Precise Localization of Motor Branching and Motor Points: A Cadeveric Study

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In order to facilitate precise localization of motor nerves and motor points, and to increase effectiveness and minimize complications of neurolytic blocks. Locations of motor branching points and motor points of 31 cadavers were measured as relative to medial femoral condyle and mid posterior calf line. Needle insertion points 1.5 centimeters and 0.5 centimeters proximal to the level of medial femoral condyle yielded the best chance(66.25%-76.19%) of finding motor branches to medial gastrocnemius muscles and lateral gastrocnemius respectively. The points with greatest chance of success (67.69%-86.41%) for soleus, tibialis posterior and flexor hallucis longus motor branches blocks were found to be at 2.5, 6, and 11 centimeters distal to the level of medial femoral condyle respectively. However,even if these points are used as guidelline when performing motor branch block prodedure, the risk of sensory nerve fiber injury are still as high as 20.98% upto 50.0%. To avoid such complication,the authors have proposed a set of landmarks that would make it possible to access all of the motor branches of any single calf muscle with only three or less needle insertions, and still maintaining about 1% risk of sensory fiber injury.

Keywords: *Neurolysis, Nerve, Tibial, Cadaver, Motor branch, Phenol, Anatomy*

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Nerve blocks are one of the most commonly used procedures to control localized spasticity in neurorehabilitation. Commonly used therapeutic agents range from short acting anesthetic agents to long acting anesthetic agents(1) and neurolytic agents such as alcohol(2) and phenol. Stroke(3), spastic diplegic and tetraplegic cerebral palsy(4-8), spinal cord injury and traumatic brain injury(9-13) are the most common causes of spasticity treated with these methods in the literature.

These procedures usually have a lasting effect up to months after treatment, depending on the chosen agent and technic of application(14-18). Regardless of the neurolytic agent used chronic neuropathic pain can occur as a result of sensory nerve fiber injury or irritation. Other problems are, pain during injection, tissue destruction, increased risk of thrombopheblitis and lack of selectivity on motor function(2). Precisely placing the injecting needle tip to the pure motor branch (muscular branch) which contains no cutaneous sensory fiber would help to avoid these complications and at the same time reduce the amount of neurolytic agent injected. So, ability to precisely place the injecting needle tip closest to the motor nerve and motor point will be very valuable for excecuting such a procedure.

Currently, there are several technics which are commonly employed to help improve needle localization. Strong visible muscular contraction in response to electrical stimulation applied via the tip of the injection needle is most commonly used as an indicator that the needle tip is positioned in closest proximity to the target nerve(19). However, animal researches showed that electrical stimulation alone may not completely prevent the injection into the mixed nerve trunk(20).

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Presence of “end-plate potentials” electromyographic signals picked up from the needle tip can also indicate that the needle tip is closest to the neuromuscular junction but such technic requires that the patient does not contract the target muscles, which is usually not practical when treating pediatric patients(4). Open phenol injection into the motor nerve during surgical exploration has been reported to be highly effective with a very low incidence of post injection sensory complication(16,21) compared to the closed techincs, but such methods are generally felt to be too invasive.

Despite the fact that spastic ankle plantar flexion and inversion are one of the most common indications for such procedures. To the authors’ acknowledgement, there are only two anatomical studied of Tibial nerve motor branch and motor points localization especially intended for this purpose(22,23). None of these studies include the branching pattern of motor branches to the flexor hallucis longus muscles.

Because of the large anatomical variation, a simple description of the mean and standard deviation of the distances of the motor branches and motor points from the reference landmarks, as presented in previous research, are only moderately helpful in reducing the number of needle insertions and probing. Currently available data can not yet dictate the most effective strategic sequence and points of needle insertions that allow maximum access to all motor branches while minimizing the number of needle insertions and probing.

The objective of the present study was to describe the distribution and branching pattern of motor nerve and motor points that innervate the gastrocnemius, soleus, tibialis posterior and flexor hallucis longus muscles. Data analysis focused not only on mean distances and standard deviations from a fixed anatomical reference point, but also on trying to find out technics for safe needle tips placement closest to the desired motor branches with minimal needle insertions. The authors hope that this knowledge will make the procedures become more effective and safer.

Material and Method

From Febuary1999 to October 2001 the authors studied 31 cadevers (16 male, 15 female). The average age 74 yrs (SD = 11). The cadevers were placed in the prone position with the dissected limbs in anatomical position. All dissection and measurement were done by one of the authors. Some limbs were excluded from the calculation because they were previously used for other studies and were not compatible with the present study or because dissection failed to identify the motor branch supplying the studied muscles.

The authors defined the constant reference point and measurement procedure for standardized measurement (Fig. 1). First, an imaginary “mid-posterior calf line” was drawn along the longitudinal axis of the leg over the posterior surface of the calf, passing over Achilles tendon insertion. The most prominent tip of the medial femoral condyle was used as another fixed anatomical reference point.

Then another imaginary “reference level” line was drawn from the peak of the medial femoral condyle towards and perpendicular to the “mid posterior calf line”.

Distances from the “reference level” to the points where the motor nerve (motor branch) branches off from the main nerve and the distances to the point where the motor branch pierce into the muscle belly were measured. These measurements were always made parallel to the “mid posterior calf line”. The value was assigned negative value if that intersecting point was proximal to the zero reference point, and negative value if the point was proximal to the zero reference point.

Descriptive statistics, possibility of needle tip meeting the motor point, motor nerve or mixed nerve trunk was calculated. These possibility calculations were based on the generally accepted assumption that any motor branches within 2 centimeters from the injecting needle tip can be identified with the help of electrical stimulation and some probing.

Results

A significant number of the cadevers showed unequal number of motor branching patterns supplying the right versus the left sided muscles as shown in Table 1. Fig 2 shows the probability of injection placing needle into the motor nerves, motor points, and mixed nerve at each needle insertion points near and far from the zero reference point. Details regarding motor branching pattern innerving to each muscle are separately described below.

Medial gastrocnemius

A total of 84 motor branches were found to innervate the medial gastrocnemius muscles in 62 legs dissected. On average there are 1.35 motor branches per leg supplying this muscle. There is 1 branch in 44 legs (70.96%), 2 branches in 14 legs (22.58%) and 3 branches in 4 legs.

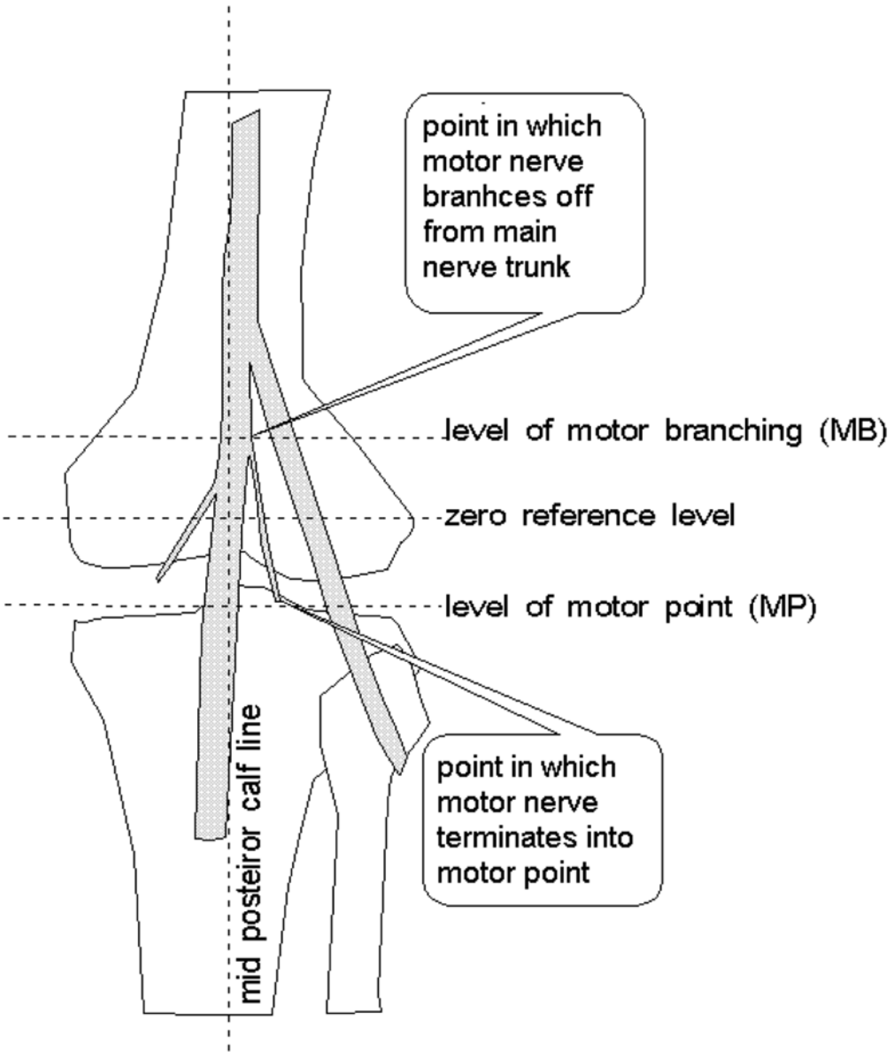

Fig. 1 Measurement technique used in the presented research

Table 1. Number of cadevers with symmetrical and asymmetrical motor nerve branching pattern innervating various calf muscles of both legs

	Asymmetrical motor nerve branching pattern	Symmetrical motor nerve branching pattern
Soleus	6	25
Tibialis posterior	7	24
Medial gastrocnemius	13	18
Lateral gastrocnemius	14	17
Flexor hallucis longus	9	23

The greatest probability of blocking a motor branch is at 1.5 cm proximal to the zero reference level(fig 2a),64 of the total 84 motor branches (76.19%) could be accessed with one needle insertion at that point. However, at that level 48.38% of the medial gastrocnemius motor nerve did not yet branch off from the main tibial nerve trunk, so there is a relatively high risk that injection at this level may cause an injury to the mixed nerve. If needle insertion is made at 4 centimeters or more distal to the zero reference line there is virtually no risk of injection into a mixed nerve, while the chance of meeting a motor branch is still pretty good (31 of 84 branches, about 36.90%).

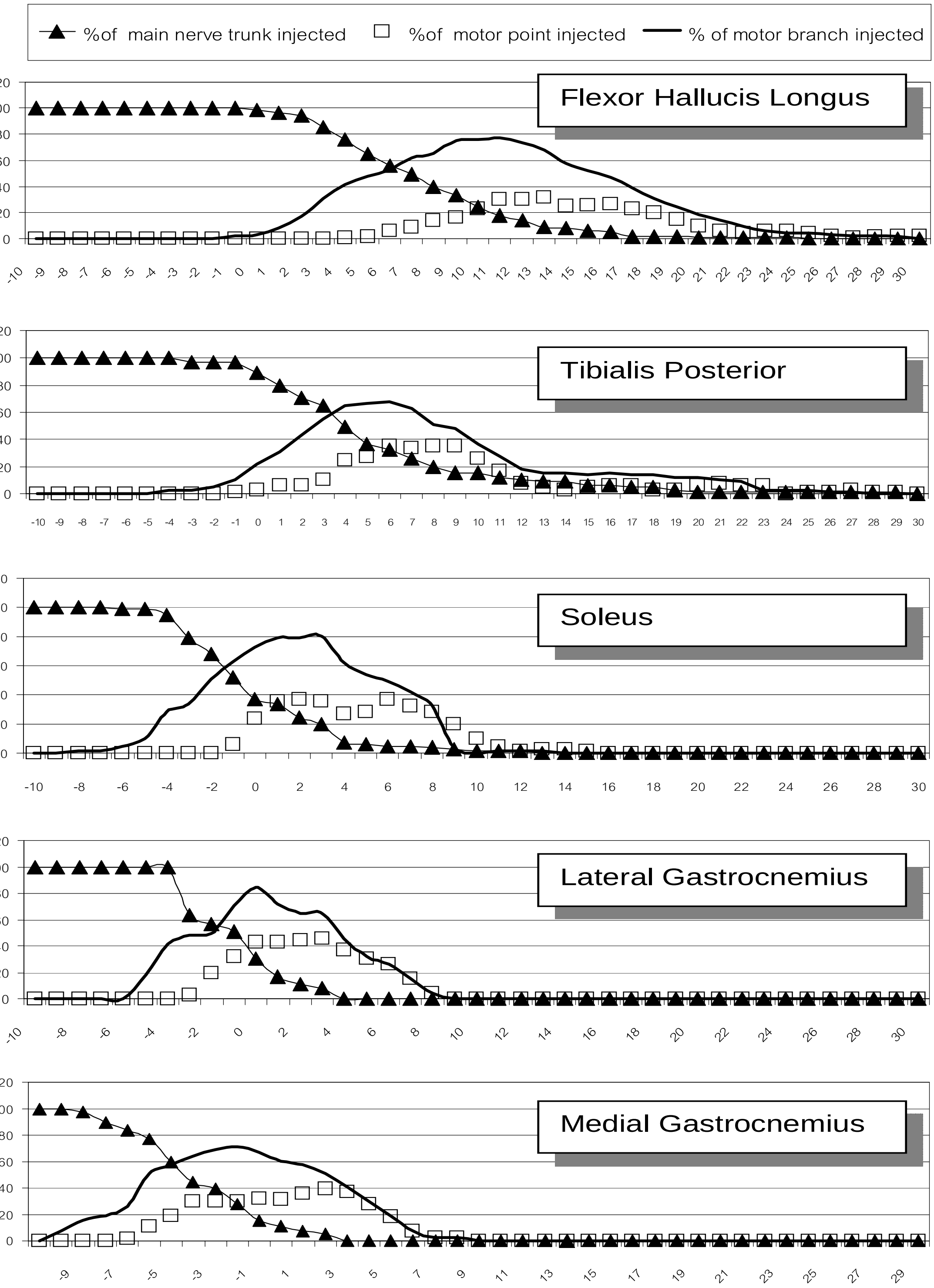

Fig. 2 Estimated percentage of the main nerve trunks , motor points , and motor branches innervating each muscles in the calf, that may be injected if injection is performed at various needle insertion locations. Numbers on vertical axis are percentage. Numbers on horizontal axis represents distance of simulated location of needle insertion in centimeters. Positive and negative value indicate a point distal and proximal distal to the “zero reference level”respectively

Table 2. Suggested locations for neurolytic block to relieve spasticity

Target muscles	First location for needle insertion (cm)	Second location for needle insertion (cm)	Third location for needle insertion (cm)
Medial Gastrocnemius	+3	–3	Not needed
Lateral Gastrocnemius	+3	–3	Not needed
Soleus	+8	+2	Not needed
Tibialis posterior	+18	+10	+4
Flexor hallucis longus	+18	+12	+6

Lateral gastrocnemius

A totals of 80 motor branches were found to innervate the lateral gastrocnemius muscles in 62 legs dissected. In one leg the authors could not identify the motor branch innervating this muscle, it is, thus, not counted in this set of calculation. On average there are 1.31 motor branches per leg supplying this muscle. There is 1 branch in 45 legs (73.77%), 2 branches in 13 legs (21.31%) and 3 branches in 3 legs.

The best chance of blocking a motor branch is at 0.5 cm proximal to the zero reference level (figure 2b) 53 of the total 80 motor branches (66.25%) could be accessed with one needle insertion at that point. At that level 54.09% of the lateral gastrocnemius motor branches did not yet branch off from the main nerve trunk, so there is relatively high risk that injection at this level may cause injury to the mixed nerve. If needle insertion is made at 4 centimeters or more distal to the zero reference line there is virtually no risk of injection in to a mixed nerve, while the chance of meeting a motor branch is still pretty good (25 of 80 branches, about 31.25%).

Soleus

A total of 81 motor branches were found to innervate the Soleus muscles in 62 legs dissected. In one leg the authors could not identify the motor branch innervating this muscle, so only 61 legs were counted in this set of calculation. On average there are 1.32 motor branches per leg supplying this muscle. There was 1 branch in 45 legs (73.77%), 2 branches in 12 legs (19.67%) and 3 branches in 4 legs.

According to figure 2c, the highest chance of blocking a motor branch is at 2.5 cm distal to the zero reference level,70 of the total 81 motor branches (86.41%) can be accessed with one needle insertion at that point in which, 20.98% of the soleus motor nerves did not yet branch off from the tibial nerve. So there is a relatively high chance that injection at this level may cause injury to the mixed nerve. If needle insertion is made at 13 centimeters or more distal to the zero reference line there is virtually no risk of injection into a mixed nerve, but the chance of meeting a motor branch would then be equally low (1 of 81 motor branches, about 1.23%).

Tibialis posterior

A totals of 65 motor branches were found to innervate the medial gastrocnemius muscles in 62 legs dissected. In 9 legs the authors could not identify the motor branch innervating this muscle, so only 53 legs were counted in this set of calculation. On average there are 1.22 motor branches per leg supplying this muscle. There was 1 branch in 44 legs (83.01%), 2 branches in 6 legs (11.32%) and 3 branches in 3 legs.

According to figure 2d, the highest chance of blocking a motor branch was at 6 cm distal to the zero reference level, where 44 of the total 65 motor branches (67.69%) could be accessed with one needle insertion at that point. However, at that level the tibialis posterior motor nerve did not yet branch off from the tibial nerve truhk, so there is 50% chance that injection at this level may also cause injury to the mixed nerve. Only needle insertions made at 28 centimeters or more distal to the zero reference line will have no risk of inadveranty injection in to a mixed nerve, but at such a distal level almost every tibialis posterior motor nerve has terminated into motor points at other proximal levels. Only 1 of 65 motor branches (1.53%) are available there.

Flexor hallucis longus

Of the 61 cadeveric legs, 9 legs were not included in the present study because the authors could not identify the motor branch innervating this muscle, so only 53 legs were counted in this set of calculation. A total of 93 motor branches were found to innervate the medial gastrocnemius muscles in 53 legs. At average there are 1.75 motor branches per leg supplying this muscles. There was 1 branch in 27 legs

(50.94%), 2 branches in 14 legs (26.41%), 3 branches in 8 legs (15.09%) and 4 branches in 14 legs.

According to figure 2e, the best chance of blocking a motor branch is at 11 cm distal to the zero reference level, 95 of the total 123 motor branches (77.23%)can be accessed with one needle insertion at that point. However, the presented data showed that there is relatively high risk (41.50%) that injection at this level may cause injury to the mixed nerve. At 25 centimeters or more distal to the zero reference line there is no risk of injection in to a mixed nerve, but the chance of meeting a motor branch is equally poor. Only 1.19% (1 of 84 branches) of all motor branches are available there.

Discussion

The present finding is compatible with previous reports that phenol injection in multiple sites is usually needed to completely control spasticity in a muscle(5,21), and the high variation of branching pattern was found in one of the previous studies(22). Possibly this difference may be due to tearing of the motor branch during the cadaveric dissection process. Further study using high resolution tomographic scans may clarify this discrepancy.

The above data analysis shows that the branching point of all the motor nerves innervating every studied muscle is distributed over a wide area, and there is frequently more than one motor branch innervating a muscle. Injection made at any single point,at best can only access between 73.77 to 86.41% of all motor branches. So, more than one needle insertion is needed to access and then block all the motor branches without disturbing the main mixed nerve trunk. Besides, single needle insertion,even at the level which yield greatest probability of finding a motor branch, still bears a 20.98% to 50% risk of main tibial nerve trunk injury. On the other hand, attempting neurolytic blocks at very distal levels where all motor branches had branched off from main trunk of tibial nerve would allow us to block only 1.23% to 36.9% of all motor branches. It is thus logical that a series of injection performed between these two level, with the first block performed more distally than the following points should result in more complete block while minimizing the chance of accidental main nerve trunk injection.

A series of locations for needle insertions is presented in Table 2. This guideline would make it possible to block up to 99% of all motor nerves innervating any particular calf muscles with minimum number of needle insertion and lowest risk of injecting the mixed nerve. No more than 3 needle insertions should be needed in order to completely block motor branches to any muscles. When simulate the result of neurolytic block using this set of landmarks,the risk of main nerve trunk injection was shown to be less than 1%.

Even if it is theoretically possible, complete neurolysis of all motor branches to all calf muscles should be preserved only for cases in which no functional loss is at risk such as patients with complete paraplegia.

Whether the use of this landmark would be really useful in clinical practice, a further prospective study quantifying actual clinical results and rate of complications is needed. To compare pre and post block motor and sensory nerve conduction across the injected nerve segment area could be used as objective evidence to demonstrate frequency and severity of inadverant main nerve trunk (mixed nerve) injection when doing phenol neurolytic block in a further study. A prospective study of spastic tone reduction and incidence of neuropathic pain after nerve block using this guideline should be the definite evidence whether or not to use the general knowledge of the present study as the standard procedure in clinical practice.

Conclusion

The data show that motor points and motor branching points of every calf muscles are dispersed over the whole leg segment. The authors suggest locations for sequential neurolytic block that should theoretically enable partial and/or complete block of motor branches or motor point innervating the calf muscles selectively with the lowest risk of injection into mixed nerves. In case one wishes to access all the available motor points, a single location of needle insertion is not adequate while multiple needle insertions are still needed due to the wide distribution of motor points.

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การศึกษารูปแบบการแตกแขนงของเส้นประสาทสั่งการที่ควบคุมการทำงานของกล้ามเนื้อต่าง ๆ ที่บริเวณน่อง

ภาริส วงศ์แพทย์, โกสุม ชินเศรษฐกิจ, สิริพิมพ์ สุอาชาวรัตน์, ธัญญารัตน์ แดงประเสริฐ, วิภาวัลย์ วงศ์แพทย์

คณะผู้วิจัยได้ทำการศึกษาศพอาบน้ำยาจำนวน 31 ร่าง และทำการบันทึกลักษณะ, จำนวน, และตำแหน่งของการแตกแขนงเส้นประสาทสั่งการ (motor branch) ของเส้นประสาทที่ควบคุมกล้ามเนื้อเฉพาะแต่ละมัดบริเวณน่องจากการวัดระยะโดยเปรียบเทียบกับจุดอ้างอิงคงที่คือยอดแหลมของปุ่มกระดูก medial femoral condyle และเส้นสมมุติที่แบ่งครึ่งตามความยาวของน่องด้านหลัง พบว่าตำแหน่งที่มีโอกาสสูงที่สุด (66.25%-76.19%) ที่จะประสบความสำเร็จจากการลงเข็มฉีดยาเพื่อทำการเข้าถึงแขนงเส้นประสาทสั่งการของกล้ามเนื้อ medial gastrocnemius และ lateral gastrocnemius อยู่ห่างจากระดับจุดอ้างอิงคงที่ดังกล่าวสูงขึ้นมาทางโคนขา1.5, และ 0.5 ซม.ตามลำดับ ส่วนตำแหน่งที่มีโอกาสประสบความสำเร็จสูงที่สุดในการเข้าถึงแขนงเส้นประสาทสั่งการของกล้ามเนื้อ soleus, tibialis posterior และ flexor hallucis longus (67.69%-86.41%) นั้นอยู่ที่ระดับ ห่างจุดอ้างอิงฯ ไปทางปลายเท้า 2.5, 6 และ 11 ซม. ตามลำดับ อย่างไรก็ตาม การเลือกทำหัตถการฉีดน้ำยาทำลายเส้นประสาทตามจุดดังกล่าวมีข้อเสียคือยังมีโอกาสฉีดน้ำยาไปถูกเส้นประสาทรับความรู้สึกได้อยู่ระหว่าง 20.98% ถึง 50.0% เพื่อป้องกันปัญหาดังกล่าวผู้วิจัยได้เสนอจุดตำแหน่งที่หมายชุดหนึ่งที่อาจทำให้สามารถเข้าถึงแขนงเส้นประสาทสั่งการทั้งหมดที่ไปเลี้ยงกล้ามเนื้อหนึ่งใดได้ด้วยการลงเข็มฉีดยาไม่เกิน 3 ตำแหน่งโดย มีโอกาสในการฉีดยาไปถูกเส้นประสาทรับความรู้สึกเพียงประมาณ 1% เท่านั้น
