Anatomical localization of nerve entry points and centers of intramuscular nerve dense region in quadriceps femoris and its significance in blocking muscle spasticity

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Abstract: This study aimed to determine the body surface locations and depths of the nerve entry points (NEPs) and the centers of the intramuscular nerve dense region (CINDRs) of the quadriceps femoris. Twelve adult cadavers were dissected. The curves connecting the greater trochanter with the pubic tubercle and with the lateral femoral epicondyle were designated as the horizontal (H) and longitudinal (L) reference lines, respectively. NEP was anatomically exposed. Sihler’s staining, barium sulfate, and computed tomography (to determine projection points (P) on the body surface) were employed. The intersection of the longitudinal line through P point and the H line and the horizontal line through P point and the L line were recorded as PH and PL, respectively. The projection of NEP or CINDR in the opposite direction across the transverse plane was P’. Percentage positions of PH and PL on lines H and L and NEP and CINDR depths were determined under the Syngo system. Two NEPs were identified in each muscle. For the rectus femoris, vastus intermedius, vastus lateralis, and vastus medialis, their PH were located at 56.79% and 56.90%, 56.90% and 57.89%, 42.51% and 43.81%, and 77.67% and 81.74% of line H; PL were at 5.92%, 16.64%, 6.50%, 8.99%, 16.68%, 34.89%, 42.84%, and 48.28% of line L; depths were at 14.00%, 14.70%, 18.96%, 19.73%, 21.53%, 25.76%, 21.70%, and 17.18% of line PP’, respectively; and they had two, one, one, and one intramuscular nerve dense region, respectively. PH of CINDRs were located at 60.63%, 63.39%, 59.95%, 45.30%, and 78.97% of line H; PL were at 20.95%, 57.59%, 42.45%, 49.14%, and 61.63% of line L; and depths were at 12.16%, 11.73%, 26.31%, 34.46%, and 19.28% of line PP’, respectively. Awareness of these positions and depths can improve the localization efficiency and efficacy of blocking targets for quadriceps femoris spasticity.

Keywords: Quadriceps femoris, spasticity, nerve entry point, intramuscular nerve dense region, target localization

Introduction

The quadriceps femoris includes the rectus femoris, vastus intermedius, vastus lateralis, and vastus medialis, which can extend the knee joint, bend the hip joint, and help in stabilizing the knee joint, slowing down the speed at which the calcaneus contacts the ground, and reducing the collision between the knee articular surfaces during normal walking [1, 2]. However, muscle spasticity may occur with stroke, traumatic brain or spinal cord injury, or lateral sclerosis of the spinal cord [3-7]. Spasticity of the quadriceps femoris will lead to difficulties in knee joint stability, knee bending, stepping, etc., which will seriously affect the daily life of patients [8].

At present, many methods are used to treat quadriceps muscle spasticity, such as oral medications [9, 10], partial tendon detachment or extension by surgery [11], selective neurectomy [12-14], extramuscular neurolysis by injecting phenol or ethanol into the extramuscular nerve trunk or nerve branch, and chemical nerve block by injecting botulinum toxin A (BTX-A) intramuscularly [15, 16]. The latter two methods are especially effective and commonly
used. However, the precondition of applying these two methods to achieve therapeutic effect lies in the accurate localization of the blocking targets. Although clinicians can roughly inject drugs to the target site by palpation, electromyography, ultrasonography, and electrical stimulator, etc., they still experience difficulties in accurately identifying the location of the blocking target [17-19], avoiding pain caused by exploratory puncture, and grasping the puncture depth, thereby generating some undesirable complications, such as muscle fibrosis, contracture, and antibody formation [15]. Therefore, accurate localization of blocking targets becomes the key factor for the successful implementation of these two treatment methods.

Studies have shown that neurolysis by injecting phenol or ethanol into the extramuscular nerve trunk can lead to non-spastic muscle involvement and paresthesia [17, 20]. The nerve entry point (NEP) is relatively close to the motor endplate, so injection at this point is more favorable for nerve regeneration to the motor endplate area [4]. BTX-A relieves muscle spasticity by inhibiting acetylcholine release from the presynaptic membrane at the motor endplate [21-23]. However, staining of motor endplates requires fresh specimens. Since the quadriceps femoris is the largest muscle in the body, this may be the reason why staining the motor endplate band of the quadriceps femoris has not been studied. Fortunately, some studies have reported that the location of the intramuscular nerve dense region (CINDR) is consistent with that of the motor endplate band [24-26] and can be used as a substitute target for the motor endplate band.

Given the aforementioned gap in research, this study aimed to accurately determine the body surface puncture locations and depths of the NEPs and the centers of the intramuscular nerve dense region (CINDRs) of the quadriceps femoris to improve the efficiency and efficacy of blocking target localization for quadriceps femoris spasticity. We hoped to achieve this by using barium sulfate, spiral computed tomography (CT), and three-dimensional reconstruction, and by accurately localizing the body surface positions and depths of NEP and CINDR of the quadriceps femoris under the Syngo system.

Materials and methods

Specimens and ethics

In this study, 12 formaldehyde-fixed cadavers (six men and six women) aged 35-75 years and without histories of neuromuscular diseases and deformities in the lower extremities were examined. Cause of death for donors included: cancer, cardiovascular disease, and traffic accidents. None of the cadaver donors belonged to any vulnerable groups, and all donors or their immediate family members had provided free written informed consent. The protocol of this study was approved in advance by the Ethics Committee of our university (Approval No.: #2016-1-006).

Gross anatomy observation, measurement, and reference line design

Oblique (from the anterior superior iliac spine to the pubic tubercle), horizontal (at the level of the tibial tuberosity), and longitudinal (from the anterior superior iliac spine to the fibular head through the greater trochanter) incisions were made. The skin and subcutaneous layer were cut as one layer and turned inward to the posterior femoral region. The origin and insertion points of the muscle were exposed. The arrangement of muscle fibers, source of nerve muscle branches, and presence of blood vessels at the NEP were observed. Muscle length, width, and thickness were measured using a Vernier caliper. The greater trochanter (a), pubic tubercle (b), and lateral femoral epicondyle (c) were selected as body surface markers. To conveniently describe the superior-inferior and medial-lateral relationships between the NEP and CINDR of the quadriceps femoris and body surface markers, the curve between the greater trochanter and the pubic tubercle closed to the skin was designed as a horizontal (H) reference line, and the curve between the greater trochanter and the lateral femoral epicondyle was designed as a longitudinal (L) reference line.

Sihler's intramuscular nerve staining

Twelve quadriceps femoris (six on the left and six on the right) were removed by cutting closely to the muscle origin and insertion, and Sihler’s staining process was carried out. For depigmentation, 3% potassium hydroxide and 0.2%
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hydrogen peroxide solution were used for 4-5 weeks until the muscle mass was transparent or translucent. For decalcification, Sihler I solution (one portion of glacial acetic acid + two portions of glycerol + 12 portions of 1% chloral hydrate) was applied for 4-5 weeks; the solution was changed once a week until the retracted muscle mass was stretched again. For staining, the specimens were immersed in Sihler II staining solution (one portion of Ehrlich's hematoxylin solution + two portions of glycerol + 12 portions of 1% chloral hydrate) for 4 weeks, which was changed once during the staining period. For the decolorization process, Sihler I solution was used for 4-20 h, ideally until the muscle turned lavender and the nerve branches were black. For neutralization, 0.05% lithium carbonate solution was used for 2 h and stirred. Prior to the above steps, specimens were washed with running water for 30 min. For transparency, the specimens were placed in glycerol for 1 week with a stepwise gradient increment (i.e., 40%, 60%, 80%, and 100%). The intramuscular nerve distribution pattern was observed under X-ray reading lamp. The percentage positions of the CINDRs on the muscle length and muscle width were measured with a Vernier caliper. Photographs were taken, and the pattern was plotted. The pattern plot was restored to the corresponding position of the human skeleton according to its corresponding proportion.

Spiral CT localization of NEP and CINDR

The right quadriceps femoris and NEPs of six cadavers, left quadriceps femoris, and NEPs of the other six cadavers were anatomically exposed. Muscle length, width, and thickness were measured. By combining the results of Sihler's staining process, the corresponding position of the CINDR was found, NEP and CINDR were labeled with barium sulfate (1 ml of glue: 4 g of medical barium sulfate powder), mixed with 801 glue (Wenzhou 801 Glue Company, China), dried by heat, and sutured layer by layer in situ. A needle was inserted at each of the body surface markers a, b, and c. A barium sulfate-soaked silk thread was sutured on the skin between ab and ac to represent lines H and L, respectively. Three-dimensional reconstruction was conducted by 16-row spiral CT (Siemens, Germany) with a collimation of 64 mm, a layer thickness of 1 mm, a pitch of 1:1, automatic tube milliamper current, and a voltage of 120 kV. Under the Syngo system (Siemens, Germany), on the transverse section, the first white point, i.e., barium sulfate-labeled NEP or CINDR, was searched for from the distal end to the proximal end of the lower limb.

According to the results, each of the four heads of the quadriceps femoris had two NEPs. In this study, the NEPs of the rectus femoris, vastus intermedius, vastus lateralis, and vastus medialis were labeled NEP$_{1a}$, NEP$_{1b}$, NEP$_{2a}$, NEP$_{2b}$, NEP$_{3a}$, NEP$_{3b}$, NEP$_{4a}$, and NEP$_{4b}$ respectively. There were two CINDRs in the rectus femoris and one in each of the other three heads, so CINDRs were named CINDR$_{1a}$, CINDR$_{1b}$, CINDR$_{2a}$, CINDR$_{3a}$, and CINDR$_{4a}$ respectively. Under the same bed indicator light, the projection points (P) of a NEP or CINDR on the body surface were localized by CT and percutaneous needle puncture perpendicular to the coronal plane, and the puncture points were P$_{1a}$, P$_{1b}$, P$_{2a}$, P$_{2b}$, P$_{3a}$, P$_{3b}$, P$_{4a}$, and P$_{4b}$ or P$_{1a}$', P$_{1b}$', P$_{2a}$', P$_{2b}$', P$_{3a}$', P$_{3b}$', P$_{4a}$', and P$_{4b}$' respectively. For the decolorization process, Sihler I solution was used for 2-20 h and stirred. After localization, the quadriceps femoris was removed, and Sihler's staining of intramuscular nerves was performed to verify whether the morphology and position of the INDR were consistent with those on the contralateral side and whether barium sulfate labeling was accurate and to exclude individual variants.

Statistical processing

Measured data are expressed as percentage (n%) to eliminate the influence of individual dif-
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References. SPSS17.0 (SPSS Inc., Chicago, IL, USA) was used to process the data. The paired t-test was used for comparison between the left and right sides, and the independent sample t-test was used for comparison between male and female cadavers. The significance level was α=0.05.

Results

Gross anatomy findings

The muscle fibers in the four heads of the quadriceps femoris are arranged in pennate shapes, and their innervation originates from the femoral nerve. The femoral nerve enters the thigh from the deep surface medial to the midpoint of the inguinal ligament and travels for 3-5 cm to form broom-like branches. Among them, usually, two muscular nerve branches dominate each head of the quadriceps femoris, named as the upper branch and the lower branch, i.e., each head has two NEPs. The NEPs of the rectus femoris are located on the deep surface on the lateral side of the mid-upper part of the muscle. The NEPs of the vastus lateralis are located on the superficial surface on the lateral side of the mid-upper part of the muscle. The NEPs of the vastus medialis are located on the superficial surface of the upper end of the muscle and the superficial surface on the medial side of the middle part of the muscle. Each NEP has accompanying blood vessels (Figure 1).

Spiral CT and NEP localization

Barium sulfate-labeled NEPs, reference lines, and bone landmarks are shown as white color in CT images. The puncture positions of the injection needles were the positions where the NEPs were projected on the skin. The lengths of lines H and H’ as well as lines L and L’ can be measured using curve measuring tools in the two-dimensional images of the transverse and coronal sections, respectively, and the lengths of P-NEP and PP’ can be measured with straight
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Distribution pattern of intramuscular nerves in the quadriceps femoris

Rectus femoris: After the superior nerve branch innervating this muscle enters the rectus femoris, it is usually divided into two primary nerve branches, which travel obliquely in the inferolateral direction and begin to project arborized branches at approximately 15.08% of the muscle length. After entering the muscle, the inferior nerve branch is usually divided into three primary nerve branches, among which the first primary branch travels in the lateral direction and then travels in the inferolateral direction to 48.41% of the muscle length. The branches of the primary branch along the way are anastomosed with the branches of the superior nerve branch to form INDR₁; the second and third primary branches descend on the medial side of the muscle parenchyma and are densely branched at 63.10%-79.37% of the muscle length, anastomosing with each other to form INDR₂. The area of these two nerve dense regions and the positions of the central points on muscle length and muscle width are shown in Figure 3 and Table 2.

Vastus intermedialis: After the superior and inferior nerve branches enter the muscle, they descend to 34.85%-55.37% level of the muscle length and send out abundant arborized branches oblique to both sides, forming INDR₂ (Figure 4).

Vastus lateralis: After the superior and inferior nerve branches enter the muscle, the nerve branches at all levels travel toward the infero-
Anatomical localization of NEPs and CINDRs

Table 1. Location of \( P_L \) and \( P_H \) of NEP on lines \( H \) and \( L \), respectively, and depth of NEP (%)

<table>
<thead>
<tr>
<th>NEPs</th>
<th>( L'/L )</th>
<th>( H'/H )</th>
<th>( P-NEP/PP' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEP 1a</td>
<td>5.92±0.19</td>
<td>56.79±1.40</td>
<td>14.00±0.72</td>
</tr>
<tr>
<td>NEP 1b</td>
<td>16.64±0.71</td>
<td>65.90±1.43</td>
<td>14.70±0.78</td>
</tr>
<tr>
<td>NEP 2a</td>
<td>6.50±0.29</td>
<td>56.90±1.43</td>
<td>18.96±0.61</td>
</tr>
<tr>
<td>NEP 2b</td>
<td>8.99±0.45</td>
<td>57.89±1.65</td>
<td>19.73±0.55</td>
</tr>
<tr>
<td>NEP 3a</td>
<td>16.68±0.86</td>
<td>42.51±1.21</td>
<td>21.53±0.80</td>
</tr>
<tr>
<td>NEP 3b</td>
<td>34.89±1.11</td>
<td>43.81±1.28</td>
<td>25.76±0.79</td>
</tr>
<tr>
<td>NEP 4a</td>
<td>42.84±1.13</td>
<td>77.67±1.81</td>
<td>21.70±0.66</td>
</tr>
<tr>
<td>NEP 4b</td>
<td>48.28±1.17</td>
<td>81.74±2.30</td>
<td>17.18±0.64</td>
</tr>
</tbody>
</table>

\( \text{NEP, nerve entry points.} \)

lateral direction, perpendicular to the oblique arrangement of muscle fibers, and anastomose to form INDR\(_3\) at 25.73%-72.64% of the muscle length (Figure 4).

Vastus medialis: The superior nerve branch is relatively thin and branches after it enters the muscle, which mainly dominates the muscle fibers at the upper part of this head. Meanwhile, the inferior nerve branch is relatively thick and branches after it enters the muscle, which mainly shuttles among muscle bundles and forms INDR\(_4\) at the middle and lower parts of the muscle length (31.92%-80.13%) (Figure 4). The area of these three INDRs and the positions of the CINDRs on the muscle length and muscle width are shown in Figure 4 and Table 2.

Spiral CT localization of CINDRs

Spiral CT localization images of CINDRs of the rectus femoris, vastus intermedius, vastus lateralis, and vastus medialis are shown in Figure 5. In this study, the CINDR\(_{1a}\) localization of the rectus femoris is taken as a representative for explanation (Figure 5). Table 3 shows the percentage position of the projection point \( (P) \) on the body surface of the CINDR of each head of the quadriceps femoris projected on lines \( H \) and \( L \) and the percentage depth of CINDR. No statistical difference was noted between the left and right sides or between male and female cadavers \( (P>0.05) \).

Discussion

This study successfully demonstrated the intramuscular nerve distribution pattern of the quadriceps femoris, the largest muscle in the whole body. By using barium sulfate to mark NEPs and CINDRs, spiral CT, three-dimensional reconstruction, and designing reference lines with bone landmarks, NEPs and CINDRs were more accurately localized on the body surface, and the puncture depths were obtained.

Muscle spasticity is one of the common clinical manifestations of many patients with central nervous system injury \([27, 28]\). Patients with muscular spasticity often have hypermyotonia of the upper limb flexors and lower limb extensors \([22, 28]\). The quadriceps femoris is a powerful extensor of the knee joint. Quadriceps femoris spasticity causes knee joint hyperextension, resulting in difficulties in knee bending and stepping and the “knee lock” phenomenon, with a circle-drawing gait and a tendency to fall, which affects walking \([11, 29]\). Therefore, one of the important problems that rehabilitation doctors need to solve urgently at present is to effectively relieve spasticity as soon as possible and allow patients to have isolated movement, thus alleviating pain and restoring daily life of patients. However, in the clinical process of blocking muscle spasticity by drug injection, accurate localization of the blocking target is not yet possible.

With regard to blocking of an extramuscular nerve motor point for muscle spasticity, some researchers anatomically exposed the nerve branches of the rectus femoris, used as references lines the connection line from the intersection point of the femoral nerve and the deep surface of the inguinal ligament to the midpoint of the superior edge of the patella as well as the connection line from the anterior superior iliac spine to the medial femoral condyle, and localized the positional relationship between the NEP and the two reference lines \([30]\). A study described the positional relationship between the nerve motor point of the quadriceps femoris and the line connecting the intersection point of the femoral nerve and the deep surface of the inguinal ligament with the midpoint of the superior edge of the patella \([31]\). Page et al. described the positional relationship between the nerve motor points of the four heads of the quadriceps femoris and the line connecting the intersection point of the femoral nerve and the deep surface of the inguinal ligament with the midpoint of the superior edge.
Anatomical localization of NEPs and CINDRs of the patella [32]. Although these anatomical studies provide useful information on the localization of blocking targets for extramuscular neurolysis by phenol or ethanol injection, the first two studies only described one of the four heads, and the medial-lateral relationship between the motor points and body surface markers was expressed as an absolute value rather than as a percentage, the influence of individual differences could not be eliminated, and only one motor point was described. Page et al. considered localization of the motor...
Table 2. Area of INDR in each head of the quadriceps femoris and percentage position of CINDR on muscle length and width

<table>
<thead>
<tr>
<th>INDRs</th>
<th>Area (cm²) ±</th>
<th>CINDR on muscle length (%) ±</th>
<th>CINDR on muscle width (%) ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDR₃ₐ</td>
<td>25.80±4.62</td>
<td>33.01±0.98</td>
<td>62.01±1.40</td>
</tr>
<tr>
<td>INDR₃₉</td>
<td>12.06±2.73</td>
<td>70.90±1.40</td>
<td>35.38±1.04</td>
</tr>
<tr>
<td>INDR₂</td>
<td>31.89±5.29</td>
<td>45.37±1.07</td>
<td>42.21±1.16</td>
</tr>
<tr>
<td>INDR₃</td>
<td>75.30±12.56</td>
<td>48.93±1.10</td>
<td>75.46±1.46</td>
</tr>
<tr>
<td>INDR₄</td>
<td>63.17±11.85</td>
<td>55.36±1.11</td>
<td>18.92±0.59</td>
</tr>
</tbody>
</table>

CINDR, centers of the intramuscular nerve dense region.

Figure 4. Intramuscular nerve distribution pattern of the right vastus intermedius, vastus lateralis, and vastus medialis, and positions of INDRs in the muscle. (A) Sihler’s staining process. Ruler: cm. (B) Schematic drawing of (A) and the positions of INDRs and CINDRs in the muscle. The red boxes represent INDRs, and the red dots represent CINDRs. CINDR, centers of the intramuscular nerve dense region.

points of the four heads at the same time and found that both the rectus femoris and vastus lateralis have two nerve motor points. However, Page’s study did not clarify the medial-lateral relationship between the motor points and body surface markers, on the contrary, it was inconsistent with the results of present study that each of the four heads had two nerve motor points. In addition, these studies failed to localize the motor points on the body surface, so the operability was not high.

In blocking intramuscular nerve motor points for muscle spasticity, Gallina described the absolute value of the positional relationship between the innervation zone of the vastus medialis and the line connecting the anterior superior iliac spine with the midpoint of the superior edge of the patella [33]. Kaymak defined the innervation area of the quadriceps femoris and the injection site of BTX-A through anatomy, cholinesterase staining, and electromyography, taking the connection line between
Anatomical localization of NEPs and CINDRs

Table 3. Location of \( P_{H} \) and \( P_{L} \) of the CINDR on lines \( H \) and \( L \), respectively, and depth of CINDR (%)

<table>
<thead>
<tr>
<th>CINDR</th>
<th>( L'/L )</th>
<th>( H'/H )</th>
<th>( P\text{-}\text{CINDR}/P' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CINDR <em>1a</em></td>
<td>20.95±1.01</td>
<td>60.63±1.63</td>
<td>12.16±0.52</td>
</tr>
<tr>
<td>CINDR <em>1b</em></td>
<td>57.59±1.35</td>
<td>63.39±1.68</td>
<td>11.73±0.31</td>
</tr>
<tr>
<td>CINDR <em>2</em></td>
<td>42.45±1.33</td>
<td>59.95±1.38</td>
<td>26.31±0.78</td>
</tr>
<tr>
<td>CINDR <em>3</em></td>
<td>49.14±1.20</td>
<td>45.30±1.46</td>
<td>34.46±1.12</td>
</tr>
<tr>
<td>CINDR <em>4</em></td>
<td>61.63±1.56</td>
<td>78.97±1.71</td>
<td>19.28±0.86</td>
</tr>
</tbody>
</table>

CINDR, centers of the intramuscular nerve dense region.

The results of the present study show that the areas of the five INDRs in the quadriceps femoris are 25.80±4.62 cm², 12.06±2.73 cm², 31.89±5.29 cm², 75.30±12.56 cm², and 63.17±11.85 cm², respectively. This means that as long as the injection location is accurate, only 7-15 U of BTX-A needs to be injected into the rectus femoris, the vastus intermedius needs 6-12 U, the vastus lateralis needs 15-30 U, and the vastus medialis needs 13-25 U to achieve relatively good efficacy. This will greatly save the dosage and cost of drugs.

Figure 5. CT image of the center of intramuscular nerve dense region of the left quadriceps femoris (e.g., CINDR _1a_). A: Spiral CT three-dimensional reconstruction image shows the projection positions of the CINDR on the body surface and the designed reference lines. B: Lengths of lines \( L \) and \( L_{1a}' \) measured on the coronal section through line ac. C: Lengths of lines \( H \) and \( H_{1a}' \) measured on the transverse section through line H. D: Depth of CINDR _1a_ measured on the transverse section through \( P_{1a} \). CINDR, centers of the intramuscular nerve dense region; CT, computed tomography.

BTX-A blocking of muscle spasticity is a dose-dependent chemical denervation in the action site of the motor endplate [26], and its efficacy depends on the distance between the injection needle and the motor endplate. Upon BTX-A injection into the muscle, BTX-A immediately spread within a few centimeters near the needle tip [34]. If the position of the BTX-A injection point deviates from the motor endplate by 1 cm, the anti-spasm effect will be directly reduced by 50% [23]. Therefore, CINDRs were used as targets in this experiment. Studies have shown that 1 U of BTX-A can infiltrate 1.5-3 cm, and 2.5-5 U can infiltrate 4.5 cm [35]. Currently, the clinical dosage of BTX-A injected for quadriceps femoris spasticity is 100-200 U [8, 36-38].

The results showed that the injection points of the rectus femoris are at 40% and 60% of the connection line, those of the vastus intermedius are at 50% and 65%, those of the vastus medialis are at 75% and 85% of medial to the connection line, and those of the vastus lateralis are at 50% and 65% of lateral to the connection line [29]. The positions of these targets are completely different from those described in the present study, which should be caused by the different reference lines.

The anterior superior iliac spine and the patella of the patient as the reference line under ultrasound guidance. The results showed that the injection points of the rectus femoris are at 40% and 60% of the connection line, those of the vastus intermedius are at 50% and 65%, those of the vastus medialis are at 75% and 85% of medial to the connection line, and those of the vastus lateralis are at 50% and 65% of lateral to the connection line [29]. The positions of these targets are completely different from those described in the present study, which should be caused by the different reference lines.
Anatomical localization of NEPs and CINDRs

The results of this experiment suggest that when clinicians need to perform extramuscular neurolysis and intramuscular chemical nerve blocking, the NEP and CINDR localization results in this paper can be used as reference, respectively. During localization, the length of the curve from the greater trochanter to the femoral epicondyle can be measured with a tape ruler against the skin, and a horizontal line can be drawn at the corresponding percentage position. Then, the curve length is measured from the greater trochanter to the pubic tubercle, and a longitudinal line is drawn at its corresponding percentage position. The intersection of the two lines on the skin is the puncture point (point P) on the body surface. Then, the length of line PP’ perpendicular to coronal plane through point P is measured using a pelvis measuring instrument, and the corresponding percentages were multiplied to obtain their puncture depths. Notably, when injecting drugs for extramuscular neurolysis, the syringe plunger needs to be pumped back to prevent drugs from straying into accompanying blood vessels.

In this study, during data measurement, curve measurement close to the skin was adopted, and the results were expressed as percentages in the same individual. The results obtained are accurate and have strong operability, which provide a scientific basis for improving the efficiency and efficacy of treatment for quadriceps femoris spasticity. However, we still suggest auxiliary localization in clinical application in combination with electrical stimulator, ultrasonography, or electromyography to further reduce the pain caused by exploratory puncture and to improve the efficacy and efficiency. Nevertheless, the generalization of our results is limited by the relatively small sample size, and it has not yet revealed whether there are differences among different races. The efficacy and efficiency still need clinical application for confirmation.

In conclusion, the definition of NEPs, CINDRs, and depths can improve the localization efficiency and efficacy of blocking targets for quadriceps femoris spasticity. Moreover, patients with quadriceps femoris spasticity may benefit from extramuscular neurolysis and chemical nerve block by intramuscular BTX-A injection when the defined points are used as reference guides.

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Disclosure of conflict of interest

None.

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