Compared with dual nerve stimulation, ultrasound guidance shortens the time for infraclavicular block performance

L'échoguidage réduit le temps jusqu'à l'efficacité d'un bloc infraclaviculaire par rapport à la stimulation nerveuse double

Richard Brull, MD · Mario Lupu, MD · Anahi Perlas, MD ·
Vincent W. S. Chan, MD · Colin J. L. McCartney, MB

Received: 26 January 2009 / Accepted: 6 August 2009 / Published online: 29 August 2009
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Abstract

Purpose The success rate for infraclavicular brachial plexus block using nerve stimulation reportedly ranges from 60 to 80%. Ultrasound guidance may be associated with greater success. This study compared ultrasound guided infraclavicular block with a dual motor endpoint nerve stimulation technique.

Methods One hundred three hand surgery patients were randomized to receive either ultrasound-guided (ultrasound group) or dual motor endpoint nerve stimulation (stimulation group) infraclavicular block using 2% lidocaine 15 mL and 0.5% bupivacaine 15 mL with epinephrine. Block success was defined as loss of sensation to pinprick in each of the radial, ulnar, median, and musculocutaneous nerve distributions when measured 20 min after block performance. Block performance time, readiness for surgery (no supplemental block, skin infiltration, or general anesthesia), and complications were also assessed.

Results Patient characteristics were similar between groups. Success rate was 92% in the ultrasound group and 80% in the stimulation group ($P = 0.18$). Block performance time was shorter in the ultrasound group (median 5 min) compared with the stimulation group (median 10.5 min) ($P < 0.001$). Paresthesiae were more frequent in the stimulation group (45%) than in the ultrasound group (6%) ($P < 0.001$). After final injection, more patients were ready for surgery in the ultrasound group (85%) than in the stimulation group (65%) ($P = 0.04$). At 1 week postoperatively, complications were minor and transient and did not differ between groups.

Conclusion There was no statistically significant difference in the success rate between ultrasound guidance and dual motor endpoint stimulation for infraclavicular block. However, ultrasound guidance shortens performance time and improves readiness for surgery compared with dual motor endpoint stimulation (Clinical Trial Registration Number: NCT00326261).

Résumé

Objectif Selon la littérature, le taux de réussite d'un bloc infraclaviculaire du plexus brachial réalisé par stimulation nerveuse se situe entre 60 % et 80 %. L'échoguidage pourrait être associé à un taux de réussite plus élevé. Cette étude a comparé un bloc infraclaviculaire réalisé par échoguidage à une technique de double stimulation nerveuse des extrémités motrices.

Méthode Cent-trois patients devant subir une chirurgie de la main ont été randomisés à recevoir un bloc infraclaviculaire réalisé soit par échoguidage (groupe échoguidage) ou par double stimulation nerveuse des extrémités motrices (groupe stimulation) à l'aide de 15 mL de lidocaïne 2 % et de 15 mL de bupivacaine 0,5 % avec épinephrine. La réussite du bloc a été définie en tant que la

This report was presented in part at the Annual Spring Meeting of the American Society of Regional Anesthesia and Pain Medicine, April 19–22, 2007, Vancouver, BC.

R. Brull, MD · M. Lupu, MD · A. Perlas, MD ·
V. W. S. Chan, MD

Department of Anesthesia and Pain Management, Toronto
Western Hospital, University Health Network, University
of Toronto, Toronto, ON, Canada

R. Brull, MD
e-mail: richard.brull@uhn.on.ca

C. J. L. McCartney, MB (✉)
Department of Anesthesia, Sunnybrook Health Sciences Centre,
2075 Bayview Avenue, Toronto, ON M4N 3M5, Canada
e-mail: colin.mccartney@utoronto.ca

perte de sensation à la piqure à l'aiguille des distributions nerveuses radiale, cubitale, médiane et musculocutanée lorsque mesurée 20 min après la réalisation du bloc. Le temps jusqu'à efficacité du bloc, l'état de préparation à la chirurgie (pas de bloc supplémentaire, infiltration cutanée ou anesthésie générale) et les complications ont également été évalués.

Résultats Les caractéristiques des patients étaient semblables dans les deux groupes. Le taux de réussite était de 92 % dans le groupe échoguidage et de 80 % dans le groupe stimulation ($P = 0,18$). Le temps jusqu'à efficacité du bloc était plus court dans le groupe échoguidage (médiane de 5 min) par rapport au groupe stimulation (médiane de 10,5 min) ($P < 0,001$). Les paresthésies étaient plus fréquentes dans le groupe stimulation (45 %) que dans le groupe échoguidage (6 %) ($P < 0,001$). Après l'injection finale, davantage de patients du groupe échoguidage étaient prêts pour la chirurgie (85 %) que dans le groupe stimulation (65 %) ($P = 0,04$). À une semaine après l'opération, les complications étaient mineures et passagères et ne différaient pas entre les deux groupes.

Conclusion Il n'y a pas eu de différence significative d'un point de vue statistique en ce qui a trait au taux de réussite du bloc infraclaviculaire réalisé par échoguidage ou par double stimulation nerveuse des extrémités motrices. Toutefois, l'échoguidage réduit le temps jusqu'à efficacité du bloc et améliore l'état de préparation à la chirurgie comparativement à la double stimulation des extrémités motrices. (Clinical Trial Registration Number: NCT00326261).

Infraclavicular brachial plexus blockade provides good to excellent anesthesia for surgery of the elbow, forearm, wrist, or hand. While various nerve stimulator-guided approaches to infraclavicular block have been described in the literature,^{1–6} success rates reportedly range from only 60 to 79%. The highest success rate is associated with multiple-cord stimulation,^{3,5,6} such that the elicitation of motor twitches corresponding to at least two cords (i.e., dual motor endpoint) is the most reliable goal for traditional nerve stimulator-guided infraclavicular block. Early reports suggest that ultrasound may be associated with faster onset, greater success, and fewer adverse effects compared with some traditional stimulation-guided approaches for infraclavicular block.^{7–11} However, the most recent evidence suggests that, in expert hands, success rates and onset times for ultrasound-guided and single motor endpoint stimulation-guided infraclavicular block are equivalent.¹² The dual motor endpoint technique has not been compared with an ultrasound-guided technique for

infraclavicular block in a randomized fashion. The purpose of this study was to determine if ultrasound-guided infraclavicular block is associated with a greater success rate compared with the dual motor endpoint stimulation technique.

Methods

After obtaining institutional research ethics board approval of the study protocol and written informed consent from all subjects, 106 adult patients, who were American Society of Anesthesiology physical status I–III and scheduled for elective elbow, forearm, wrist, or hand surgery, were studied prospectively. The patients of all four hand surgeons at Toronto Western Hospital were eligible for participation in the present study. Exclusion criteria included age <18 or >70 yr, language barrier, contraindication(s) to regional anesthesia, weight >100 kg, pre-existing neurological deficit in the distribution to be anesthetized, local infection, coagulopathy, chest or shoulder deformities, severe respiratory disease, or clavicle fracture.

Using a computer-generated randomization table, patients were allocated to receive an infraclavicular block using either ultrasound guidance (ultrasound group, $n = 53$) or stimulation guidance (stimulation group, $n = 53$). Non-invasive blood pressure, electrocardiogram, and pulse oximetry were applied, and intravenous access was secured on the non-operative side for infusion of a 0.9% saline solution. All patients received midazolam 2–4 mg iv as needed preoperatively for sedation and anxiolysis.

The patient and the research fellow evaluating the infraclavicular block were blinded to group allocation. To ensure the patients were unaware of group allocation, a linear 7–13 MHz Philips/ATL HDI 5000 Ultrasound or a 5–12 MHz Philips HD11 Ultrasound (Philips Medical Systems, Bothell, WA, USA) and a nerve stimulator (Stimuplex®, B. Braun Medical, Bethlehem, PA, USA) were applied to each patient's skin regardless of group. For the ultrasound group, the nerve stimulator was not grounded, and although an audible signal was present, the nerve stimulator did not function during the block procedure. For the stimulation group, a “sham” ultrasound probe was placed adjacent to the needle insertion point, and the ultrasound screen was placed in a stand-by position facing away from the patient so that the ultrasound machine did not display any anatomical structures of practical use to the anesthesiologist. All patients were positioned supine with the operative-side elbow flexed to 90° and the palm of the hand lying comfortably across the abdomen. All infraclavicular blocks were performed in a nerve block procedure room by one of four experienced regional anesthesiologists. Prior to needle puncture, the skin site was sterilized with a 2% solution of chlorhexidine in 70% isopropyl

alcohol and infiltrated with 1% lidocaine 1 mL. A standardized local anesthetic admixture containing 2% lidocaine 15 mL and 0.5% bupivacaine 15 mL with epinephrine 1:200000 (total volume, 30 mL) was used as the injectate in both study groups.

Ultrasound group

The ultrasound probe was positioned medially to the coracoid process and caudally to the clavicle to allow visualization of the axillary artery in the parasagittal plane. Slight rotational movements of the probe were made until a short-axis view of the cords of the brachial plexus was obtained and identified as round hypoechoic nodules located around the second part of the axillary artery. A sterile 22G 50–80 mm insulated needle (Stimuplex®, B. Braun Medical, Bethlehem, PA, USA) was advanced using an in-plane needle approach under ultrasound guidance.⁹ In one needle pass, the needle tip was positioned under direct vision adjacent to the lateral cord (9 o'clock position relative to the second part of the axillary artery). In another needle pass, the needle tip was positioned adjacent to the posterior cord (6 o'clock position relative to the second part of the axillary artery). At each of these two positions, 15 mL of the local anesthetic solution were injected incrementally to yield a total volume of 30 mL.

Stimulation group

A sterile 22G 50 mm insulated needle (Stimuplex®, B. Braun Medical, Bethlehem, PA, USA) connected to a grounded nerve stimulator was inserted medially to the tip of the coracoid process and angled 15° to the coronal plane.⁴ Two of the following three motor endpoints were sought:

- (1) lateral cord stimulation (elbow flexion, finger flexion, or thumb opposition);
- (2) posterior cord stimulation (wrist extension);
- (3) medial cord stimulation (finger flexion, thumb or wrist adduction).

In order to elicit the motor responses, the needle was redirected 0.5–1 cm superiorly or inferiorly (while maintaining posterior–inferior needle angulation) as needed. At a minimum threshold current of 0.3–0.5 mA for each endpoint, 15 mL of the local anesthetic solution were injected incrementally at each position for a total of 30 mL. If two motor responses were not elicited within 20 min of needle insertion, the procedure was abandoned in favour of a different approach to brachial plexus blockade, and the patient was excluded from data analyses.

All patients were interviewed by telephone at 24 hr and 7 days postoperatively. The occurrences of any adverse

events or potential block-related complications were recorded, including paresthesiae, motor deficits, pain, and bruising.

Block evaluation

After injection of local anesthetic, sensory loss and motor blockade were evaluated every 5 min for 30 min. Data collection was performed by an independent observer (research fellow) who was blinded to the group assignment. The extent of sensory loss was tested in the median, radial, ulnar, and musculocutaneous nerve distributions and was evaluated using a 3-point score: 2 = normal sensation, 1 = loss of sensation to pinprick (i.e., analgesia), or 0 = loss of sensation to light touch (i.e., anesthesia). Also recorded were the block performance time (defined as the duration of time from placement of the ultrasound probe on the skin to needle removal or palpation of anatomical landmarks to needle removal), number of needle-skin punctures (i.e., attempts), duration of needle-skin penetration, incidence of transient paresthesiae during block performance administration, and any other complications, including pain upon injection of the local anesthetic.

Block success was defined as diminished sensation to pinprick (sensory score ≤ 1) in each of the radial, ulnar, median, and musculocutaneous nerve distributions when measured 20 min after block performance. In cases where “block success” was not achieved after 20 min, a supplemental (“rescue”) nerve block could be administered in the block room, if necessary, at the discretion of the attending anesthesiologist. In the event of inadequate analgesia intraoperatively, a standardized algorithm was followed. First, the surgeon infiltrated the surgical skin site with 1–2% lidocaine or 0.25–0.5% bupivacaine without epinephrine. Next, fentanyl 25 µg *iv* was administered every 5 min as needed, to maximum 100 µg · hr⁻¹, and finally, conversion to general anesthesia if necessary. The algorithm for inadequate anxiolysis was administering propofol 10–20 mg every 5 min as needed, followed by conversion to general anesthesia if necessary. Readiness for surgery was defined as no requirement for supplemental nerve block, skin infiltration, or general anesthesia.

On postoperative day 7, telephone follow up was conducted by a blinded research assistant to inquire about potential block-related complications, such as paresthesiae, dysesthesiae, weakness, bruising, and pain. All complications were monitored until complete resolution.

Statistical analysis

The primary outcome measure for this study was block success, defined as diminished sensation to pinprick

(sensory score ≤ 1) in each of the radial, ulnar, median, and musculocutaneous nerve distributions when measured 20 min after block performance. We hypothesized that ultrasound guidance increases the success rate of infraclavicular block from 68%^{1–6} to 90% compared with a dual endpoint stimulation technique. Assuming $\alpha = 0.05$ and $\beta = 0.2$ required a sample size of 106 patients (53 per group). Data were analyzed using SPSS® 11.0 for Windows (SPSS Inc., Chicago, IL, USA) and MedCalc® version 10.4 (MedCalc Software, Mariakerke, Belgium). Data are presented as mean $\pm$ SD unless otherwise specified. Tests of significance included the Student's *t* test and the Mann–Whitney test of ranks for parametric and non-parametric testing of continuous variables, respectively. The Chi square test was used to analyze categorical data. Times to achieve sensory loss to pinprick and light touch were compared using the log rank test. Results were analyzed on an intent-to-treat basis. Statistical significance was established at $P < 0.05$.

Results

From December 6, 2005 to May 14, 2008, 128 patients were assessed for eligibility to participate in this study. Twenty-two patients were excluded (17 patients refused participation and 5 patients did not meet inclusion criteria). One hundred six patients were randomized (53 patients in the ultrasound group, 53 in the stimulation group). Three patients did not receive the study intervention and were excluded from data analyses. The reason for exclusion was inadequate time for block assessments (one patient in the ultrasound group and two patients in the stimulation group). In total, 103 patients (52 patients in the ultrasound group, 51 in the stimulation group) received their designated intervention and underwent data analyses. The procedure was abandoned in two patients in the stimulation group for failure to elicit two motor responses within the 20-min pre-specified time limit. These patients were considered as having normal sensation (i.e., no block) at all times. At the postoperative day 7 telephone call, 24 patients in the ultrasound group and 25 in the stimulation group were unavailable for follow up. Patient characteristics were similar between groups (Table 1).

Block success was achieved in 92% of patients in the ultrasound group compared with 80% in the stimulation group (difference 12%; 95% confidence intervals [CI] [−4 to 29%]; $P = 0.18$). Patients in the ultrasound group lost their sensation to pinprick in all four nerve distributions faster than patients in the stimulation group ($P = 0.02$) (Table 2). Loss of sensation to light touch (i.e., anesthesia) in all four nerve distributions was similar in both groups at each measured time interval (Table 2). In the ultrasound

Table 1 Patient characteristics

	Ultrasound (<i>n</i> = 52)	Stimulation (<i>n</i> = 51)
Gender (male/female)	33/19	34/17
Age (yr)	46.8 $\pm$ 17.1	43.6 $\pm$ 15.7
Height (m)	1.7 $\pm$ 0.1	1.7 $\pm$ 0.1
Weight (kg)	81.1 $\pm$ 19.0	81.7 $\pm$ 18.1
ASA I/II/III (<i>n</i>)	22/25/5	24/20/7
Surgical procedure (<i>n</i>)		
Tendon	14	6
Bone	22	22
Nerve	4	7
Other	12	16

Values are presented as number of patients, or mean $\pm$ SD
ASA American Society of Anesthesiologists physical status

Table 2 Loss of sensation to pinprick and light touch

Min	Ultrasound (<i>n</i> = 52)	Stimulation (<i>n</i> = 51)	<i>P</i> value ^a
Loss of sensation to pinprick (<i>n</i>)			
10	32 (62%)	23 (45%)	0.02
15	45 (87%)	33 (65%)	
20	48 (92%)	41 (80%)	
25	48 (92%)	41 (80%)	
30	48 (92%)	41 (80%)	
Loss of sensation to light touch (<i>n</i>)			
10	6 (12%)	5 (10%)	0.34
15	11 (21%)	10 (20%)	
20	26 (50%)	19 (37%)	
25	26 (50%)	19 (37%)	
30	26 (50%)	19 (37%)	

Values are presented as number of patients with the corresponding percentages in parentheses

Min minutes after block performance

^a Log rank test

group, 85% of patients were ready for surgery 20 min after final injection compared with 65% of patients in the stimulation group (difference 20%; 95% CI [2–36%]; $P = 0.04$) (Table 3). Patients in the stimulation group required more fentanyl (53.0 $\pm$ 50.4 μ g) for intraoperative analgesia than those in the ultrasound group (25.5 $\pm$ 31.6 μ g) (difference 27.5 μ g; 95% CI [10.9–44.0 μ g]; $P = 0.001$). There was no difference between groups in intraoperative propofol consumption, i.e., ultrasound group 90 $\pm$ 131 mg and stimulation group 108 $\pm$ 135 mg (difference 18.8 mg; 95% CI [−33.9 to 71.5 mg]; $P = 0.52$).

The block performance time was significantly shorter in the ultrasound group (median 5 min; interquartile range

Table 3 Intraoperative characteristics

	Ultrasound (<i>n</i> = 52)	Stimulation (<i>n</i> = 49)	Difference (%)	95% CI	<i>P</i> value
Readiness for surgery	44 (85%)	32 (65%)	20	2 to 36%	0.04
Supplemental nerve block	7 (14%)	15 (31%)	17	−1 to 33%	0.06
Skin infiltration	0 (0%)	1 (2%)	2	−5 to 11%	1.00
General anesthesia	1 (2%)	1 (2%)	0	−8 to 9%	1.00

Values are presented as number of patients with the corresponding percentages in parentheses

CI confidence intervals

[IQR] 5 min) compared with the stimulation group (median 10.5 min; IQR 6.8 min) ($P < 0.001$). In the stimulation group, the first and second motor endpoints most commonly encountered were the posterior and the lateral cords, 43 and 55% of patients, respectively. During block performance, three patients (6%) in the ultrasound group reported paresthesiae compared with 22 (45%) in the stimulation group (difference 39%; 95% CI [23–53%]; $P < 0.001$). Inadvertent vascular puncture occurred in four patients (8%) in the stimulation group compared with none (0%) in the ultrasound group (difference 8%; 95% CI [−0.4 to 19%]; $P = 0.11$). However, the incidence of tachycardia (surrogate for intravascular injection) was small, ultrasound 0%, stimulation 2% (difference 2%; 95% CI [−5 to 11%]; $P = 0.98$).

Forty-nine patients (ultrasound 24 patients, stimulation 25 patients) were unavailable for postoperative day 7 follow up due to unanswered telephone calls. All possibly block-related complications reported at postoperative day 7 were minor and transient.

Discussion

In our study, we found no statistically significant difference in success rate between ultrasound guidance and dual motor endpoint stimulation for infraclavicular block. Depending on the investigators' definition of block success, the success rate of ultrasound-guided peripheral nerve blockade can vary, and this makes comparisons between similar studies difficult. Sauter *et al.*¹² recently assessed the quality of infraclavicular block using ultrasound guidance (1–3 injections) and compared the results with single motor endpoint stimulation. These authors recorded equally high success rates in the ultrasound group (95%) and in the stimulation group (85%) ($P = 0.26$) using criteria for success as either partial (“analgesia”) or complete (“anesthesia”) sensory block in all peripheral nerves distal to the elbow by 30 min following block performance.¹² However, as these authors noted, their study was powered to detect a 5 min difference in block onset time and not a difference in block success. Therefore, a significant difference between ultrasound and

stimulation for infraclavicular block success cannot be excluded based on Sauter *et al.*'s study alone. Other previously published randomized studies comparing ultrasound with stimulation for infraclavicular block actually compared combined ultrasound-stimulation guidance with stimulation guidance alone. With close to complete sensory block in all nerves below the elbow by 30 min as their criterion for success, Gurkan *et al.*¹³ recently demonstrated that combined ultrasound-stimulation guidance (95%) has a success rate similar to that of single motor endpoint stimulation (93%). With block performance time as the primary outcome, Dingemans *et al.*¹⁴ compared ultrasound guidance alone with a single motor endpoint combined ultrasound-stimulation technique. With success defined as complete sensory block in the median, radial, ulnar, and musculo-cutaneous nerve distributions, the authors of this unblinded study reported a large difference in success between their groups (ultrasound 86%, stimulation 57%; $P = 0.007$).

Block performance time for infraclavicular block also varies widely depending on the definition used and the number of motor endpoints sought. In the present study, when block performance time was defined as the time between probe placement (ultrasound group) or landmark palpation (stimulation group) and needle removal, we found that ultrasound nearly halves block performance time compared with a dual motor endpoint stimulation technique. We purposefully included the “pre-scanning time” required to obtain and optimize the short-axis sonographic view of the cords, which, in our opinion, is inextricably linked to safe and successful ultrasound-guided infraclavicular block. With performance time defined as the time elapsed between needle insertion and needle removal, Dingemans *et al.*¹⁴ similarly demonstrated a shorter block performance time using ultrasound alone (3.1 ± 1.6 min) compared with a combined ultrasound-stimulation technique (5.2 ± 4.7 min) ($P = 0.006$). In contrast, Sauter *et al.*¹² found similar block performance times between the ultrasound (4.1 ± 1.3 min) and single motor endpoint stimulation (4.3 ± 1.3 min) ($P = 0.64$) groups. However, when the “pre-scanning time” was excluded, Sauter *et al.*¹² demonstrated a significantly shorter block performance time for the ultrasound group

compared with the single motor endpoint stimulation group ($P = 0.003$). Finally, Gurkan *et al.*¹³ found that a combined ultrasound-stimulation technique (7.2 ± 1.0 min) prolonged block performance time compared with stimulation alone (6.4 ± 1.0 min) ($P < 0.05$), with performance time measured from the time of placing the ultrasound probe on the skin to the time of needle removal. Thus it appears from these studies and ours that, compared with ultrasound alone, seeking one or more motor endpoints—with or without ultrasound guidance—unnecessarily prolongs block performance time without adding any benefit with regard to block success.

Traditional teaching assumes that unintentional paresthesiae elicited during block performance stem from needle-nerve contact, and as such, should be avoided for fear of persistent neurological symptoms.^{15,16} Therefore, it is not surprising that nearly half of the patients in our stimulation group complained of paresthesiae during block performance compared with only three patients in our ultrasound group. In a similar trial by Sauter *et al.*, it is surprising and rather difficult to explain that 20% of patients in the ultrasound group experienced paresthesiae during block performance compared with only 2.5% of the stimulation group.¹² One explanation may be that some providers use ultrasound to advance the needle tip as closely as possible to the nerve, i.e., a shorter needle tip-to-nerve distance than what would normally be achieved using stimulation guidance alone.¹⁷ Nonetheless, we found that the incidence of persistent paresthesiae is minimal by postoperative day 7, and no patient in our study reported paresthesiae persisting beyond 4 weeks.

The foremost limitation of the present study is inadequate power to exclude type II error from our primary outcome. Post hoc power analysis reveals that 258 patients per group would be required to detect a significant difference in block success rate. Nonetheless, the present study demonstrates statistically significant and clinically important differences in block performance time between groups that remain worthy of dissemination. Another limitation of our study is that our results are not generalizable to anesthesia providers of different ultrasound skill levels. For example, “pre-scanning” time likely varies indirectly with operator experience using ultrasound. Our results would have been more generalizable had we included providers with varying degrees of ultrasound experience rather than only experienced operators; however, ultrasound-guided infraclavicular block is generally considered to be an intermediate technical skill that is not necessarily appropriate for the novice sonographer.

Finally, while all study patients were blinded to the most feasible extent, it is possible that some patients may have surmised their group allocation based on the presence or absence of muscle twitching during block performance.

In summary, this study found no statistically significant difference in success rate between ultrasound guidance and dual motor endpoint stimulation for infraclavicular block. However, ultrasound guidance can shorten performance time and improve readiness for surgery compared with a dual motor endpoint stimulation technique for infraclavicular block.

Acknowledgements This project was supported by a grant to Dr. Colin McCartney from the Physicians’ Services Incorporated Foundation (Toronto, ON, Canada) and the Canadian Anesthesiologists’ Society. Dr. Vincent Chan receives equipment support and honoraria from Philips Medical Systems, SonoSite®, and GE Medical. Dr. Colin McCartney receives equipment support from GE Medical and SonoSite® and honoraria from SonoSite®.

Conflicts of interest None declared.

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