

# Morphological Variations of the Celiac Plexus and its Clinical Implications: a literature Review

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**Disclose and conflicts of interest: none to be declared by all authors**

## ABSTRACT

**Introduction:** the surgical approach to celiac plexus requires precise identification of the location of this structure, in order to avoid complications related to the procedure. There is, however, great variation in descriptions of the celiac plexus appearing in the literature. The aim of this study was thus to compile information on morphological aspects of the celiac plexus as a way of providing a more thorough theoretical grounding for surgical practice.

**Review:** a literature review of items found in the PubMed, Medical Literature and Retrieval System Online and Scientific Electronic Library Online databases was carried out in six stages, with data collection and sample selection conducted by three reviewers. The search strategy involved the use of the Medical Subject Heading (MeSH) terms, “celiac plexus”, “solar plexus”, “anatomy” and “anatomic variation” combined as pairs using the Boolean AND operator. The publications included were full articles in english concerning cadaver dissection, with no time limits, with the descriptors present in the title or the abstract, and detailed morphological description of the plexus. The final sample comprised four articles, which, taken together, described the dissection of 197 cadavers of individuals aged between 14 and 86 years.

**Conclusions:** descriptions of the morphological features of the celiac plexus vary greatly in the literature. Similarities concern topography in descriptions of anatomical relations between the celiac plexus, the celiac trunk and the superior mesenteric artery, while there are discrepancies regarding the extent of the plexus in relation to the vertebral level and the distribution of nerve endings.

**KeyWords:** Celiac plexus; Solar plexus; Anatomy; Anatomic variation.

## Introduction

Autonomic plexuses are sympathetic, parasympathetic and sensory nerve networks, generally located in the proximity of major arteries<sup>1</sup>. The celiac plexus (CP) – also called the solar plexus – is the largest autonomic plexus, comprising a dense network of interconnected ganglion nerve fibers<sup>2,3</sup>. The structure is located in the retroperitoneal region and is closely connected with the celiac trunk and the superior mesenteric artery<sup>4-6</sup>.

Descriptions of the CP in the literature vary greatly<sup>5</sup>. Some anatomy text books included on the basic reading list in medical schools, such as Standring<sup>7</sup> and Brown & Moore<sup>8</sup>, describe the structure as being composed of two contralateral ganglia, while others, such as Machado & Haertel<sup>9</sup> and Tortora & Derrickson<sup>1</sup> characterize it as being composed of three or four contralateral ganglia, respectively. According to Marino *et al.*<sup>10</sup>, it is common for authors to present an illustration of a perfectly dissected CP with no variations, even though this does not correspond to the real state of the structure.

The CP receives afferent nerve fibers from the vagal trunk, the thoracic splanchnic nerves and the phrenic nerve<sup>8,7</sup>. These fibers radiate out from

the plexus, accompanying the blood vessels in the direction of the upper abdominal organs, from which secondary plexuses originate<sup>7,9</sup>. This distribution provides innervation for the liver, pancreas, stomach, diaphragm, gall bladder, spleen, kidneys, suprarenal glands, mesentery, spermatic cord, small intestine, transverse colon and the vessels themselves<sup>1,3,5,8,11</sup>.

In so far as it innervates these regions, the CP constitutes an important transmission route for pain stimuli coming from the upper abdomen<sup>12</sup>. In patients with chronic pain caused by malignancy in this location, CP neurolysis is an effective pain management alternative<sup>12</sup>. Ward *et al.*<sup>5</sup> thus note the importance of identifying the exact location of the plexus, in order to avoid complications arising from the toxicity of the substance injected during the neurolysis procedure.

Despite being described in anatomy text books, there are gaps and inconsistencies in the characterization of the CP in this literature. The aim of this review is to compile information on the morphological aspects and anatomical variations in the CP and to demonstrate the importance of this knowledge for clinical practice. We thus hope to improve knowledge of the morphology of this network of nerves as a way of providing anatomical information that is crucial for surgical procedures.

### Materials and Methods

An integrative review of the literature was conducted in order to group together results and provide a systematic account of a database search on this subject. The review involved the following six steps: (1) identification of the subject and development of research question; (2) development of inclusion criteria; (3) development of search strategies; (4) data collection and sample selection by three reviewers; (4) critical analysis of data; (5) discussion and summary of results; and (6) presentation of the review, based on careful interpretation of the studies included in the analysis.

Preliminary research, involving extensive consultation of the literature on the morphological characteristics of the CP, produced the following research question: "Which morphological and topographic variations in the CP are described in the scientific literature and what are the clinical implications of these?"

Data collection was carried out between June and July 2020. A search for publications was conducted using the PubMed, Medical Literature and Retrieval System Online (MEDLINE), and Scientific Electronic Library Online (SciELO) databases. Controlled

descriptors in the English language were chosen using the Medical Subject Headings (MeSH) system, and combined into pairs using the Boolean AND operator. Table 1 presents an overview of the search terms used.

Publications included were full articles, in English, involving studies of cadaver dissection, irrespective of year of publication, whose title or abstract contained the search terms used and whose text presented a detailed morphological description of the CP. Reviews, repeat articles and articles whose subject matter lay outside the scope of the present study were excluded from the sample. Data collection and sample selection were carried out by three reviewers, guided by the research question and the eligibility criteria.

### Results

After application of the eligibility criteria, the identification process and triage, as outlined in figure 1, four articles relevant to the research question that presented detailed morphology of the CP remained.

The studies selected presented descriptions of cadaver dissections, with a minimum of 20 and a maximum of 100 dissections. Taken together, the four articles examined 197 cadavers of individuals aged between 14 and 86 years<sup>4,5,10,13</sup>.

Table 1. Database Search Terms.

Database	Search Terms
PubMed	Celiac plexus AND anatomy; solar plexus AND anatomy; celiac plexus AND anatomic variation; solar plexus AND anatomic variation.
SciELO	Celiac plexus AND anatomy; solar plexus AND anatomy; celiac plexus AND anatomic variation; solar plexus AND anatomic variation.
MEDLINE	Celiac plexus AND anatomy; solar plexus AND anatomy; celiac plexus AND anatomic variation; solar plexus AND anatomic variation.

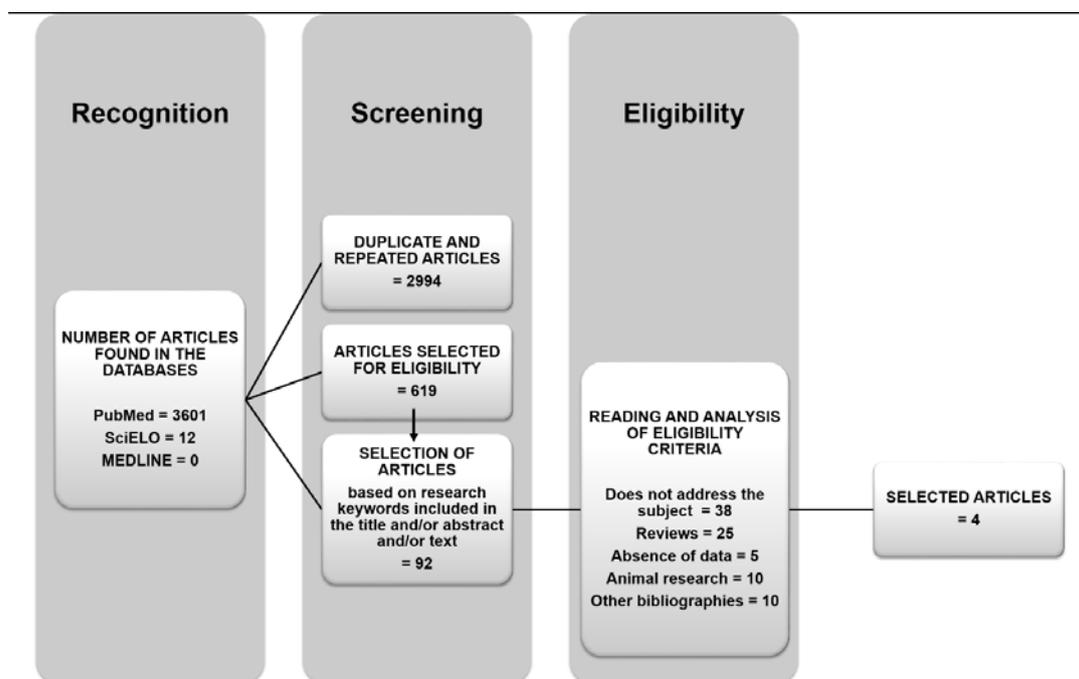


Figure 1. Search Flowchart.

The data were extracted and processed using a tool designed by the authors with the following fields: authors, year of publication, objective, description of methodology and results. The characteristics of each study are presented in Table 2.

report one to five contralateral ganglia<sup>5</sup>, in the form of a triangle, a rhomboid<sup>4</sup> or an oval<sup>5,10</sup>, of a grayish-pink color<sup>10</sup>.

The extent of the CP, in relation to vertebral level, is a matter of dispute among authors, some locating it

**Table 2.** Characteristics of studies investigating CP anatomy.

Author(s) (year)	Objective	Method	Results
Ward <i>et al.</i> (1979)	To improve needle placement during therapeutic block of the celiac plexus.	Cadaver dissection. n=20 cadavers, 10 female and 10 male. 12 embalmed cadavers and 8 cadavers 2 - 12 hours post-mortem.	Topography: Location: Below celiac trunk, vertebral level varying from intervertebral disc between T12 and L1 to the middle of L2. The ganglia on the left-hand side are generally found lower nearer the anterior vertebral edge than those on the right. Morphological Features: Predominant ganglion shape: Oval with oblique orientation Mean size of ganglia: 2.79 cm x 1.43 cm on the right and 2.39 cm x 1.83 cm on the left. Number of ganglia: 1 to 5 on each side.
Paz & Rosen (1989)	To clarify the complex abdominal structure of the celiac ganglion and its nerves.	Cadaver dissection. n=46 cadavers, 26 female and 20 male. Condition of body parts not described.	Topography: Location: In the space between T12 and L2, with formation of a celiaco-mesenteric complex joining the celiac trunk to the superior mesenteric artery. Morphological Aspects: Predominant ganglion shape: triangular, followed by rhomboid. Mean size of ganglia: 3.1 x 3.2 x 3.5 cm. Number of ganglia: one ganglion on each side, on average.
Marino <i>et al.</i> (1996)	To establish a quick and simple technique for accessing the celiac aorta by laparotomy, carried out by subpancreatic transplexal exposure.	Cadaver dissection. n=100 cadavers Condition of body parts not described.	Topography: Location: Around the celiac trunk, passes to the left of the aorta and follows the vascular network. The lateral edge runs perpendicular to the axis of the vein. Morphological Aspects: Predominant ganglion shape: oval. Mean size of ganglia: 3 mm thick. Grayish-pink color Number of ganglia: 3 ganglia on each side, on average, the largest of these considered to be the semilunar ganglion.
Nomura <i>et al.</i> (2005)	To establish an effective operative technique that would maintain the quality of life of patients and to provide a surgical resolution for patients with advanced gastric cancer.	Cadaver dissection. n=31 cadavers Condition of body parts not described.	Topography: Information not provided in study. Morphological Aspects: Number of ganglia: 61.3% present only one ganglion and 32.7%, a tangle of interconnected ganglia.

## Discussion

The present article reviewed the literature available on morphological aspects of the CP and their variation, in view of the fact that understanding of the morphology of this structure is essential for performing surgical procedures in the upper abdominal region<sup>4,12</sup>.

The bibliographical findings indicate that the CP and its network of ganglia vary considerably in terms of number of ganglia, shape, size, and position<sup>14</sup>. Put briefly, descriptions of the composition of the plexus

from T12 onwards<sup>4,5</sup> and others relating it to the celiac trunk<sup>4,5,10</sup>.

The shape of the ganglia that make up the plexus has been described Marino *et al.*<sup>10</sup> and Ward *et al.*<sup>5</sup> as being generally oval. Paz & Rosen<sup>4</sup> found a triangular shape in 66% of ganglia on the left-hand side and in 48.4% on the right, with others being rhomboid or variable in form. Zhang *et al.*<sup>6</sup> identified a laminar shape for 66.67% and a nodular form in 16.67% of celiac ganglia studied.

Basic medical text books such as Standring<sup>7</sup>, Tortora & Derrickson<sup>1</sup> and Moore *et al.*<sup>15</sup> do not provide information on the size of ganglia. Ward *et al.*<sup>5</sup> found the mean size of celiac ganglia to be 2.79 cm x 1.43 cm and 2.39 cm x 1.83 cm, on the right and left, respectively; while Paz & Rosen<sup>4</sup> found it to be 3.1 cm x 3.2 cm x 3.5 cm, with no difference between sides.

In terms of anatomical relations, the CP was found to be located inferior to the celiac trunk<sup>4,5</sup> or surrounding this structure<sup>10</sup>, stretching as far as the level of the superior mesenteric artery<sup>4</sup>. Measured by vertebral level, the CP is described as lying between T12 and L2<sup>4,5</sup>.

Surgeons should be aware of all these morphological and topographic alterations<sup>5</sup>. Medical students, meanwhile, obtain information from text books, such as Standring<sup>7</sup>, Tortora & Derrickson<sup>1</sup> and Moore *et al.*<sup>15</sup>, which, do not usually provide information on the variability of this structure. Early acquisition of knowledge of the CP could improve the training of interventionist physicians, who would then begin their clinical-surgical practice having already acquired this knowledge during training.

One of the surgical procedures most commonly used to alleviate abdominal pain is celiac plexus neurolysis (CPN)<sup>16</sup>. In this technique, a neurolytic agent is smeared all over the plexus, in order to permanently destroy the afferent visceral nociceptors, and, hence, interrupt the emission of signals to the central nervous system<sup>17</sup>. The success of the technique depends more on the distribution of the agent than on the concentration<sup>12</sup>. Understanding of the topography and morphology of this structure is thus of fundamental importance for medical surgeons.

The CP comprises a dense network of sympathetic, parasympathetic and sensory nerve fibers<sup>14</sup>. This dense plexus is formed by celiac ganglia receiving fibers originating in the thoracic splanchnic nerves<sup>18</sup> and others from the posterior vagal trunk<sup>4</sup>.

Parasympathetic innervation occurs by way of fibers from the posterior vagal trunk capable of reaching the CP<sup>4,5,14</sup>. According to Standring<sup>7</sup>, the sympathetic fibers reach the CP through the thoracic splanchnic nerves, represented by the greater splanchnic, lesser splanchnic and least splanchnic nerves. These nerves originate in the thoracic medullary segments and pass downwards until they penetrate the crura of the diaphragm and arrive at the nerve ganglia<sup>7</sup>. Paz & Rosen<sup>4</sup>, however, found a triangular opening located

lateral to the crura of the diaphragm, through which the thoracic splanchnic nerves enter the abdominal cavity in 70-91% of the cadavers studied.

The greater splanchnic nerve usually originates in the medullary segments of T5 to T9<sup>7,18</sup> and passes downwards until it reaches the lateral pole of the celiac ganglia<sup>4</sup>. The lesser splanchnic nerves, originating at T10 and T11, and the least splanchnic nerves, at T12<sup>18</sup>, may send fibers to the CP after entering the diaphragm<sup>7</sup>. Paz & Rosen<sup>4</sup> found that the lesser splanchnic and least splanchnic nerves may exist as a single, double or triple nerve, with variations depending on the side on which it is located. This is clinically important because procedures involving these nerves are used to manage chronic upper abdominal pain<sup>18</sup>.

With regard to sensory fibers, it is known that afferent nociceptive signals are transmitted from the upper abdominal viscera through the CP and the thoracic splanchnic nerves to the spinal cord<sup>19</sup>. Through this route, the CP receives afferent signals from organs such as the pancreas, the hepatobiliary tree, the spleen, the liver, kidneys, stomach and adrenal glands<sup>5,14,20</sup>. The CP is thus the main region for the transmission of pain originating in upper abdominal organs<sup>14</sup>. The CPN procedure enables efficient reduction of pain caused by pathologies in the regions innervated by this plexus<sup>21</sup>.

## Conclusion

The information compiled in the present study shows that the descriptions of morphological aspects of the CP, such as shape, color, quantity and size, vary considerably in the available literature. Despite similarities regarding anatomical topography in description of anatomical relations between the CP, the celiac trunk and the superior mesenteric artery, sources disagree and lack clarity with regard to the extent of the CP in terms of vertebral level. Greater clarity is also needed concerning the distribution of nerve endings in the CP.

Although detailed understanding of the anatomy of the CP is essential knowledge for medical surgeons, there are various discrepancies in the information available on morphological and topographic aspects of this structure, especially in text books for medical students. The present article has identified the need to shed further light on the anatomy of the CP in order to provide a better guide for surgeons and to update the information contained in medical school textbooks.

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### Mini Curriculum and Author's Contribution

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Received: April 10, 2021  
Accepted: August 8, 2021

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