ABSTRACT

Background: Thoracic splanchnicectomy is an important surgical procedure for the management of upper abdominal pain especially in cases of chronic pancreatitis or pancreatic cancer. The pattern of the thoracic splanchnic nerves is highly variable and the outcome of the surgical procedure depends on awareness of the variant anatomy of thoracic splanchnic nerves. This study was undertaken to find out the variations in the formation, course and termination of greater splanchnic nerve in South Indian population.

Materials & Methods: Thirty five human cadavers of either sex (female- 12, male -23), between 45 and 70 years of age, embalmed by conventional method for undergraduate Anatomy classes were bilaterally dissected. Greater splanchnic nerve was studied with regard to its formation, course and termination.

Results: Greater Splanchnic nerve was present in all the specimens. In 41.4%, the highest root of origin was T6 ganglion and in 35.7% of the cases, the lowest root of origin was T9 ganglion. The greater splanchnic nerve passed through the diaphragm and terminated in celiac ganglion and partly in suprarenal gland, aortic-renal ganglia or renal plexus.

Conclusion: The authors hope that the detailed anatomy of the greater splanchnic nerve provided in the present study will be helpful for students as well as surgeons for a better outcome of the thoracic splanchnicectomy.

Key Words: Greater splanchnic nerve, intermediate splanchnic ganglia, splanchnicectomy.

INTRODUCTION

Thoracic splanchnic nerves are medial branches of the thoracic sympathetic trunk. The greater splanchnic nerve (GSN) which consists of myelinated preganglionic efferent and visceral afferent fibres that carries pain sensation from upper abdominal organs, is formed usually by four roots from T5 to T9 or T10 ganglia. The GSN, as it pierces the crus of the diaphragm, makes an angle of divergence between the intrathoracic and subdiaphragmatic part and terminates mainly in the celiac ganglia, but may send direct branches to suprarenal gland or end partly in aorticorenal ganglion. A splanchnic ganglion is usually found along the course of the greater splanchnic nerve. Abdominal pain is a major clinical problem in patients suffering from chronic pancreatitis, carcinoma of pancreas, liver, gallbladder and stomach. Thoracic Splanchnicectomy, the surgical interruption of the splanchnic nerves, is an effective treatment in the control of intractable visceral pain. A considerable variation in the pattern of thoracic splanchnic nerves has been encountered by many authors. The present study is aimed to describe the anatomical variations in the pattern of greater splanchnic nerve in South Indian population.

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MATERIALS & METHODS
Present study was carried out on 35 embalmed cadavers (male-23; female-12) between the age group of 45 and 70, allotted for undergraduate teaching. The posterior walls of the cadavers were bilaterally dissected (n = 70). The cadavers with congenital deformity of thoracic wall or with adherent pleura (due to pleuritis, etc.) or in those cadavers where the thoracic splanchnic nerves were damaged during dissection by undergraduates were excluded from the study. After the removal of the thoracic viscera, the posterior thoracic wall was exposed and the parietal pleura were carefully removed. The thoracic sympathetic trunk and the thoracic splanchnic nerves were exposed. The sympathetic chains were cleaned and the ganglia were defined. The GSN was studied with regard to its origin, course, termination, presence of intermediate splanchnic ganglia along the course of GSN, and its connections with lesser or least splanchnic nerves. The dimensions of the splanchnic nerves and intermediate splanchnic ganglia were measured using digital calipers. Pattern of passage of the splanchnic nerves through the diaphragm into abdominal cavity was noted and the angle of divergence was also measured.

OBSERVATIONS
Greater splanchnic nerve was observed in all the cases (Figure-1) and it originated from two to six roots (Table-1). GSN was formed from T4 to T11 ganglia either directly from the thoracic ganglia or by interganglionic roots i.e., from the segment between two thoracic sympathetic ganglia. The most common number of roots was three in 71.4% of specimens, followed by four in 65.7%. In males, the common number of roots was three in 39.1% (18 of 46 specimens), whereas in females it was four in 45.8% (11 of 24 specimens). The maximum number of roots being six was found in four specimens in male cadavers.

The highest root of origin of GSN was from T6 ganglia in 41.4%, followed by T5 (24.3%) and T7 (21.4%). In males, the highest root was T6 in 40.3% and in females, 36.8%. The lowest root of origin was T9 in 35.7% (male- 37.1%; Female- 36.8%), followed by T10 in 24.3% (Male – 25.8%; female – 23.7%) shown in table-2.

Table 1: Number of roots of origin of greater splanchnic nerve.

<table>
<thead>
<tr>
<th>No. of roots</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>0</td>
<td>4</td>
<td>13</td>
<td>13</td>
<td>5</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>left</td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>3</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>Total (%)</td>
<td>0</td>
<td>10</td>
<td>25</td>
<td>23</td>
<td>8</td>
<td>4</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 2: Highest and lowest root of origin of the greater splanchnic nerve.

<table>
<thead>
<tr>
<th>Root</th>
<th>Right</th>
<th>Left</th>
<th>Total (%)</th>
<th>Root</th>
<th>Right</th>
<th>Left</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>2</td>
<td>2</td>
<td>4 (5.7)</td>
<td>T11</td>
<td>1</td>
<td>-</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>T4/5</td>
<td>1</td>
<td>-</td>
<td>1 (1.4)</td>
<td>T11/10</td>
<td>1</td>
<td>1</td>
<td>2 (2.9)</td>
</tr>
<tr>
<td>T5</td>
<td>7</td>
<td>10</td>
<td>17 (24.3)</td>
<td>T10</td>
<td>10</td>
<td>7</td>
<td>17 (24.3)</td>
</tr>
<tr>
<td>T5/6</td>
<td>-</td>
<td>1</td>
<td>1 (1.4)</td>
<td>T9/10</td>
<td>5</td>
<td>1</td>
<td>6 (8.6)</td>
</tr>
<tr>
<td>T6</td>
<td>16</td>
<td>13</td>
<td>29 (41.4)</td>
<td>T9</td>
<td>10</td>
<td>15</td>
<td>25 (35.7)</td>
</tr>
<tr>
<td>T7</td>
<td>7</td>
<td>8</td>
<td>15 (21.4)</td>
<td>T8/9</td>
<td>3</td>
<td>4</td>
<td>7 (10)</td>
</tr>
<tr>
<td>T7/8</td>
<td>-</td>
<td>1</td>
<td>1 (1.4)</td>
<td>T8</td>
<td>4</td>
<td>3</td>
<td>7 (10)</td>
</tr>
<tr>
<td>T8</td>
<td>1</td>
<td>-</td>
<td>1 (1.4)</td>
<td>T7/8</td>
<td>1</td>
<td>1</td>
<td>2 (2.9)</td>
</tr>
<tr>
<td>T8/9</td>
<td>1</td>
<td>1</td>
<td>1 (1.4)</td>
<td>T7</td>
<td>3</td>
<td>-</td>
<td>3 (4.3)</td>
</tr>
</tbody>
</table>

Table 3: Frequent root of origin of greater splanchnic nerve from specific thoracic ganglia.

<table>
<thead>
<tr>
<th>Root</th>
<th>Right</th>
<th>Left</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>2</td>
<td>2</td>
<td>4 (5.7)</td>
</tr>
<tr>
<td>T4/5</td>
<td>1</td>
<td>-</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>T5</td>
<td>8</td>
<td>11</td>
<td>19 (27.1)</td>
</tr>
<tr>
<td>T5/6</td>
<td>-</td>
<td>1</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>T6</td>
<td>13</td>
<td>17</td>
<td>30 (42.7)</td>
</tr>
<tr>
<td>T6/7</td>
<td>1</td>
<td>3</td>
<td>4 (5.7)</td>
</tr>
<tr>
<td>T7</td>
<td>19</td>
<td>25</td>
<td>44 (62.7)</td>
</tr>
<tr>
<td>T7/8</td>
<td>10</td>
<td>8</td>
<td>18 (28.6)</td>
</tr>
<tr>
<td>T8</td>
<td>15</td>
<td>17</td>
<td>32 (45.7)</td>
</tr>
<tr>
<td>T8/9</td>
<td>9</td>
<td>8</td>
<td>17 (24.3)</td>
</tr>
<tr>
<td>T9</td>
<td>16</td>
<td>21</td>
<td>37 (52.9)</td>
</tr>
<tr>
<td>T9/10</td>
<td>5</td>
<td>2</td>
<td>7 (10)</td>
</tr>
<tr>
<td>T10</td>
<td>10</td>
<td>7</td>
<td>17 (24.3)</td>
</tr>
<tr>
<td>T10/11</td>
<td>2</td>
<td>2</td>
<td>4 (5.7)</td>
</tr>
<tr>
<td>T11</td>
<td>1</td>
<td>1</td>
<td>2 (2.9)</td>
</tr>
</tbody>
</table>
The most frequent contribution for the GSN was from T7 ganglia (62.7%), followed by T9 in 52.9%, T8 in 45.7% and T6 in 42.7% (Table-3). Mean length and breadth of the greater splanchnic nerve were 5.61 ± 2.54 cm and 0.31± 0.11 cm respectively.

Intersplanchnic connection between greater and lesser splanchnic nerve was observed unilaterally in 14.3% (10 of 70 specimens: Male-8; female-2). These connections were found above the diaphragm, six on the left side and four on the right side.

Greater splanchnic nerve passed via separate hiatus through the crus of the diaphragm in 53 of 70 sides examined. The GSN and lesser splanchnic nerve had a common hiatus in 14 specimens and all the three thoracic splanchnic nerves passed through a common hiatus in three specimens.

The angle of divergence between the intrathoracic and subdiaphragmatic part of the GSN varied from 00 – 1050. The most common angle was between 51-600 in 17.1% of cases, followed by 61-700 and 41-500 in 10% of cases each. In three specimens it passed at an angle of more than 1000 (Table-4).

The GSN terminated in celiac ganglia in all the specimens. Apart from celiac ganglia, in two specimens the GSN also terminated in suprarenal gland and in four specimens, in aortico-renal ganglia. It was also observed that in one instance, it partly terminated in the celiac, aortico-renal ganglia, suprarenal gland and renal plexus.
Intermediate splanchnic ganglion was observed in 44.3% (31 of 70 specimens). In male, it was found in 50% of the specimens and in female, in 33.3%. Bilateral presence was found in six cadavers (Female-2; male-4). Size of the ganglia varied from 0.33 x 0.39cm to 1.33 x 0.71 cm. We observed that these ganglia were located at the level of T10, T11 or T12, on the GSN. In ten of the specimens in which the splanchnic ganglia was absent, we observed thickening of the GSN at the place of where the ganglia was usually situated.

**Fig-1: Normal presentation of thoracic splanchnic nerves.** (GSN-Greater splanchnic nerve; IG-Intermediate ganglion; CG-Celiac ganglion; ARG-Aorticorenal ganglion; LSN-Lesser splanchnic nerve; ISN- Least splanchnic nerve).

**DISCUSSION**

The pattern of formation of GSN as observed in 35 south Indian cadavers is described in the present study. The GSN was formed by ganglionic as well as interganglionic roots. Previous studies show that the roots of origin of GSN could be as high as eight roots (Table-5). Standard text books of Anatomy have described that the GSN is formed by T5 to T9 or T10 ganglia. In the present study, the GSN originated from two to six roots and the highest root of origin was T4 ganglia in 5.7% of the cases. In 24.3%, the GSN originated from T5 ganglia. Edwards & Baker have mentioned in their study that in 5%of the bodies the greater splanchnic nerve arose from only one ganglion and in a single instance GSN arose from seven ganglia. According to the number of ganglia from which splanchnic nerve arose, the pattern of formation of GSN could be classified into seven groups in the present study whereas Swayam Jothi et al. have reported 19 patterns of origin of GSN in 50 specimens and in one specimen the GSN was absent. Edwards & Baker found marked lack of bilateral symmetry in origin of these nerves. No bilateral symmetry was noticed in any of the specimens in the present study also.

Edward & Baker found that the most frequent origin of the greater splanchnic nerve was from the T7, T8 and T9 ganglia whereas the most common arrangement was T6, T7 and T8 sympathetic ganglia in a study by Reed. In the present study, the most frequent contribution for the GSN was from four ganglia: T6, T7, T8 and T9.

In the present study, intersplanchnic connection between greater and lesser splanchnic nerve was observed unilaterally in 14.3% (10 of 70 specimens) whereas, Yang et al. found connections between GSN and LSN in 54.3% of cases. Jit & Mukerjee have reported in 10 instances, communications between GSN and LSN, six above the diaphragm and four, below the diaphragm which differs from the present study where the communications were observed above the diaphragm.
After its formation, the GSN pierced the diaphragm either in a separate hiatus or in a common hiatus with other thoracic splanchnic nerves. Gest et al.\(^7\) observed separate pathway for the three splanchnic nerves in only 7% (three of 44 sides). The most common pattern in their study was for the GSN and LSN or all the three nerves to pass through common hiatus which was observed in 77%, which differs widely from the present study where the common pattern was a separate hiatus for each thoracic splanchnic nerves (53 of the 70 specimens). As the GSN passed through the diaphragm towards its termination, it made an angle between the intrathoracic and subdiaphragmatic parts. Only in two instances the course of the GSN was almost straight as it terminated in celiac ganglion. The most common angle was 51-60\(^\circ\) in 17.1% of cases. Gest et al.\(^7\) in their study reported the common angle of divergence as 90\(^\circ\) and observed identical angles on right and left in eight individuals. In the present study, identical angle on both sides were not observed in any of the cadavers. However, the difference between angle of divergence on right and left side were \(\leq 50\) in eight cadavers.

Jit & Mukerjee\(^6\) observed that the GSN terminated in celiac ganglia and also in aortico-renal ganglion in six specimens. In two instances they found the GSN to partly terminate in celiac ganglion, the aortico-renal ganglion, posterior renal ganglion and posterior renal plexus. In the present study, the GSN terminated in celiac ganglia in all the specimens. In two specimens it sent direct branches to the suprarenal gland. In one instance, it partly terminated in the celiac, aortico-renal ganglia, and renal plexus.

In a study by Dayal et al.,\(^9\) the mean length of the GSN was 54.05 ± 27.312 mm. In the present study, we found the length to be 5.61 ± 2.54 cm. The breadth of the GSN as estimated in the present study was 0.31 ± 11 cm.

Any ganglia situated outside the sympathetic trunk is intermediate ganglia\(^9\). Intermediate splanchnic ganglion has been observed as early as 1823 by Lobstein\(^10\) in two cases. Cunningham\(^11\) observed splanchnic ganglion in 77% of the cases and found thickening of the GSN in the specimens where the splanchnic ganglia was absent. The incidence of intermediate splanchnic ganglia in the present study is compared with previous studies in Table-6. Kuntz\(^12\) found ganglia and scattered ganglion cells in thoracic and lumbar splanchnic nerves. The ganglion cells were abundant and constant in all the splanchnic nerves and the number of unmyelinated fibers found in distal part of splanchnic nerve exceeded that of proximal part proving that postganglionic fibers arose from sympathetic ganglia as well as splanchnic ganglia and thus these splanchnic nerves with ganglion function as synaptic relays and not just conduction pathways.\(^{12}\) Naidoo et al.\(^13\) found medial collateral branches arising from intermediate splanchnic ganglia in all cases which was observed in the present study as well. These medial branches joined the aortic or esophageal plexus.

Bradley\(^14\) reported variations in the disposition of satellite filaments of the main splanchnic nerves which may enter the abdomen independently. The GSN gave off branches to aortic, pulmonary and esophageal plexus.\(^6\) In the present study we observed satellite filaments from the GSN which pierced the diaphragm through separate hiatus.

Thoracic splanchnicectomy is an important surgical procedure for the management of upper abdominal pain especially in chronic pancreatitis or pancreatic cancer. Maher et al.\(^15\) found that at early follow-up, most patients considered themselves vastly improved, but at 5-year median follow-up, only three patients (20%) appear to have obtained long-term reductions in their pain and disability scores. In a study by Howard et al.\(^16\), after a median follow-up of 32 months, 38 (69%) of 55 patients reported a return of abdominal pain. These inconsistent results could be due the medial collateral branches which provide alternate pathway to upper sympathetic chain and the anatomical variations found in the splanchnic nerves.\(^12\) We hope that the present study describes
the variations in the pattern of the greater splanchnic nerve. Awareness of the variant anatomy is important for a successful outcome of surgical and endoscopic interventions of thoracic splanchnic nerves [17-19].

Conclusion: The authors hope that the detailed anatomy of the greater splanchnic nerve provided in the present study will be helpful for students as well as surgeons for a better outcome of the thoracic splanchnicectomy.

REFERENCES