Surg Radiol Anat (2011) 33:175–179
DOI 10.1007/s00276-010-0737-y

ANATOMIC VARIATIONS

Anatomic relationship between the spinal accessory nerve and the jugular vein: a cadaveric study

M. Saman · P. Etebari · M. N. Pakdaman · M. L. Urken

Received: 14 August 2009 / Accepted: 7 October 2010 / Published online: 20 October 2010

Abstract
Background/Purpose Previous studies of the course of the Spinal Accessory Nerve (SAN) and its relationship to the Internal Jugular Vein (IJV) have yielded conflicting results because of the small number of anatomic specimens and anatomic variability. Classic teaching in Head and Neck Surgery is that the SAN almost always crosses the IJV anteriorly in the upper neck. However, because of the morbidity associated with the injury to the IJV during nerve dissection, it is imperative that the surgeon is wary of the posteriorly crossing nerve. In order to further elucidate the anatomy of the SAN in relation to its surrounding structures, we have studied its anatomy at various points. Specifically, we have aimed to: (1) characterize the anatomic relationship of the SAN to the IJV at three major points: (a) within jugular foramen (JF), (b) at base of skull (BoS), and (c) at the posterior belly of the digastric muscle, (2) record the distance travelled by the SAN from the BoS to its medial to lateral crossing of the IJV, and (3) characterize the anatomy of the JF by with respect to greatest length, width, and partitioning.
Methods Sixty-one cadavers, 27 male, and 34 female (84 necks) were dissected and the course of the SAN was followed from the BoS to the crossing the IJV. Data recorded included the relationship of the SAN to the IJV (a) within the JF from an intracranial view, (b) exiting the JF at BoS, and (c) in the neck at the level of the posterior belly of the digastric muscle where anterior versus posterior positioning of the crossing nerve with respect to the IJV was noted. The distance travelled by the SAN from BoS until crossing the IJV, the length and width of the JF within the cranial fossa, and JF partitioning were also recorded.
Results Within the JF, the SAN travelled anteromedial to the IJV in 73/84 (87%) necks. While exiting the JF, the SAN was found lateral to the IJV in 56/84 (67%) of necks. In the anterior triangle of the neck the SAN crossed the IJV anteriorly in 67/84 (80%) necks, posteriorly in 16/84 (19%) and in the one case of IJV bifurcation, the nerve pierced the vein. The average distance travelled by SAN from BoS to crossing the IJV was 2.38 cm. The average length and width of the JF were, respectively, 1.42 and 0.78 cm, and the IJV was partitioned in 36/84 necks, with 3 of the partitions being bony and the remainder fibrinous. No relationship was found between JF dimensions/partitioning and the anatomic relationship of the structures exiting it.
Discussion/Conclusion In this study, the dimensions and relationship of the IJV and SAN are described in detail. This relationship is specifically noted at three major points, namely within the cranium, at the BoS, and in the anterior neck triangle. In its medial to lateral path in the anterior neck triangle, the SAN crossed the IJV anteriorly in a majority of the cases. However, a posteriorly crossing nerve was not uncommon. These findings support results in

M. Saman (✉)
Department of Otolaryngology-Head and Neck Surgery, New York Eye and Ear Infirmary, New York, NY, USA
e-mail: m.saman@live.com

M. N. Pakdaman
Department of Otolaryngology-Head and Neck Surgery, Massachusetts Eye and Ear Infirmary, Boston, MA, USA

P. Etebari
Department of Developmental Dentistry, University of Texas Health Sciences Center (UTHSCSA), San Antonio, TX, USA

M. Saman · M. L. Urken
Department of Otolaryngology-Head and Neck Surgery, Beth Israel Medical Center, New York, NY, USA

previous literature in that the SAN is located anterior to the IJV in the majority of the cases, however, it is imperative for the surgeon to be mindful to the anatomic variability and possible posterior crossing of the IJV by the SAN in the neck to avoid injury to the IJV during the dissection of the nerve. The distance travelled by the nerve prior to crossing the IJV was measured and can be used as a helpful tool for the surgeon in finding the nerve during dissections. We were not able to demonstrate a correlation between the relationship of the SAN and IJV at other recorded points and their crossing relationship. Similarly, no correlation was found between the anatomy of JF and the relationship of the SAN and IJV at any point.

Keywords IJV · San · Neck dissection · Accessory nerve · Jugular foramen · Jugular vein · Neck anatomy · Neck surgery

Introduction

The anatomy and course of the external branch of the spinal accessory nerve (SAN) to its two destination muscles, the trapezius and the sternocleidomastoid muscles, have been described by various authors. However, the relationship of the nerve's course to its surrounding structures, particularly its anatomic relationship to the internal jugular vein (IJV) in the lateral neck [3, 6, 11, 17] remains a matter of controversy. Although it is widely accepted that in level II, the SAN crosses the IJV anteriorly in a majority of the cases, a recent study by Hinsley and Hartig [7] found this relationship in an overwhelming 96 percent they cases. The practical application of this variation lies in the attempt to preserve the IJV while dissecting along the SAN during modified radical or selective neck dissections for clearance or staging of nodal disease in head and neck cancer. In classic Head and Neck surgery teaching, the SAN nearly always passes anterior to the IJV in it medial to lateral crossing of the vein. However, a posterior position relative to the IJV may put the vein at risk of injury by the surgeon. Injuries to the IJV can lead to significant morbidity. For this reason it is imperative that the surgeon is wary of a posteriorly crossing SAN in level II. A clear anatomical understanding of the course of the accessory nerve during neck dissection is imperative.

Both the SAN and IJV exit the skull through the jugular foramen (JF). Previous anatomic studies have shown great variability in the surgical anatomy of the JF [11, 19, 20]. The anatomic variability involving the size and presence of true anatomic partitioning of the JF as classically described have been demonstrated not only among the various genders and races, but also within the same individual's cranium [2, 8, 10, 18]. To our knowledge, no previously published study has considered the anatomy of the JF as a predictive factor in the course of the SAN in relation to the IJV in the lateral neck.

In this study, we characterize the anatomic relationship of the SAN to the IJV at three primary landmarks: (1) inside the JF within the cranial cavity, (2) exiting the JF at base of skull (BoS), and (3) in the anterior triangle of the neck, at the level of the posterior belly of the digastric muscle. Additionally we note the distance traveled by the nerve from BoS to point at which it begins to cross the vein. We then characterize the anatomy of the JF by measuring its greatest length and width, and its partitioning in order to determine a correlation between JF anatomy and the SAN-IJV relationship.

Materials and methods

In this cadaveric study, 84 neck sides from 61 embalmed cadavers (27 male, 34 female) were dissected in the anatomy teaching laboratory of UTHSCSA. All 61 cadavers were preserved in formalin. Specimens had been previously bisected in the midsaggital plane with calvaria and brains removed. Evaluation of the specimens was performed by the examining authors (MS, PE) and only specimens with intact neck structures and untouched relative structural positions were included ($n = 84$). All measurements were made using a Vernier Caliper with 1/64" graduations and were verified by the examiners (MS, PE.)

During dissection and examination, the head and neck were placed in the classic anatomic position of the supine body. Within the cranial fossa, the dura mater covering the JF was removed, the accessory nerve was identified, and its relationship to the IJV was noted. Subsequently, SAN and IJV exiting the JF at the BoS were identified and the relationship of the nerve and vein at this point was recorded after verification by examiners. The two structures were then followed caudally to the anterior triangle of the neck behind the posterior belly of the digastric muscle at which point we noted the relationship between the nerve and the vein.

Next, in specimens in which the nerve crossed the vein, the relationship of the two structures at crossing and the distance traveled by the SAN from the BoS before crossing were noted. Finally, we turned to characterizing the anatomy of the JF by measuring its greatest length and width. In addition, we noted the presence and quality (bony vs. fibrous) of the partitions within JF. At all points care was taken not to disrupt the natural relationship of the structures. Any specimen in which the natural relationships were disrupted or that the examiners did not unanimously agree on the results was disqualified from the study.

Results

Jugular foramen

The average length of the jugular foramen was 1.42 cm with a range of 0.7–2.2 cm, while the width averaged 0.78 cm with a range of 0.4–1.4 cm. Distinct compartmentalization, with a bony or fibrous septum, was observed in 36 of the 84 specimens, with 27 cases having one partition and 9 cases with 2 partitions. Three partitions were bony, and the remainders were fibrous (Table 1).

SAN relationship to IJV

Within the foramen, in 73 cases the SAN was anteromedial to the IJV, medial in 2 cases, and posterior in 9 cases (Fig. 1). At the BoS, the SAN was anteromedial to the IJV in 56 cases, medial in 21 cases, and posterior in the remaining 7 cases. Within the anterior cervical triangle or the posterior belly of the digastric muscle, the SAN was anterior to the IJV in 57 cases, posterior in 16 cases, and pierced the jugular vein in only one case (Table 2).

At crossing with IJV

The mean distance from the BoS to the intersection of the IJV and SAN was 2.38 cm, with a range of 1.23 to 4.92 cm (Fig. 2). In one case, the intersection was immediately at the BoS. In the one case of IJV bifurcation, the SAN crossed through the vein bifurcation at the anterocervical triangle after having travelled 3.18 cm before crossing the vein. In this specimen, SAN was medial to the IJV within the JF, both intracranially and at BoS, and the JF had one fibrous partition. There was no statistically significant relationship found between the distance to the crossing or JF anatomy and the relationship of the SAN to the IJV in this specimen.

Table 1 Characteristics of the Jugular Foramen

Length	
Mean	1.42 cm[a]
Range	0.7–2.2 cm
Width	
Mean	0.78 cm
Range	0.4–1.4 cm
No. of partitions	
no partitions	48
1 partition	27
2 partitions	9
JF compartmentalization	
Bony	3
Fibrous	33

Some JF's were destroyed

[a] Measured in inches and converted

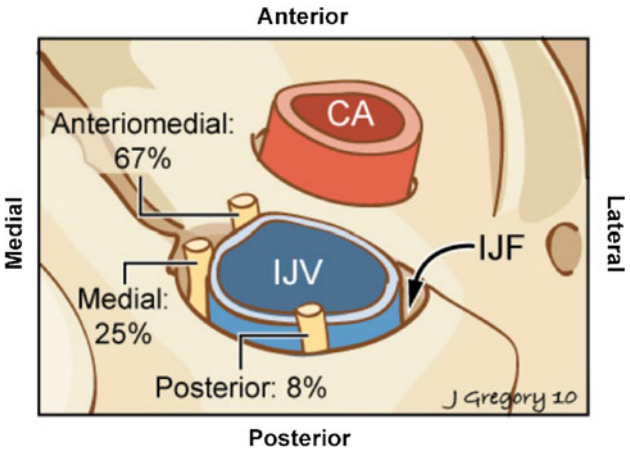

Fig. 1 Schematic presentation: Intracranial view of the jugular foramen after removal of the dura mater. The various relationships of the SAN relative to the IJV within the JF and their incidence in this study are demonstrated. *CA* carotidartery, *IJV* internal jugular vein, *IJF* internal jugular foramen

Table 2 Relationship of spinal accessory nerve (SAN) to internal jugular vein (IJV) at various points along their course

Within JF	BoS	ACT or behind PBD at crossing IJV
AM—73	AM—56	Anterior—67
Med—2	Med—21	Posterior—16
Post—9	Post—7	Through IJV—1

AM anteromedial, *Med* medial, *Post* posterior, *BoS* base of skull, *ACT* anterior cervical triangle, *PBD* posterior belly of digastric

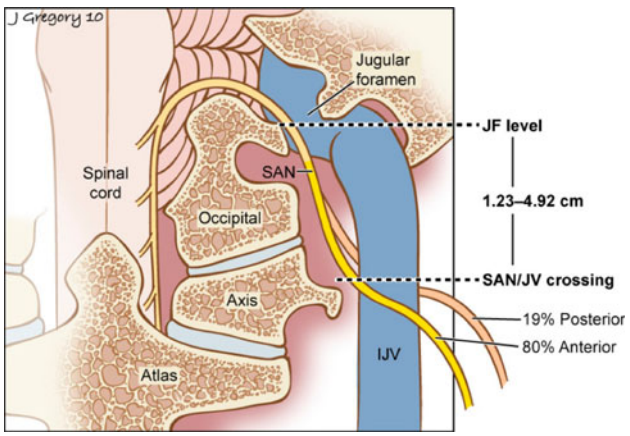

Fig. 2 Schematic coronal section, antero-posterior view of the spinal accessory nerve (SAN) from the jugular foramen to crossing the internal jugular vein (IJV) in the neck. The distance travelled by SAN before crossing IJV and its variable relationship to IJV at crossing are demonstrated. Not demonstrated is our one finding of bifid IJV in which SAN traversed through the bifurcation

Discussion

The radical neck dissection was first described by Crile in 1906 [4]. Although In Head and Neck Surgery the position of the SAN is taught to be anterior to the IJV in its medial to lateral crossing in the lateral neck, variations in the anatomy of the SAN in relations to the IJV has been described previously [1, 3, 11, 12, 15–17, 21]. Adequate understanding of the anatomy of the lateral neck is essential if the surgeon aims to avoid injury to the IJV during SAN dissection intra-operatively. In this study, our results also show that anatomic variation in not a rarity. Our data shows that the SAN crossed the IJV anteriorly in the majority of cases (80%), however, a posterior relationship was not as uncommon (19%) (Fig. 2) as previously described by other authors [7]. During neck dissection, knowledge of this variable relationship proves invaluable as division of tissue anterior to the SAN may lead to inadvertent IJV injury.

The jugular vein begins as a continuation of the sigmoid sinus, exits the BoS via the jugular foramen, and travels to the base of the neck to unite with the subclavian vein [16]. Various case studies and case series have reported a bifid or double jugular vein, where most commonly the nerve courses in-between the duplicate veins [6, 9, 14, 16]. One case report describes the SAN coursing behind both limbs of the bifurcated vein [1]. In our sample size of 84 necks, only one case of bifurcated IJV was seen, in which case the nerve crossed the vein through the bifurcation.

Embryology

Several theories exist regarding the IJV development and the formation of this anomaly. Embryologically, the anomaly has been theorized to have origins in vascular, neural, and bony development. The vascular theory describes the origin of the IJV from the precardinal veins that drain blood from the cranial aspect of the embryo [13]. A nearby capillary complex supports these vessels and allows for additional support of the head and brain. Duplication may involve a secondary venous ring that develops posterior to the precardinal veins. Persistence of this ring may lead to the anomaly [5, 9, 16]. The neural theory describes a migration of the lateral branch of the SAN where the position of the proximal SAN is beyond 2 cm inferior to the transverse process of the atlas, leading to piercing of the IJV by the SAN and a duplicate jugular vein [9, 16]. The bony theory, which does not explain the relationship with the SAN, describes a variation in the bony ridges of the jugular foramen, where a secondary bony process emerges and divides the jugular foramen into multiple compartments [9, 16].

Downie et al. [14] distinguish between IJV duplication and fenestration, where duplication resembles an upside-down "Y" with two vessels entering the subclavian vein and fenestration exists when the IVJ rejoins proximal to entering the subclavian vein.

Conclusion

In this study, the relationship of the IJV and SAN are described in detail. At all three points noted, the SAN was found lateral to the IJV in a significant majority of cases. The SAN pierced the IJV in the one case of IJV duplication. In the lateral neck, at the point of the medial to lateral crossing of the IJV by the SAN, the nerve was positioned anterior to the vein in a majority (80%) of the cases. However, a posteriorly crossing SAN was not uncommon (19%) (Fig. 2). These findings support results in previous studies in that the SAN crosses the IJV anteriorly in the majority of the cases, although perhaps not with the overwhelming frequency reported by some authors [6]. For this reason, it is imperative that the surgeon be mindful of the anatomic variability and possible posterior crossing of the IJV by the SAN in the neck to avoid injury to the vein during the dissection of the nerve in level II. The distance travelled by the nerve prior to crossing the IJV was measured and can be used as a helpful tool for the surgeon in finding the nerve during dissections. We were not able to demonstrate a conclusive correlation between the relationship of the SAN and IJV at other recorded points and their crossing relationship. Similarly, no correlation was found between the anatomy of JF and the relationship of the SAN and IJV at any point. Further studies may be useful in an effort to find anatomic predictors of the relationship between the SAN and the IJV.

Acknowledgments We would like to thank Matthew Cykowski, M.D. who provided extensive guidance in regard to study methodology. We are grateful to Babak Sadoughi, M.D., friend and teacher, for his insightful comments and suggestions. Special thanks to The Willed Body Program, Department of Cellular and Structural Biology, UTHSCSA, Christi Walter, Ph.D., Professor and Chair. And finally, we would like to thank Ms. Jill Gregory, C.M.I, F.A.M.I for her masterful, artistic, and accurate illustrations of our anatomic findings.

References

1. Alaani A, Webster K, Pracy JP (2005) Duplication of internal jugular vein and relation to the spinal accessory nerve. Br J Oral Maxillofac Surg 43(6):528–531
2. Ayeni SA, Ohata K, Tanaka K et al (1995) The microsurgical anatomy of the jugular foramen. J Neurosurg 83(5):903–909
3. Caliot P, Bousquet V, Midy D et al (1989) A contribution to the study of the accessory nerve: surgical implications. Surg Radiol Anat 11(1):11–15

4. Crile G (1906) Excision of cancer of the head and neck. With special reference to the plan of dissection based on one hundred and thirty-two operations. JAMA 47(22):1780–1786
5. Downie SA, Schalop L, Mazurek JN et al (2007) Bilateral duplicated internal jugular veins: case study and literature review. Clin Anat 20(3):260–266
6. Gardiner KJ, Irvine BW, Murray A (2002) Anomalous relationship of the spinal accessory nerve to the internal jugular vein. Clin Anat 15(1):62–63
7. Hinsley ML, Hartig GK (2010) Anatomic relationship between the spinal accessory nerve and internal jugular vein in the upper neck. Otolaryngol Head Neck Surg 143(2):239–241
8. Idowu OE (2004) The jugular foramen—a morphometric study. Folia Morphol (Warsz) 63(4):419–422
9. Iseri M, Ustundag E, Aydin O (2007) A rare anatomical variation of the spinal accessory nerve. J Laryngol Otol 121(3):277–278
10. Kveton JF, Cooper MH (1988) Microsurgical anatomy of the jugular foramen region. Am J Otol 9(2):109–112
11. Levy D, Vacher C, Lezy JP (2001) Relations of the accessory nerve with the internal jugular vein: surgical implications in cervical lymph node clearances. Surg Radiol Anat 23(3):155–157
12. Lu L, Haman SP, Ebraheim NA (2002) Vulnerability of the spinal accessory nerve in the posterior triangle of the neck: a cadaveric study. Orthopedics 25(1):71–74
13. Moore KL, Persaud TVN, Torchia MG (2008) The developing human: clinically oriented embryology. Saunders/Elsevier, Philadelphia
14. Nayak BS (2006) Surgically important variations of the jugular veins. Clin Anat 19(6):544–546
15. Piffer CR, Garcia PJ, Soares JC (1980) Course of the external branch of the accessory nerve and its relations with the first portion of the internal jugular vein. Anat Anz 148(3):252–257
16. Prades JM, Timoshenko A, Dumollard JM et al (2002) High duplication of the internal jugular vein: clinical incidence in the adult and surgical consequences, a report of three clinical cases. Surg Radiol Anat 24(2):129–132
17. Soo KC, Hamlyn PJ, Pegington J et al (1986) Anatomy of the accessory nerve and its cervical contributions in the neck. Head Neck Surg 9(2):111–115
18. Sturrock RR (1988) Variations in the structure of the jugular foramen of the human skull. J Anat 160:227–230
19. Tekdemir I, Tuccar E, Aslan A et al (1998) The jugular foramen: a comparative radioanatomic study. Surg Neurol 50(6):557–562
20. Tekdemir I, Tuccar E, Aslan A et al (2001) Comprehensive microsurgical anatomy of the jugular foramen and review of terminology. J Clin Neurosci 8(4):351–356
21. Uecker FC, Wustenberg E, Zahnert T (2007) High duplication of an internal jugular vein. Laryngorhinootologie 86(8):592–594