Transcrural coeliac plexus block simulated on 200 computed tomography images

I. Y. Yang1*, S. Oraee1, C. Viejo1 and H. Stern2
1 Department of Anesthesiology and Pain Medicine and 2 Department of Radiology, Bronx-Lebanon Hospital Center, Albert Einstein College of Medicine, 1650 Selwyn Avenue, Bronx, NY 10457, USA
* Corresponding author. E-mail: iyangmd@gmail.com

The common practice and teaching for needle placement in posterior approaches to coeliac plexus block is that the needle is inserted at a distance from the midline with the needle tip directed towards L1 vertebral body, and ‘walked off’ the bone to reach the target area on either side.1–6 In transcrural coeliac plexus block (tCPB) with this technique, the needle may puncture vital organs, especially the aorta on the left side, resulting in complications.7–8 We previously reported a modified, fluoroscopy-guided tCPB case avoiding vital organ penetration and painful bony contact.9 In that case, we performed a tCPB simulation on that patient’s computed tomography (CT) image before the procedure. The needle trajectories were placed on the image avoiding vital organs and bony contact, and aiming the base of the coeliac trunk where the plexus located, on both sides. Three parameters were measured: (i) the distances from the midline to the needle entry points across the skin on both sides; (ii) the depth from the anterior margin of the vertebra to the base of the coeliac trunk, representing the endpoint of the needle advancement; and (iii) the angles between the needle trajectory lines and the skin surface. The distances and angles were found to be significantly different from the classic recommendations and drastically different between sides. During the procedure, the needles were placed according to the parameters translated from the prior measurements in the tCPB simulation. The left-sided needle was inserted very close to the midline (3.58 (1.02) cm, with a steeper angle, 84.1° (6.0°), than those for the right placements [7.04 (1.56) cm, 61.1° (6.2°)] (P<0.00001). The shortest distances, 3.1 (0.8) cm, with the steepest angles, 87.7° (4.9°), were seen in the patients whose c-a-v distributions were left–left located (P<0.00001). Males required longer distance for needle insertion (P≤0.05). Cancer patients required a shorter distance with a steeper angle for the right needle placements (P<0.05).

Conclusions. Needle placement parameters for tCPB vary in laterality, gender, pathologies, and c-a-v distributions. We would advocate a simulated block on individual patient’s CT image to obtain relevant measurements for subsequent tCPB, although a clinical outcome study is warranted.

Keywords: autonomic nerve block; coeliac plexus; computer simulation

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Editor’s key points
- Coeliac plexus block can be a useful technique in the management of pancreatic pain.
- There is no consensus about the best imaging technique to use for needle placement.
- Pre-procedural CT was used to define the coeliac plexus, and simulate accurate needle placement.
- The standard approach may result in block failure or complications with correct placement not always possible.
- The position for correct needle insertion was affected by sex, side and intra-abdominal pathology.

Background. We previously reported a modified transcrural coeliac plexus block (tCPB) case, using parameters obtained from a pre-procedural computed tomography (CT) image of that patient for the subsequent tCPB under fluoroscopy. In this study, we performed the same tCPB simulation on 200 CT images to determine optimal needle placement parameters with a comparison to the classic technique.

Methods. On each CT image across the coeliac trunk, the tCPB was simulated on both sides with the needle trajectory placed between the vertebra and organs targeting the coeliac trunk. The distances of the needle entrance from the midline, the insertion angles, and depths were measured and analysed in the groups: laterality, gender, intra-abdominal condition, and coeliac-aortic-vertebral (c-a-v) distribution.

Results. Thirty placements failed to avoid organ penetration. The left-sided placements required a shorter distance, 3.58 (1.02) cm, with a steeper angle, 84.1° (6.0°), than those for the right placements [7.04 (1.56) cm, 61.1° (6.2°)] (P<0.00001). The shortest distances, 3.1 (0.8) cm, with the steepest angles, 87.7° (4.9°), were seen in the patients whose c-a-v distributions were left–left located (P<0.00001). Males required longer distance for needle insertion (P≤0.05). Cancer patients required a shorter distance with a steeper angle for the right needle placements (P<0.05).

Coeliac plexus block can be a useful autonomic nerve block; coeliac plexus; computer simulation
been very encouraging. In this series, we performed simulating tCPB on 200 CT images to examine needle placement parameters in laterality, gender, pathologies, and coeliac-aortic-vertebral (c-a-v) distributions for the block with a comparison with the classic technique.

Methods
The study was approved by the Institutional Review Board of the Bronx-Lebanon Hospital Center, Albert Einstein College of Medicine.

Abdominal CT scan with i.v. contrast from 200 adult patients were retrieved from the intramural Imagecast™ system (GE Healthcare, Allendale, NJ, USA). The axial slice across the coeliac trunk was selected for each patient by scrolling the images from the aortic hiatus of the diaphragm downward until the first anterior branch of the abdominal aorta appeared. The coeliac trunk was identified by its ramifications divided into the left gastric, common hepatic, and/or splenic arteries. In addition, it was differentiated from the superior mesenteric artery with its respective branches caudal.

To prepare the tCPB simulation, the topographic characteristics of the viscera-skeleton-vessels distribution on each selected image were reviewed. Special attention was paid to the c-a-v correlations. They were assigned into three c-a-v groups: (i) the L–l c-a-v group: the coeliac trunk exited from the left aortic wall (L) and the aorta located anterior to the left lateral one-third (l) of the vertebral body; (ii) the M–m c-a-v group: the coeliac trunk exited from the mid-anterior aortic wall (M) and the aorta located anterior to the middle one-third (m) of the vertebral body; and (iii) the Other c-a-v group, including L–r, M–l and, rarely, L–r, M–r, or R–m combinations (R representing the coeliac trunk exited from the right aortic wall and r representing the aorta located anterior to the right lateral one-third of the vertebral body).

Simulating needle placements were then implemented on each image (Fig. 1). The image was rotated 180° to imitate a prone position for the virtual procedure. The trajectory lines were placed as follows: (i) the lines traversed between the vertebral body and the vital organs without contact; (ii) they crossed the back skin but avoided the rib; (iii) the lines ended at the base of the coeliac trunk after passing through the crus of the diaphragm; and (iv) one line for each side. The distances between the needle entry points (E) and the spinal process (S) of the vertebra (ES, for the left side and ES, for the right side) were measured in centimetres against the intrinsic, horizontal scale on the image. The needle insertion angles (A) from the skin surface (A, for the left and A, for the right) were measured in degree with a protractor. The vertical distance from the anterior margin of the vertebra to the base of the coeliac trunk (d) was measured in centimetres against the intrinsic, vertical scale on the image. This represented the depth of the needle advancement endpoint from the vertebral silhouette on the future imaging. The measured parameters were analysed in the groups of laterality, gender, intra-abdominal condition, and c-a-v distribution.

Statistical analysis
The sample size was determined with the formula described by Campbell and colleagues. The components of the sample size formula were set as follows: (i) the α-level at 0.01 and the β-level at 0.1, (ii) the estimated standard deviation (SD) of the mean distance from the spinous process of the vertebral body for needle insertion being 0.5 cm from a small series of 13 successful clinical cases, (iii) the estimated SD of the mean needle insertion angle from the skin surface being 5° from the same patient group, and (iv) the acceptable margin of error for mean being 0.1 cm and 1° (99% confidence intervals). A 10% size increase was added to cover the possibly skewed data distribution.

The measured parameters were expressed as mean (SD). The comparisons made between the groups were: the left side vs the right side, and male vs female. The two-tailed Student’s t-test, using two-sample t-test calculator (UsableStat, http://www.usablestats.com), was used to examine the statistical significance. In the c-a-v groups and among the patients with or without intra-abdominal pathologies, the differences between the groups were examined with analysis of variance (ANOVA). The AOV calculator—one-way ANOVA from summary data (Statistics Calculators, http://www.danielsoper.com)—was used to determine the statistical significance. P-values of <0.05 were considered statistically significant.
Results

The characteristics of the 200 patients whose CT images of the upper abdomen were reviewed included 98 males and 102 females with a mean (range) age of 53.2 (16–94). One hundred and seven patients had normal upper abdomen. Ninety-three patients had pathologies including 70 with chronic pancreatitis, 21 with pancreatic cancers, one with liver cancer, and one with oesophageal cancer.

Topographic observation of c-a-v distribution revealed that 47.5% patients presented with L–l c-a-v distribution, 15% with M–m c-a-v distribution, 36% patients with L–m or M–l c-a-v distributions, and 1.5% patients with L–r, M–r, or R–m c-a-v distributions.

In 400 attempted needle simulations, 30 (7.5%) failed because it was impossible to avoid the vertebra without penetrating the vital organs. Twenty-five failures (83.3%) occurred on the right side (Fig. 2A), whereas five (16.7%) penetrating the vital organs. Twenty-five failures (83.3%) because it was impossible to avoid the vertebra without penetrating the vital organs. Twenty-five failures (83.3%) occurred on the right side (Fig. 2A), whereas five (16.7%) occurred on the left side (Fig. 2B). In four patients, no trajectory line could be placed on either side (Fig. 2C). The remaining 370 needle placements were successful, and the parameters such as distance and angle required for those needle placements are summarized in Table 1.

When studying laterality, the right-sided needle placements (n=175) required a mean (so) distance E,S=7.04 (1.56) cm from the midline with a mean (so) angle A,S = 61.1° (6.2°) to the skin surface. These values were close to the classic recommendations. However, the left-sided needle placements (n=195) required a much shorter mean (so) distance E,S = 3.58 (1.02) cm with a much steeper mean (so) angle A,S = 84.1° (6.0°) when compared with those for the right side (P<0.00001). These laterality differences for both distances and angles were also significant (P<0.00001) in all subgroups when they were examined in 104 patients with normal abdomen, in 91 patients with abnormal abdomen (69 chronic pancreatitis, 22 malignancies), in 97 male patients (44 with normal pancreases, 53 with abnormal pancreases), in 98 female patients (59 with normal pancreases, 39 with abnormal pancreases), and in all c-a-v subgroups.

In relation to the gender, 97 male patients required significantly longer distances for needle insertion on both sides when compared with 98 female patients [E,S: 3.73 (1.03) vs 3.43 (1.0) cm, P<0.05; E,S: 7.26 (1.46) vs 6.8 (1.63) cm, P=0.05]. However, no difference for needle insertion angles was found [A,S: 83.5° (6.1°) vs 84.6° (5.8°); A,S: 60.7° (5.8°) vs 61.6° (6.7°), P>0.1]. In 91 patients with abnormal upper abdomens, 52 male patients required longer distances but similar angles than those for 39 female patients. It was significant for right needle insertions [E,S: 7.22 (1.48) vs 6.56 (1.53) cm, P=0.05] but was not significant for left needle insertions [E,S: 3.70 (1.05) vs 3.28 (1.09) cm, P=0.07]. In 69 patients with chronic pancreatitis, 41 male patients required significantly longer distances but similar angles for needle insertion on both sides than those for 28 female patients [E,S: 3.78 (1.06) vs 3.25 (1.05) cm, P=0.04; E,S: 7.47 (1.30) vs 6.64 (1.31) cm, P=0.01]. In 22 patients with malignancy, no differences were found between 11 males and 11 females.

Among the patients with intra-abdominal malignancies, pancreatitis, and without pathology, there were no significant differences for left-sided needle insertion distances (P>0.5) and angles (P>1.0) and right-sided needle insertion distances (P=0.053), but there were significant differences for right needle insertion angles (P=0.03). However, the cancer patients required significantly shorter distances for right-sided needle insertions [E,S: 6.14 (1.93) vs 7.12 (1.5) cm, P=0.03] with steeper angles [A,S: 65.1° (7.9°) vs 60.8° (6.4°), P=0.02] when compared with those with normal upper abdomens.

With regard to the c-a-v distribution, there were very significant differences between groups in all four parameters (P<0.0001): E,S, E,S, A,S, and A,S. The L–l c-a-v group showed the shortest E,S, 3.1 (0.8) cm, the longest E,S, 7.5 (1.5) cm, the steepest A,S, 87.7° (4.5°), and the shallowest A,S, 58.6° (4.5°).
Transcrural coeliac plexus block simulation

Table 1 Simulating needle placement parameters. EₜS, the distance from the midline to the left needle entry point; EₛS, the distance from the midline to the right needle entry point; Aₜ, the left needle insertion angle from the skin surface; Aₛ, the right needle insertion angle from the skin surface. Values were expressed as mean (SD). L–l, left–left located c-a-v distribution; M–m, mid–mid located c-a-v distribution. Others, other combinations of c-a-v distribution

<table>
<thead>
<tr>
<th></th>
<th>EₜS (cm)</th>
<th>EₛS (cm)</th>
<th>Aₜ (°)</th>
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<tbody>
<tr>
<td>Overall</td>
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<tr>
<td>Sex</td>
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<tr>
<td>Males</td>
<td>3.58 (1.02) (n=195)</td>
<td>7.04 (1.56) (n=175)</td>
<td>84.1 (6.0) (n=195)</td>
<td>61.1 (6.2) (n=175)</td>
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<tr>
<td>Females</td>
<td>3.73 (1.03) (n=97)</td>
<td>7.26 (1.46) (n=91)</td>
<td>83.5 (6.1) (n=97)</td>
<td>60.7 (5.8) (n=91)</td>
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<td>Abdomen</td>
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<td>Normal</td>
<td>3.63 (0.97) (n=104)</td>
<td>7.12 (1.59) (n=93)</td>
<td>84.1 (5.3) (n=104)</td>
<td>60.8 (6.4) (n=93)</td>
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<td>Cancer</td>
<td>3.38 (1.12) (n=22)</td>
<td>6.14 (1.93) (n=16)</td>
<td>84.1 (8.3) (n=22)</td>
<td>65.1 (7.9) (n=16)</td>
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<tr>
<td>Pancreatitis</td>
<td>3.56 (1.08) (n=69)</td>
<td>7.14 (1.306) (n=66)</td>
<td>83.9 (6.1) (n=69)</td>
<td>60.6 (5.3) (n=66)</td>
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<td>Coeliac-aorta-vertebra</td>
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<tr>
<td>L–l</td>
<td>3.1 (0.8) (n=95)</td>
<td>7.5 (1.5) (n=81)</td>
<td>87.7 (4.5) (n=95)</td>
<td>58.6 (5.5) (n=81)</td>
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<td>M–m</td>
<td>4.6 (0.9) (n=30)</td>
<td>6.2 (1.0) (n=30)</td>
<td>77.2 (5.3) (n=30)</td>
<td>65.9 (6.1) (n=30)</td>
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<tr>
<td>Others</td>
<td>3.8 (0.9) (n=70)</td>
<td>6.8 (1.6) (n=64)</td>
<td>82.0 (4.3) (n=70)</td>
<td>62.0 (5.7) (n=64)</td>
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(5.5°). The M–m c-a-v group showed the longest EₜS, 4.6 (0.9) cm, the shortest EₛS, 6.2 (1.0) cm, the shallowest Aₛ, 77.2° (5.3°), and the steepest Aₜ, 65.9° (6.1°) (P<0.00001). The Others group (L–l, M–l, L–r, M–r, or R–m c-a-v) showed variable values (Table 1).

The average vertical distance from the anterior margin of the vertebra to the base of the coeliac trunk (d) was quite constant: 2.28 (0.49) cm (n=200). There was no difference between d’s in patients with normal abdomens: 2.28 (0.53) cm (n=107) and d’s in patients with abnormal abdomens: 2.28 (0.45) cm (n=93).

Discussion

The coeliac plexus block was originally described to block the splanchnic nerves without imaging assistance during the early 20th century.11 Currently, all coeliac plexus blocks are achieved under imaging guidance.12 What is the best imaging modality for the block remains controversial. For the posterior approaches, the fluoroscopic and CT guidance are the most commonly used methods.13–17 CT imaging provides anatomic details but represents an intermittent time-consuming process with more radiation exposure.18 Fluoroscopy dynamically monitors needle advancement and contrast-containing injectate spreading with continuous imaging but lacks anatomic details.19 The advantages of both imaging techniques can be combined by analysing and measuring patient-specific functional anatomy on the pre-procedural CT images and later translating them into the subsequent fluoroscopy-guided block, as described in our previous study.9

Despite the debate over the imaging guidance modality, the way to place the blocking needle has not changed much from its original technique.1–8 The common methodological description in textbooks and literature has a feature of ‘one set of needle placement parameters fits all patients in any condition’ whereby: (i) the needles are inserted equally on each side with a distance from the midline (typically, 7–8 cm off the midline);6 (ii) the needles are advanced equally on each side with an angle from the skin surface (typically, 45° or larger);4 (iii) the needle tips are to walk/slide off the vertebra equally on each side; and (iv) the technique is equal for both men and women. In contrast, our study with a tCPB simulation model on CT images demonstrated a significant difference from these classic depictions in all the aspects.

First, there was a laterality difference in needle insertion distances and angulations between the left and the right sides in our series. Although the right-sided needle placement parameters were found to be similar to the classic recommendation, the left-sided needle trajectories required a much closer distance to the midline with a near-perpendicular angle from the skin surface to reach the target. The differences in distances and angles for needle placements between the left and the right sides appeared to be very significant at P<0.00001. Additionally, these laterality differences for both distances and angles were found to be consistent in all examined subgroups at the same significance level (P<0.00001). The shorter distance with steeper angling required for the left blocking needle placement is probably because in the majority of the patients, the aorta is located anterior to the left side of the vertebral body, and the coeliac trunk exits from the left lateral wall of the aorta. If the aorta was located anterior to the left one-third of the vertebra with the coeliac trunk exiting from the left lateral wall of the aorta simultaneously, as seen in the L–l c-a-v group (47.5%), the distance for the left needle insertion was then further shortened to 3.1 (0.8) cm with the insertion angle being further steepened to 87.7° (4.5°). Meanwhile, the distance for right needle placement was lengthened to 7.5 (1.5) cm with the insertion angle reduced to 58.6° (5.5°) in the same patient (P<0.00001).
Fifteen per cent of the patients presented with an M–m c-o-v distribution. From the geometric point of view, this centrally located vasculature in relation to the vertebra should lead the needles to be placed equally for both sides in these patients. However, our observation revealed that the needle insertion distances and angles were not equal from side to side in this subgroup. The left-side needle lines were placed 4.6 (0.9) cm from the midline with an angle of $77.2^\circ$ (5.3°), whereas the right-side needle lines were placed 6.2 (1.0) cm from the midline with an angle of $61.1^\circ$ (6.2°). The laterality difference in this subgroup was also statistically significant ($P<0.00001$). Obviously, this difference is not related to the vessel–bone distribution. The laterality difference in surrounding vital organ size and distribution may play a significant role. In all respects, we would confidently conclude that the blocking needle placement should never be carried out the same way for both sides.

Secondly, there was a statistically significant gender difference for needle placement between men and women. Generally, the male patients ($n=97$) required longer distances ($P<0.05$) but the same angles ($P>0.1$) to place the needles on both sides when compared with those for the female patients ($n=98$). It was true in the subgroups of the patients with abnormal abdomen ($n=91$) and the patients with chronic pancreatitis ($n=69$). In 22 patients with malignancy, there was no gender difference between 11 males and 11 females. The explanation for the different distances but the same angles between men and women may lie in sexual dimorphism in human body size. On average, men are larger than women. In length measurements, this difference amounts to about 10%, and is relatively constant across human societies. Therefore, the needles placed in men for the block should logically be inserted more laterally than that in women. On the other hand, the needle insertion angles should not be different between men and women for the following reasons: the gender difference in size of viscera is evenly distributed except for the amount of adipose tissue. The needle trajectory lines on both sides across the line parallel to the back skin surface can be depicted as the two legs of a trapezoid (Fig. 1). When a smaller trapezoid (i.e. in female patients) overlaps to a larger trapezoid (i.e. in male patients) at the midpoint of the base (i.e. the spinous process across the line parallel to the back skin surface), the base angles (i.e. $A_1$ and $A_2$) should be similar on each side to project the legs of the two trapezoids to an equivalent area. The observation that there was no gender difference in 22 patients with upper abdominal malignancies is probably because of the small number of the patients in our series resulting from the limitation of our community hospital settings.

Some patients’ posterior intra-abdominal vital organs surrounding the coeliac trunk were so tightly proximal to the vertebral column that the simulating blocking needle trajectory could not be placed to bypass the bone without passing the vital organs. Among our 400 simulated needle placements, 30 (7.5%) attempts failed because of this close proximity of various vital organs to the vertebra. The majority of failures occurred on the right side (25/30, 83.3%) (Fig. 2a). It is apparently due to the large size organs, such as the liver, occupying the right upper quadrant of the abdomen and the longer distance for the right-sided needle to travel to reach the left-sided coeliac trunk. Left upper quadrant of the abdomen is much less crowded. In most of our patients (195/200, 97.5%), there was a ‘window’ from the skin surface to the base of the coeliac trunk between the c-o-v axis and the vital organs on the left side. Therefore, left-sided needle placements had a much lower failure rate (5/30, 16.7%). This observation is also different from the classic teaching. In the classic teaching, left-sided needle is to be inserted 7–8 cm lateral to the midline and advanced until the pulsation emanating from the aorta and transmitted to the advancing needle is noted,6 with the fear that a needle inserted on the left side would in most instances pass through the aorta before puncturing the crus of the diaphragm.8 The aortic pulsation felt through an advancing needleatraumatically is frequently difficult. If the needle is placed through the ‘window’ as described earlier, the intentional searching for the aortic pulsation with an advancing needle becomes unnecessary and the procedure will be safer.

Four patients (2%) did not have a ‘window’ on either side (Fig. 2c). All posterior approaches to CPB would be traumatic and unsafe. In these cases, we would recommend the use of ultrasound-guided gastroscopic CPB anteriorly. Although only 7.5% of the patients had tight proximity of various vital organs to the vertebra, preview of their CT images before CPB could discover this condition and thus avoid traumatic attempts.

Pre-procedural, diagnostic CT studies are usually performed while the patient is in a supine position, whereas the tCPBs are carried out with the patient in a prone or a lateral decubitus position. The retroperitoneal anatomies are usually not altered significantly with postural changes. If there is a concern about the postural influences to the blocking needle placement parameters, it would be prudent to obtain an additional CT image before the simulated tCPB planning with the patient in a position that will be taken for the subsequent procedure. In conclusion, needle placement parameters for tCPB significantly diverge in patients due to anatomic variations in laterality, gender, intra-abdominal pathology, and c-o-v distribution. We would advocate performing a block simulated on every individual patient’s CT image to obtain relevant measurements before subsequent tCPB. A clinical outcome study using this technique is warranted.

**Conflict of interest**

None declared.

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