simulated path of needle insertion in the anterior and lateral approaches to SGB at the C7 level was assessed.

3. Results

3.1. Cadaveric part

A total of 30 left and right stellate ganglia from 15 cadavers (Male-9, Female -6) were examined with mean age was 72.6 ± 13.6 years, causes of death included coronary artery disease, congestive heart failure and cardiopulmonary arrest.

Morphologically, the 30 stellate ganglia, independent of laterality, could be sorted into three gross categories: fusiform-rounded, fusiform-elongated, and bi-lobed. In fusiform ganglia, there is complete fusion of C8 and T1, such that the two ganglia are indistinguishable. However, as the names indicate, rounded ganglia have a spherical appearance while elongated ganglia appear finger-like. Bilobed SG are identified as two adjacent ganglia (superior-inferior) connected by a stalk.

Table 1: Morphometry of RSG in cadavers

S. No.	Parameter	Male (N=9)	Female (N=6)
1	Fusiform elongated	6	4
2	Fusiform rounded	0	0
3	Bilobed	3	2
4	Weight(g)	0.88 ± 0.18	0.71 ± 0.20
5	Length(mm)	20.1 ± 2.4	20.2 ± 3.1
6	Volume(ml)	0.82 ± 0.47	0.68 ± 0.35

Table 2: Morphometry of LSG in cadavers

S. No.	Parameter	Male (N=9)	Female (N=6)
1	Fusiform elongated	5	3
2	Fusiform rounded	1	1
3	Bilobed	3	2
4	Weight(g)	2.02 ± 0.31	2.02 ± 0.31
5	Length(mm)	18.6 ± 0.51	16.5 ± 0.47
6	Volume(ml)	0.8 ± 0.45	0.63 ± 0.28

3.2. Ultra-sonographic (US) part

In fifty participants (14 men and 36 women), SG was not identified on the right or left side, IN One participant. Right Stellate Ganglion was identified in 12 men and 23 women whereas left stellate ganglion was identified in all 14 men and 31 women.

4. Results

5. Discussion

5.1. Anatomy of SG- findings of cadaveric studies

The cervical sympathetic chain has always been the subject of investigation for researchers due to its therapeutic uses, and susceptibility to injury during surgical dissections in the neck. Multiple anatomical studies on the cervicothoracic/stellate ganglion have identified such a ganglion in 37-100% of cadavers studied,[17] however whether significant difference exist between sides is not well understood.

Yin et al. in their study compared the appearance of LSG and RSG (and cervical sympathetic chain) in Chinese cadavers, recording significant lateral asymmetry, although morphologic characteristics of the ganglia (length, width, and thickness) were similar.[18] Zhang et al. In examining the anatomic variations of the upper thoracic sympathetic chain (including the SG), found bilateral symmetry in only 16% of cases.[19] A study from Marcer et al, shows significant morphological heterogeneity (five different shapes identified), although histologic confirmation of neuronal somata was not performed.[20] Although these studies have demonstrated anatomic dissimilarity between LSG and RSG, study by Known et al[6] simultaneously mapped the adult SG morphologically and identify the distribution of neuronal somata within the ganglia histologically. The superior-inferior length of the ganglia in their study is consistent with findings from prior studies in adults like Pather et al., Marcer et al., and Yin et al.[18]

5.2. Anatomy of sg- comparative analysis of ultrasonographic studies

Studies by Civlek et al and Won et al showed that the cervical sympathetic chain, including SG, is usually located posteromedial to the carotid sheath and anterior to the Longus Colli Muscle (LCM), between the C7 transverse process and the first rib.[21,22]

In present study encountered Ultrasound limitations in identifying the first rib from the second rib. While the first rib was identified easily being adjacent to the supraclavicular fossa. Therefore, we chose the supraclavicular fossa as the landmark on US images.

This study demonstrated that the inferior poles of 15% SGs were not clearly visible, which may be due to the fact that the inferior poles of some SGs were obscured by the bone tissue, so it was difficult to note accurately with US. When we analyzed the relationship between the superior pole of SG and the inferior thyroid artery, we found that most of the superior pole of SGs were located under the inferior thyroid artery. This finding may be beneficial to localize the position of SG in the clinical practice. The location of the SG was found variable. Therefore, we divided subjects depending upon the position of SG into two types, at the C7 transverse process level and behind the C7 transverse process level. In addition, the superior poles of 73% SGs was located to the C7 transverse process level, and the superior poles of 27% SGs was located to behind the C7 transverse process level. The result was in line with finding in a cadaver study by Kiray et al,[23] which showed that the upper pole of the SG was located at the C7 transverse process level in 63.2% of specimens, and the remaining 36.8% of specimens were located between the first rib and the C7 transverse process. However, another cadaver study by Saylam et al. has shown some differences, revealing that 40% SG/inferior ganglion were located at the level of C7, 25% at the level of C7-Th1 disc, and 35% at the level of T1.[24] Different study samples might be the reason for this relevant discrepancy.

The major limitation of the study was that the verification of histology concerning SG was not performed. Finally to reduce the possibility of misdiagnosis on US examination, SG was needed to satisfy the following conditions: (1) the

Table 3: Morphometry and relations of RSG on Ultra-Sonography

S. No.	Parameter	Male (n=12)	Female (n=23)
1	Width (mm)	5.8 ±0.85	5.4 ±0.90
2	Thickness (mm)	3.2 ±0.75	3.0 ±0.75
3	Cross sectional area (sq mm)	14.52 ±3.95	14.4 ±3.75
4	Length (mm)	18.2 ±0.65	18.0 ±0.75
5	Shape		
	Fusiform elongated	8	15
	Fusiform rounded	0	0
	Bilobed	4	8
6	inferior pole visibility	10	21
7	Superior pole location		
	At C7	8	17
	Behind C7	4	6
8	superior pole under and close to inferior thyroid artery	9	19
9	Distace betweeen superior pole to inferior thyroid artery	10.2 ±2.95	10.0 ±3.85
10	Intervening oesophagus	12	21
11	Vertebral artery out of C6	0	1

Table 4: Morphometry and relations of LSG on ultra-sonography

S. No.	Parameter	Male (n=14)	Female (n=31)
1	Width (mm)	5.1 ±0.95	5.0 ±0.95
2	Thickness (mm)	3.5 ±0.85	3.4 ±0.85
3	Cross sectional area (sq mm)	14.3 ±4.95	14.3 ±4.75
4	Length (mm)	18.7 ±3.85	18.5 ±3.95
5	Shape		
	Fusiform elongated	8	23
	Fusiform rounded	1	2
	Bilobed	5	6
6	Inferior pole visibility	12	30
7	Superior pole location		
	At C7	11	26
	Behind C7	3	6
8	Superior pole under and close to inferior thyroid artery	12	25
9	Distace betweeen superior pole to inferior thyroid artery	9.5 ±1.95	9.3 ±2.55
10	Intervening oesophagus	12	28
11	Vertebral artery out of C6	1	1

nodular structure; (2) between the carotid sheath and the LCM; (3) between the the supraclavicular fossa and C7 transverse process (4) can be seen on the transverse section and the longitudinal section. The efficacy of US-guided SGB by identifying and monitoring SG itself should be further evaluated in future clinical practice.[11]

5.3. Surgical considerations

Stellate ganglion block (SGB) inhibits sympathetic innervation and is a common modality of treatment for reflex sympathetic dystrophy.[25] As Cardiac electrophysiology is under regulatory control of the autonomic nervous system (ANS), SGB has its definitive role in treatment of arrhythmia.

Cervical Sympathetic Trunk (CST) injury is most commonly caused by excessive exposure of the outer surface of the bone in front of the lower cervical vertebral body. Cutting off the CST in operation is known while stripping or excessively stretching the LCM. Among the reasons recorded, excessive exposure of the cervical anterior lateral part or the transverse foramen and consequent excessive stretching of the LCM were the main reasons that the CST was injured.[26] Lu et al concluded that any injury of the CST in front of the lower cervical spine could cause Horner syndrome.[27] Therefore, during anterior lower cervical operations, hooks should not be placed above the LCM, and there is no need to expose the sympathetic trunk; a little blunt dissection below the inner edge of the LCM, placing the retractor under the LCM and pulling carefully for the sake of avoiding sympathetic trunk injury may serve the purpose. Sometimes, the position of the middle cervical ganglion must be identified during surgery.[18]

5.4. Significance of present study

The findings of the present study suggest that the variable morphology of the SG is deciding factor for surgical outcome. Knowledge of the ganglia's morphology may allow greater precision and accuracy in the transection or block the SG during stellate ganglionectomy/block towards treatment of arrhythmias, potentially improving both the safety and efficacy of the procedure.

Most US findings were similar to cadaver studies in our research which need to be backed up with histological examination. Our preliminary study demonstrates that US imaging provides the capability of precisely detecting SG. This may be helpful in reducing complications and improving the accuracy of US-guided SGB.

Familiarity with the adjacent anatomical characteristics of the LCM and CST could contribute to identifying the sympathetic trunk correctly during surgery and reducing the occurrence of surgical complications.

6. Conclusion

SG appear in three major forms and contain varying distributions of somata. Larger studies are warranted to define the relationship between gross anatomy and distribution of neuronal somata to improve the efficacy of Clinical procedures. Ultrasonographic guided SGB may improve safety and allows the visualization of the local anesthetic depot. Studying the local anesthetic spread might allow the avoidance of side effects as well as typical complications of SGB.

7. Sources of Funding

None.

8. Conflict of Interest

None.

References

1. Janes RD, Brandys JC, Hopkins DA, Johnstone DE, Murphy DA, Armour JA. Anatomy of human extrinsic cardiac nerves and ganglia. *Am J Cardiol*. 1986;57(4):299–309.
2. Kawashima T. Anatomy of the cardiac nervous system with clinical and comparative morphological implications. *Anat Sci Int*. 2011;86(1):30–49.
3. Ajijola OA, Vaseghi M, Mahajan A, Shivkumar K. Bilateral cardiac sympathetic denervation: why, who and when? *Expert Rev Cardiovasc Ther*. 2012;10(8):947–9.
4. Ardell JL, Andresen MC, Armour JA, Billman GE, Chen PS, Foreman RD, et al. Translational neurocardiology: preclinical models and cardioneural integrative aspects. *J Physiol*. 2016;594(14):3877–3909.
5. Shivkumar K, Ajijola OA, Anand I, Armour JA, Chen PS, Esler M, et al. Clinical neurocardiology defining the value of neuroscience-based cardiovascular therapeutics. *J Physiol*. 2016;594(14):3911–54.
6. Kwon OJ, Pendekanti S, Fox JN, Yanagawa J, Fishbein MC. Morphological Spectra of Adult Human Stellate Ganglia: Implications for Thoracic Sympathetic Denervation. *Anat Rec (Hoboken)*. 2018;301(7):1244–50.
7. Vaseghi M, Gima J, Kanaan C, Ajijola OA, Marmureanu A, Mahajan A, et al. Cardiac sympathetic denervation in patients with refractory ventricular arrhythmias or electrical storm: intermediate and long-term follow-up. *Heart Rhythm*. 2014;11(3):360–6.
8. Yokoyama M, Nakatsuka H, Itano Y, Hirakawa M. Stellate ganglion block modifies the distribution of lymphocyte subsets and natural-killer cell activity. *Anesthesiology*. 2000;92(1):109–15.
9. Chen Y, Xie Y, Xue Y, Wang B, Jin X. Effects of ultrasound-guided stellate ganglion block on autonomic nervous function during CO2-pneumoperitoneum: A randomized double-blind control trial. *J Clin Anesth*. 2016;32:255–61.
10. Piraccini E, Munakomi S, Chang KV. Stellate Ganglion Blocks [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.
11. Li J, Pu S, Liu Z, Jiang L, Zheng Y. Visualizing stellate ganglion with US imaging for guided SGB treatment: A feasibility study with healthy adults. *Front Neurosci*. 2022;16:998937.
12. Ding XD, Ding ZG, Wang W, Liu YP, Zhong J, Chen HX. Ultrasound guided injections of botulinum toxin type A into stellate ganglion to treat insomnia. *Exp Ther Med*. 2017;14:1136–1140.
13. Elmofty DH, Eckmann M. Do not follow the bone, follow the nerve ultrasound-guided stellate ganglion block: a reconfirmation. *Br J Pain*. 2019;13(4):226–9.
14. Bhatia A, Flamer D, Peng PWH. Evaluation of sonoanatomy relevant to performing stellate ganglion blocks using anterior and lateral simulated approaches: an observational study. *Can J Anaesth*. 2012;59(1):1040–7.
15. An HS, Vaccaro A, Cotler JM, Lin S. Spinal disorders at the cervicothoracic junction. *Spine (Phila Pa 1976)*. 1994;19(22):2557–64.
16. Johnston FG, Crockard HA. One-stage internal fixation and anterior fusion in complex cervical spinal disorders. *J Neurosurg*. 1995;82(2):234–8.
17. Pather N, Partab P, Singh B, Satyapal KS. Cervico-thoracic ganglion: its clinical implications. *Clin Anat*. 2006;19(4):323–6.
18. Yin Z, Yin J, Cai J, Sui T, Cao X. Neuroanatomy and clinical analysis of the cervical sympathetic trunk and longus colli. *J Biomed Res*. 2015;29(6):501–7.
19. Zhang B, Li Z, Yang X, Li G, Wang Y, Cheng J, et al. Anatomical variations of the upper thoracic sympathetic chain. *Clin Anat*. 2009;22(5):595–600.
20. Marcer N, Bergmann M, Klie A, Moor B, Djonov V. An anatomical investigation of the cervicothoracic ganglion. *Clin Anat*. 2012;25(4):444–51.
21. Civelek E, Karasu A, Cansever T, Hepgul K, Kiris T, Sabanci A. Surgical anatomy of the cervical sympathetic trunk during anterolateral approach to cervical spine. *Eur Spine J*. 2008;17(8):991–5.
22. Won HS, Iseki M, Hagihira S, Kuk Y, Kim YD, Kim H. Bi-national survey of Korea and Japan related to the injection site for ultrasound-guided stellate ganglion blocks and anatomic comparisons using cadaver dissection. *PLoS One*. 2020;15(5):e0232586.
23. Kiray A, Arman C, Naderi S, Guvencer M, Korman E. Surgical anatomy of the cervical sympathetic trunk. *Clin Anat*. 2005;18:179–85.
24. Saylam CY, Ozgiray E, Orhan M, Cagli S, Zileli M. Neuroanatomy of cervical sympathetic trunk: a cadaveric study. *Clin Anat*. 2009;22(3):324–30.
25. Kapral S, Krafft P, Gosch M, Fleischmann D, Weinstabl C. Ultrasound imaging for stellate ganglion block: direct visualization of puncture site and local anesthetic spread. A pilot study. *Reg Anesth*. 1995;20(4):323–8.
26. Jonnesco T. Angine de poitrine gukrie par la resection du sympathique cervico-thoracique. *Bull Acad Med*. 1920;84:1920.

27. Lu J, Ebraheim NA, Nadim Y, Huntoon M. Anterior approach to the cervical spine: surgical anatomy. *Orthopedics*. 2000;23(8):841–5.

Author biography

Savita Mhetre, PG Student https://orcid.org/0009-0000-1002-1583

Saurabh Kulkarni, Assistant Professor https://orcid.org/0009-0004-4250-5936

Archana Kalyankar, Professor and HOD

Shivaji Sukre, Dean

Cite this article: Mhetre S, Kulkarni S, Kalyankar A, Sukre S. Cadaveric and ultrasonographic morphometry of cervicothoracic ganglion (Stellate ganglion). *Indian J Clin Anat Physiol* 2024;11(2):79-84.