Autonomic Neuroscience: Basic and Clinical 181 (2014) 79–84

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

Probabilistic mapping of the cervical sympathetic trunk ganglia

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ARTICLE INFO

Article history:
Received 27 July 2013
Received in revised form 25 November 2013
Accepted 16 January 2014

Keywords:
Cervical sympathetic trunk
Sympathetic ganglia
Positional frequency map
Statistical heat map

ABSTRACT

The goal of this study was to create a heat map indicating the probabilistic location of major ganglia of the cervical sympathetic trunk (CST). Detailed dissections of human cadaveric specimens, followed by spatial registration and analysis of the cervical sympathetic ganglia in the neck and upper thorax regions (C1–T1) were performed in 104 neck specimens (both sides from 52 cadavers). Unbiased parametric mapping, visualized with a heat map, revealed a general pattern of two major ganglia located on both sides of the neck: The superior cervical ganglion (SCG) was located 80–90 mm superior to the point at which the vertebral artery entered the transverse foramen (VA–TF); the stellate ganglion (SG) was located approximately 10 mm inferior to the VA–TF in 80% of our sample, or surrounding the VA–TF in the remaining 20% of our sample. In between these ganglia, a highly variable number of smaller and less prevalent ganglia were present on either side of the neck. The middle ganglia on the right side of the neck were located closer to the SCG, possibly indicative of the middle cervical ganglion. On the left side the middle ganglia were located closer to the SG, perhaps indicative of the vertebral ganglion or the inferior cervical ganglion. Individual specimens could be classified into one of seven different patterns of cervical trunks. The results may help surgeons and anesthesiologists more accurately target and preserve these structures during medical procedures.

1. Introduction

Notable French (Bourgery et al., 1839; Regnier, 2012), German (Hyrtl, 1870), and American (Gray, 1918) anatomists describe the cervical sympathetic trunk (CST) as consisting of three ganglia: superior, middle, and inferior (with this latter ganglion often fusing with the first thoracic ganglion to form the cervicothoracic, or stellate, ganglion). However, discrepancies exist amongst experts in recent years with regard to the nomenclature and anatomical details of the cervical sympathetic chain and ganglia (Ebraheim et al., 2000; Kiray et al., 2005; Civelek et al., 2007, 2008; Saylam et al., 2009). While most authors describe a superior and an inferior or a stellate ganglion in all cases, the central region of the cervical chain is quite variable in regard not only to the presence of ganglia, but also to their specific location.

A detailed, data driven map of the CST is needed to minimize complications related to the CST during surgical procedures involving the neck region. The following examples typify this clinical issue. Procedures involving the thyroid gland may result in damage to the sympathetic chain resulting in Horner's syndrome (Ebraheim et al., 2000). Anterior surgical approaches to the cervical vertebral column and spine and the cervicothoracic junction constitute a potential for unintended lesions to the CST (Bertalanffy and Eggert, 1989; Lyons and Mills, 1998; Ebraheim et al., 2000; Lu et al., 2000). Finally, due to the elusive location of the cervical ganglia, despite commonly used anatomical landmarks such as Chassaignac's C6 tubercle, they are difficult to locate directly for targeted anesthetic block (Treggiari et al., 2003; Abdi et al., 2004; Narouze et al., 2007; Rathmell, 2012).

The goal of this present study was to map the location of ganglia along the CST using an unbiased method in contrast to the conventional anatomical description based on vertebral level landmarks and preconceived classification of ganglia types. We aligned subject maps to the vertebral artery where it enters the transverse foramen (VA–TF) – whether through C5, or C6 (Buckenham and Wright, 2004; Kim et al., 2012) – and the major superior–inferior axis of the vertebral bodies. The VA–TF is an identifiable anatomical and clinical landmark used for diagnostic and/or pre-surgical ultrasound imaging (Bartels and Flugel, 1996; Horrow and Stassi, 2001; Cloud and Markus, 2003; Buckenham and Wright, 2004; Narouze et al., 2007; Kim et al., 2012).

On both sides of the neck, we measured the length of the entire CST and plotted the locations of identifiable ganglia. We used the entrance of the VA–TF as the zero point on a "probability of ganglia location" number line extending superiorly and inferiorly onto which we mapped the presence or absence of ganglia between subjects. We utilized

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http://dx.doi.org/10.1016/j.autneu.2014.01.007

topographic techniques of spatial registration, incidence classification, positional frequency mapping and spatial heat mapping to characterize the CST. A better understanding of the topography of the CST will help surgeons localize its ganglia during anterior and anterolateral approaches of the cervical spine, as well as assist anesthesiologists in targeting the ganglia for sympathetic nerve blocks.

2. Materials and methods

2.1. Specimen dissection

Fifty-two embalmed cadavers (opportunity sample) obtained from the UCLA Donated Body Program were dissected, yielding a total of 104 specimens or neck halves. The subject demographics were as follows: 24 male and 28 females, age 83.8 (9.1) [mean (SD)] years, height 1.7 (0.1) m [66.3 (5.0) in.], weight 66.8 (18.1) kg [147.2 (40.0) lbs.].

Cadavers were placed in a supine position. The chest plate and clavicles were removed. The lungs were removed to expose the thoracic sympathetic trunk. The neck was then dissected: platysma, sternocleidomastoid, and infrahyoid muscles were transected and reflected to expose the carotid sheath. Carotid sheath structures were reflected. The superior cervical ganglion (SCG) was located physically by palpation and visual inspection, and then dissected. The remaining cervical sympathetic trunk (CST) and ganglia, and the point at which the vertebral artery entered the transverse foramen (VA–TF) – whether through C5, or C6 (Buckenham and Wright, 2004; Kim et al., 2012) (Fig. 1) – were dissected next. We defined the CST itself as the most direct superior–inferior connection of sympathetic ganglia in the cervical region, since branches between and around ganglia form a parapharyngeal plexus. In most specimens, the connection between superior and inferior portions of the CST passed medial to the VA–TF, but in some specimens, the ansa subclavia was the only connection. In specimens with both an intact trunk and an ansa subclavia, length of the CST was calculated using the connection medial to the VA–TF. We defined the SCG as the most superior of the CST ganglia. We defined the ganglion surrounding or just inferior to the VA–TF, as the stellate ganglion (SG).

2.2. Spatial registration

The CST kinks severely as it enters the thoracic cavity through the superior thoracic aperture. The angle that the CST bends was undoubtedly variable between individuals and would have been difficult to measure. In order to perform our statistical mapping, it was necessary to virtually flatten the CST first. We accomplished this by taking photographs of the CST in two different planes — one in a so-called cervical plane and one in a so-called upper thoracic plane, both of which were parallel to the surface of the articulated vertebral bodies. Photographs of the specimens in situ were taken using a Sony DSC-W70 seven-megapixel digital camera. In addition, a metric ruler lying next to each specimen was included in each picture for subsequent measurement purposes. The VA–TF in our sample was located at the transition from neck to thorax; therefore, we photographed the CST from the inferior pole of the SCG to the VA–TF and again from the VA–TF to the T2 paravertebral ganglion in accordance with the cervical and thoracic planes, respectively. After extracting the SCG, we photographed it as well, also lying adjacent to a reference ruler.

With the CST documented in two planes, all three photographs for each specimen were scaled together based on the reference ruler using the transformation tool in Adobe Photoshop CS5. This tool allows for a manual affine transformation. We did not perform any non-linear, or warping, transformations on the specimens. For specimens in whom the ruler tick marks were not uniformly spaced (i.e. the picture captured the specimen and ruler at slight angles), the median three centimeters on the ruler were used as the measurement scale for registering the three photographs.

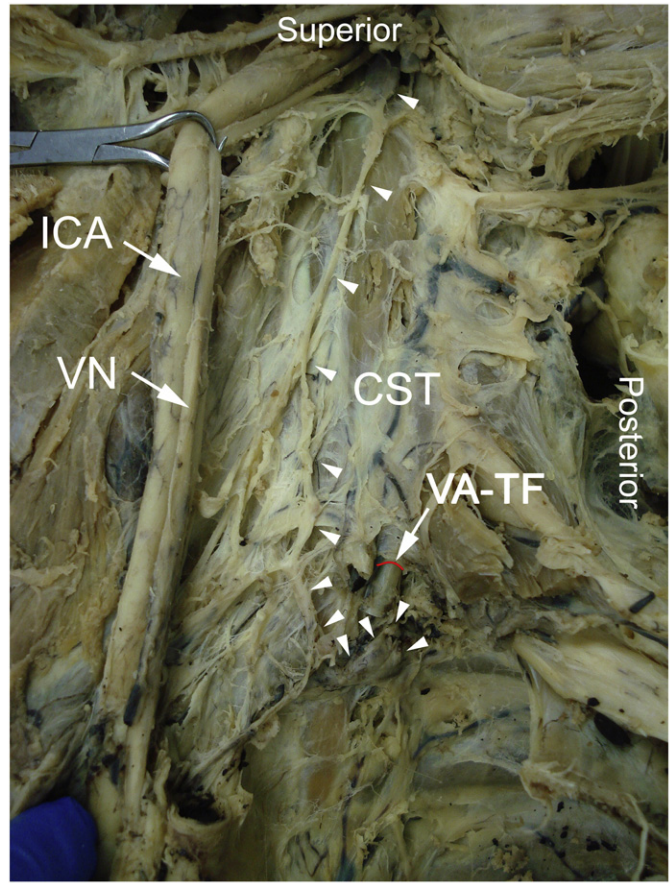

Fig. 1. A representative dissection of the CST (demarcated by arrowheads along its path). Abbreviations: internal carotid artery (ICA, reflected), vagus nerve (VN), cervical sympathetic trunk (CST), entrance of vertebral artery into the transverse foramen (VA–TF; demarcated with red line).

The resulting single plane CST composite of three photographs for each specimen was then aligned and scaled to a common reference space relative to the VA–TF (its anchor), and the superior–inferior axis of the SCG. Since every CST was now aligned in the same space, statistical parametric mapping and measurements could be performed.

We defined a "ganglion" as a visually discernable and palpable swelling, with a flat posterior side, a bump on the anterior side, and a distinct superior and inferior pole. An increase or decrease in chain width alone did not constitute a ganglion. By using this operational definition, we eliminated pre-conceived expectations of where any particular ganglion would be located. Only after mapping the data did we validate CST swellings as "ganglia" based on their relative position to the VA–TF. An unbiased rater (non-anatomist) traced and outlined the CST and VA–TF from the photographs of the specimens using Adobe Photoshop CS5. It was very possible that we missed some small ganglia with our operational definition. Therefore, an expert anatomist verified the accuracy of all the pictorial tracings from the cadaveric specimens.

2.3. Topographic mapping

We plotted the presence of chain swellings (ganglia) along the superior–inferior axis (in mm) between the VA–TF and superior edge of the SCG. For every subject, we counted the presence or absence of a swelling on the cervical chain using a binary count (1 = present, 0 = absent) for every mm on the distance line. The VA–TF served as the zero reference point on the distance number line (Fig. 2). We measured the total distance from the superior pole of the SCG to the inferior pole of the SG, and distance from the superior pole of SCG to the VA–TF.