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REPORTS OF ORIGINAL INVESTIGATIONS

The epidural electric stimulation test does not predict local anesthetic spread or consumption in labour epidural analgesia

Le test de stimulation électrique péridurale ne prédit pas la diffusion ou la consommation de l'anesthésique local lors de l'analgésie péridurale pour le travail obstétrical

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Abstract

Purpose *The epidural electrical stimulation test (EEST) is a highly specific and sensitive test for confirming placement of the epidural catheter in the epidural space. The purpose of this study was to investigate if the EEST could predict the spread and consumption of local anesthetic solutions during labour epidural analgesia.*

Methods *This observational study was conducted in labouring parturients requesting epidural analgesia. The EEST was performed after the epidural catheter placement (T0) and repeated five minutes after a test dose with 2% lidocaine 3 mL (T1). The minimum current required to elicit the motor response at each time point was recorded. A loading dose of 0.125% bupivacaine 10 mL and fentanyl 50 μg was administered and followed by patient-controlled epidural analgesia with 0.0625% bupivacaine and fentanyl 2 $\mu g \cdot mL^{-1}$ (baseline infusion 10 $mL \cdot hr^{-1}$, bolus dose 5 mL, lockout interval ten minutes, maximum dose 20 $mL \cdot hr^{-1}$). The primary outcome was the correlation between the current required to elicit motor responses at T0 and T1 and the consumption of bupivacaine in the first two hours of epidural administration. The secondary outcomes included the muscle contraction patterns determined by the EEST and the incidence of failed, inadequate, or asymmetric blocks.*

Results *The study was conducted in 102 parturients. The mean electric current required to elicit muscle response was 4.43 mA (range 1-10 mA) at T0, 5.97 mA (range 1-14 mA) at T1, and the mean Δ (T1-T0) current was 1.54 mA (range 0-8 mA). There was no correlation between either the mean baseline current required or the Δ (T1-T0) current and the total bupivacaine consumption at two hours. The incidence of inadequate blocks at two hours was 18%; however, none of the catheters required replacement. Unilateral left (34%) or right (31%) leg contraction was the most frequent pattern elicited by the EEST.*

Conclusions *The EEST shows a wide range of electrical current requirements and elicits a variety of muscle twitch patterns on the lower limbs. Although it confirms the epidural placement of the catheter, the EEST cannot be used to predict the spread or consumption of the local anesthetic solution during labour epidural analgesia.*

Résumé

Objectif *Le test de stimulation électrique péridurale (TSEP) est un test extrêmement spécifique et sensible qui*

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permet de confirmer la position du cathéter péridural dans l'espace péridural. L'objectif de cette étude était de déterminer si le TSEP pouvait prédire la diffusion et la consommation d'anesthésique local pendant l'analgésie péridurale pour le travail obstétrical.

Méthode *Cette étude observationnelle a été réalisée auprès de parturientes en travail demandant une analgésie péridurale. Le TSEP a été réalisé après le positionnement du cathéter péridural (T0) et répété cinq minutes après l'administration d'une dose test de 3 mL de lidocaïne 2 % (T1). Le courant minimal requis pour provoquer une réponse motrice à chaque point dans le temps a été enregistré. Une dose de charge de 10 mL de bupivacaïne 0,125 % et de 50 μg de fentanyl a été administrée et suivie d'analgésie péridurale contrôlée par la patiente avec de la bupivacaïne 0,0625 % et du fentanyl 2 $\mu g \cdot mL^{-1}$ (perfusion de base 10 $mL \cdot h^{-1}$, dose bolus 5 mL, période d'interdiction de dix minutes, dose maximale 20 $mL \cdot h^{-1}$). Le critère d'évaluation principal était la corrélation entre le courant nécessaire pour provoquer des réponses motrices à T0 et T1 et la consommation de bupivacaïne au cours des deux premières heures d'administration de la péridurale. Les critères d'évaluation secondaires étaient les tendances de contraction musculaire telles que déterminées par le TSEP et l'incidence de blocs inefficaces, inadéquats ou asymétriques.*

Résultats *L'étude a été réalisée auprès de 102 parturientes. Le courant électrique moyen requis pour provoquer une réponse musculaire était de 4,43 mA (extrêmes 1-10 mA) à T0, 5,97 mA (extrêmes 1-14 mA) à T1, et le courant Δ moyen (T1-T0) était de 1,54 mA (extrêmes 0-8 mA). Il n'y a pas eu de corrélation entre le courant de base moyen requis ou le courant Δ (T1-T0) et la consommation totale de bupivacaïne à deux heures. L'incidence de blocs inadéquats à deux heures était de 18 %; toutefois, aucun des cathéters n'a dû être replacé. La tendance la plus fréquemment provoquée par le TSEP était la contraction unilatérale de la jambe gauche (34 %) ou droite (31 %).*

Conclusion *Le TSEP démontre une importante variation dans les besoins en courant électrique et provoque plusieurs types de contraction musculaire au niveau des membres inférieurs. Bien qu'il confirme le positionnement péridural du cathéter, le TSEP ne peut être utilisé pour prédire la diffusion ou la consommation de la solution d'anesthésique local pendant une analgésie péridurale pour le travail obstétrical.*

Epidural analgesia is considered the gold standard for pain relief during labour due to its high efficacy and safety. Nevertheless, it may be associated with complications, such as intrathecal, intravascular or subdural catheter placement, as well as the inappropriate positioning of the latter in the epidural space, leading to failed or inadequate blocks.[1] In a large cohort study in non-obstetric subjects, up to a 27% failure rate for lumbar epidural has been described,[2] while in labour epidural analgesia, a 1.5-23% failure rate has been reported.[3,4]

The correct placement of the epidural catheter therefore remains a clinical concern. Currently, there is no available bedside imaging technique that can determine the exact position of the epidural catheter. The epidural electrical stimulation test (EEST) has shown to be a reliable method to confirm the placement of the catheter in the epidural space with both high sensitivity and specificity. The typical response to the electric stimulation of the catheter when located in the lumbar epidural space of adult subjects is the unilateral contraction of muscles innervated by the root closest to the tip of epidural catheter.[5]

The intensity of the current required to elicit a motor response as well as the location of the muscular contraction during a lumbar EEST are quite variable,[6] and these factors may elicit certain assumptions. For instance, perhaps the preferential muscular response originating from the catheter stimulation depends on the proximity of the tip of the catheter to a specific nerve root. Furthermore, perhaps the closer the tip of the catheter to the nerve root, the lower the current required to elicit a response. Consequently, the EEST may not only confirm whether the catheter is in the epidural space but also suggest where the tip of the catheter may be within the epidural space. It is possible that the positioning of the tip of the catheter, particularly in single orifice catheters, may influence the spread of the local anesthetic solution and, consequently, the results of the technique.

The purpose of this study was to determine if the EEST can be used to predict the consumption and spread of the local anesthetic solution during epidural analgesia in labouring women.

We hypothesized that the magnitude of electric current required during the EEST would correlate with the consumption and spread of the local anesthetic solution during labour epidural analgesia.

Methods

After obtaining Research Ethics Committee approval and written informed consent from the subjects, this prospective observational study was carried out at Mount Sinai Hospital in Toronto, from November 2008 to August 2009. Parturients with a cervical dilatation < 5 cm, a verbal numerical pain score (VNPS) > 6 (VNPS 0-10, where $0 =$ no pain and $10 =$ the worst pain imaginable), and requesting epidural analgesia for labour were included in

the study. The exclusion criteria were contraindication to epidural anesthesia; allergy or hypersensitivity to lidocaine, bupivacaine or fentanyl; history of spine surgery, scoliosis or failed epidural; coexisting neurological disorders; patients who received sedatives or opioids prior to insertion of the epidural catheter; and those with implanted electronic devices.

The epidural catheter insertion was performed by the attending anesthesiologist in a standard fashion with the patient in the sitting position. The epidural space was identified with the loss-of-resistance technique to air or saline using a 17G Tuohy epidural needle via a midline approach. A 19G epidural catheter (Arrow® FlexTip Plus®, Arrow International Inc., Reading, PA, USA) was advanced 3-5 cm into the epidural space and aspirated for cerebrospinal fluid or blood. A test dose of 2% lidocaine 3 mL was administered followed by a bolus of 0.125% bupivacaine 10 mL and fentanyl 50 μg. Patient-controlled epidural analgesia was then initiated with 0.0625% bupivacaine and fentanyl 2 $\mu g \cdot mL^{-1}$ with the following settings: baseline infusion 10 $mL \cdot hr^{-1}$, demand bolus 5 mL, lockout interval ten minutes, and maximum dose 20 $mL \cdot hr^{-1}$.

The EEST was performed with a nerve stimulator (Ez-Stim II model ES400, Life-Tech, Stafford, TX, USA) connected to a metallic adapter (Arrow-Johans™ ECG Adapter, Arrow International Inc, Reading, PA, USA) that was placed between the epidural catheter connector and the epidural filter. The negative lead of the nerve stimulator (anode) was attached to the metal hub of the Johans adapter, and the positive lead (cathode) was connected to an electrode placed over the deltoid muscle. The frequency of the nerve stimulator was set at 1 Hz with a pulse width of 200 msec. The current output was slowly increased from zero (up to a maximum of 20 mA) until motor activity was detected. The baseline EEST was performed immediately after the placement of the catheter (T0) before the administration of the epidural test dose and then repeated five minutes after the administration of the test dose (T1). The minimum electric current required to elicit a motor response with the EEST as well as the resulting muscle contraction pattern were assessed.

Pain scores (VNPS) were measured immediately after the epidural placement (T0), five minutes after the test dose (T1), 20 min following the loading dose (T2), and two hours after the initiation of the epidural infusion (T3). The block level was assessed using sensitivity to ice at the T2 and T3 time points. The EEST test and the block assessments were conducted by one of the investigators.

Inadequate analgesia was defined as the presence of a VNPS > 2 at two hours after the administration of the test dose, irrespective of the block characteristics. Asymmetric blocks included patchy, unilateral, and those exhibiting a difference of two or more dermatomes between the two sides. In case of incomplete analgesia at 20 min after the administration of the loading dose, a rescue bolus dose of 0.25% bupivacaine 10 mL was administered. If there was no further improvement in analgesia, the epidural was considered a failure and managed at the discretion of the attending anesthesiologist. If analgesia was found to be incomplete during the maintenance of the epidural, a top up of 0.125% bupivacaine 10 mL was administered. If not effective, an additional bolus dose of 10 mL of bupivacaine 0.25% was given. The study was terminated two hours after initiation of the epidural infusion, and the total amount of bupivacaine consumed during this period was recorded (loading dose, maintenance dose, and additional top-ups).

The primary outcome was the correlation between the baseline current requirement (T0) or the difference in current requirements at T1 and T0 (Δ [T1-T0]) and the total bupivacaine consumption within the first two hours of epidural analgesia. The secondary outcomes included the incidence of failed, inadequate, and asymmetrical blocks, the minimum current needed to elicit motor response at T0 and T1, and the muscle contraction patterns after EEST.

The sample size was calculated based on a pilot study of ten cases conducted at our hospital. In a multiple regression model with two test variables, it was estimated that a sample size of 104 patients would be required to detect a partial correlation of $\pm$ 0.30 between bupivacaine consumption and either the baseline or the Δ (T1-T0) current with 80% power and a significance level of 0.05. In the pilot study, the doses of bupivacaine used varied from 25-37.5 mg. It was thought that the correlation should be large enough to reduce the bupivacaine usage by at least 5 mg by increasing the EEST current from the smallest to the largest of its range. The baseline EEST current varied from 2-5 mA, and the difference between the baseline current and the current after the test dose ranged from 0-3 mA. Based on these estimates, the correlation (ρ) between the total bupivacaine consumption and either of the EEST outcomes (baseline or delta) would have to be at least $\pm$ 0.40 in order to reduce bupivacaine usage by 5 mg by increasing either the baseline current or the delta current by 3 mA. This was estimated by expressing the slope of the linear regression as $\beta = \rho\ s_y/s_x$, where the standard deviations (s_y and s_x) are assumed to be proportional to their ranges. As a result of the approximate nature of the above calculations, the study was powered to detect a correlation as small as $\pm$ 0.30.

The correlation was estimated using the Pearson correlation coefficient (r). P values of < 0.05 were considered statistically significant. Data were analyzed with SAS® version 9.1.3 (SAS Institute, Cary NC, USA).

Results

One hundred twenty parturients were approached to participate in the study, 110 were recruited, and 102 were included in the data analysis. Data from eight subjects were not included in the analysis as they either underwent Cesarean delivery within two hours of epidural placement ($n = 3$) or technical problems were encountered during the performance of the EEST ($n = 5$) (Fig. 1).

The demographic and obstetrical data as well as the pain scores at different time points are presented in Table 1.

The epidural technique was performed with loss of resistance to saline in 31 (29.2%) cases and loss of resistance to air in 75 cases (70.8%).

The EEST current requirements and total bupivacaine consumption as well as the number of parturients exhibiting adequate/inadequate or symmetric/asymmetric blocks are presented in Table 2. There were no failed blocks. The incidence of inadequate blocks at two hours was 18%; however, none of the catheters required replacement. In all cases, satisfactory analgesia was achieved with subsequent rescue boluses. The incidence of asymmetric blocks at two hours was 19.6%.

The mean electric current required to elicit muscle responses at baseline EEST (T0) and after five minutes of the test dose (T1) were 4.43 mA (range 1-10 mA) and 5.97 mA (range 1-14 mA), respectively, and the Δ (T1-T0) current was 1.54 mA (range 0-8 mA). The baseline EEST values were almost always below 10 mA, except for two cases where it was 10 mA; however, at T1 (i.e., five minutes after the test dose) the EEST values ranged from 10-12 mA in ten cases.

The mean (standard deviation) total bupivacaine consumption at two hours was 31.2 (6.7) mg. There was no correlation between the total bupivacaine consumption and either the baseline current ($r = 0.047$; $P = 0.64$) or the Δ (T1-T0) current requirement ($r = 0.057$; $P = 0.57$) (Figs. 2 and 3).

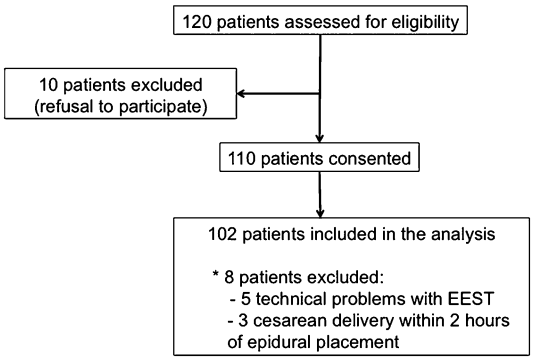

Fig. 1 Recruitment flow diagram

The mean baseline current and the Δ current required to elicit motor response did not differ significantly when compared between parturients exhibiting adequate or inadequate blocks, or between those exhibiting symmetric or asymmetric blocks. The total bupivacaine consumption at two hours did not differ between patients exhibiting adequate or inadequate blocks, or between those exhibiting symmetric or asymmetric blocks.

Unilateral left or right leg contraction was the most frequent motor response (65.2%) to the EEST, followed by contraction response of the right or left thigh (25.5%).

The median (range) sensory block 20 min after initiation of the epidural infusion was T7 (T2-L1) on the left side and T7 (T1-T12) on the right side.

Discussion

Our findings suggest that the EEST is a reliable tool to confirm the epidural catheter placement in labouring parturients. These findings are in agreement with other studies in the literature that tested the efficacy of the EEST for thoracic, lumbar, and caudal epidural catheter placement in non-obstetric subjects.[7-9] On the other hand, our results also suggest that the EEST cannot be used to predict the spread or consumption of local anesthetic solutions, in contrast to our hypothesis. We found no difference in the EEST current requirements or in the bupivacaine consumption in the first two hours of analgesia when comparing women with adequate or inadequate blocks and those with symmetric or asymmetric blocks.

The use of the EEST to confirm the epidural catheter position was first reported in 1998.[5] Tsui *et al*. described the presence of muscle twitching of the torso or lower extremities as the typical response to the neurostimulation.

Table 1 Demographic and obstetrical data

	Mean (SD)	Interquartile range
Age (yr)	32.3 (4.7)	[30,35]
Height (cm)	165.2 (6.6)	[160,170]
Weight (kg)	82.5 (16.9)	[69,90.8]
Body mass index ($kg \cdot m^{-2}$)	30.1 (5.4)	[26.6,32.9]
Nulliparous (*n*)	63	(61.8%)*
Multiparous (*n*)	39	(38.2%)*
Dilation at epidural request (cm)	3.07 (1.24)	[2,4]
VNPS (T0)	7.45 (1.67)	[6,8]
VNPS (T1)	6.13 (2.66)	[4,8]
VNPS (T2)	1.29 (2.05)	[0,2]
VNPS (T3)	1.24 (2.14)	[0,2]

*Percentage. SD = standard deviation; VNPS = verbal numerical pain score

Table 2 The epidural electrical stimulation test: current requirements and bupivacaine consumption

Block characteristic	*n*	Baseline EEST (mA)		Δ (T1-T0) EEST (mA)		Bupivacaine consumption (mg)	
		Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI
Adequate	83 (81.4%)	4.35 (2.1)	(0.19 to 8.5)	1.57 (1.3)	(0.98 to 4.1)	30.28 (6.4)	(17.73 to 42.8)
Inadequate	19 (18.6%)	4.79 (2.0)	(0.94 to 8.6)	1.42 (1.8)	(−2.04 to 4.8)	34.90 (6.5)	(22.21 to 47.6)
Symmetric	82 (80.4%)	4.38 (2.2)	(0.15 to 8.6)	1.43 (1.1)	(−0.75 to 3.6)	30.74 (6.3)	(18.45 to 43.0)
Asymmetric	20 (19.6%)	4.50 (1.8)	(0.93 to 8.1)	2.00 (2.2)	(−2.35 to 6.4)	31.85 (7.7)	(16.80 to 46.9)
Overall	102 (100%)	4.43 (2.1)	(0.33 to 8.5)	1.54 (1.4)	(−1.24 to 4.3)	31.14 (6.6)	(18.15 to 44.1)

EEST = epidural electrical stimulation test; SD = standard deviation; CI = confidence interval

$P > 0.05$ baseline EEST (adequate *vs* inadequate *vs* symmetric *vs* asymmetric blocks)

$P > 0.05$ Δ (T1-T0) EEST (adequate *vs* inadequate *vs* symmetric *vs* asymmetric blocks)

$P > 0.05$ bupivacaine consumption (adequate *vs* inadequate blocks; symmetrical *vs* asymmetrical blocks)

The EEST method has already been established as an appropriate tool to confirm the correct placement of the epidural catheter in a variety of clinical settings, e.g., for postoperative pain control in adults,[10] in labouring parturients,[11] as well as in the pediatric population.[6]

The literature on the use of the EEST in the obstetrical population is limited. Tsui *et al.*[11] investigated the feasibility and reliability of the EEST in a cohort of 39 labouring parturients. The test was performed easily in all cases, and no maternal or neonatal complications or side effects were reported. The authors suggested that the EEST could improve the success rate of epidural analgesia. In contrast to our study, muscle contraction patterns elicited by the EEST and local anesthetic consumption were not reported.

The EEST has been described with the sole purpose of confirming the placement of the epidural catheter in the epidural space. However, as previously mentioned, it is our view that the EEST may also suggest the location of the catheter tip within the epidural space. It may be that the positioning of the tip of the catheter, particularly in single-orifice catheters, may influence the results of the technique. This was the rationale behind our hypothesis, and we could find no data in the literature to confirm or refute it.

We used both the baseline current and the difference between the current obtained after the test dose and the baseline current to test our hypotheses. We assumed that the baseline current would show a direct correlation with the distance to the closest nerve root (the shorter the distance between the tip of the catheter and the nerve root, the lower the current required). We also assumed that the magnitude of the difference between T1 and T0 would translate not only the proximity of the catheter tip to the nerve root but also the extent to which the local anesthetic spreads away from the nerve root (the higher the magnitude of the difference, the closer the tip and the more localized the effect of the local anesthetic). The clinical implications of these assumptions, if any, have not been investigated, and this is exactly what we wanted to explore. Our results, however, do not support these hypotheses.

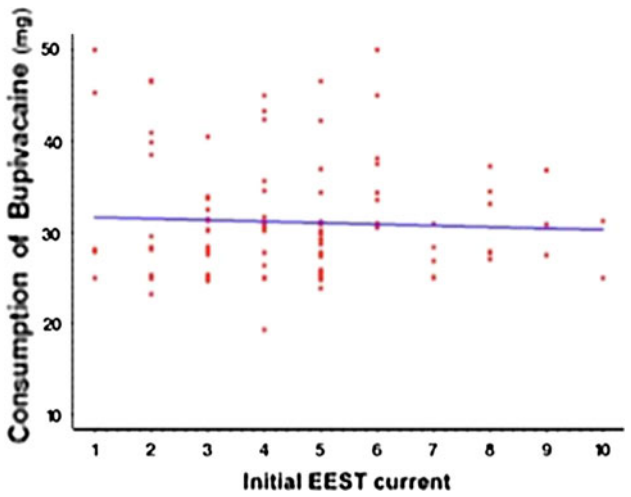

Fig. 2 Correlation between bupivacaine consumption (mg) and initial epidural electrical stimulation test (EEST) current requirement (mA); Pearson correlation coefficient = −0.087

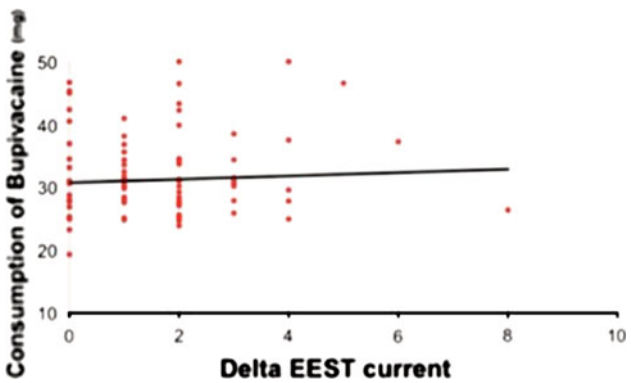

Fig. 3 Correlation between bupivacaine consumption (mg) and the Δ (T1-T0) current (mA); Pearson correlation coefficient = 0.049. T0 = baseline, immediately after epidural placement; T1 = five minutes after test dose

None of the features of the EEST were useful to predict inadequate or asymmetric blocks, or the consumption of local anesthetic. All inadequate blocks were successfully corrected with top-ups. This phenomenon has been described before.[5] The local anesthetic solution spreads further into the epidural space and establishes an adequate block in the vast majority of patients presenting with initial unilateral motor response to the EEST.[10,12]

This novel study adds to the literature inasmuch as it describes details of the muscle contraction patterns after the insertion of the epidural catheter in labouring women. Tsui *et al*.[11] summarized the EEST motor response simply as involving nerve roots from L1-L5. In our study, we observed a wide range of electrical current requirements as well as a variety of muscle twitch patterns. Unilateral left or right leg contraction was the most frequent motor response (65.2%) followed by the right or left thigh contractions (25.5%). Most of the previous studies have observed unilateral contractions in the adult population, while bilateral response has been seen in the pediatric population or after stimulation of thoracic nerve roots.[6,9] The reason for this discrepancy remains to be clarified; although, it may be hypothesized that the discrepancy may be due to the characteristics of the epidural space in these distinct patient populations or in distinct segments of the spine.

There are some limitations to this study. We were unable to identify epidural block failures. A larger sample size would have been required to investigate a possible recurring EEST pattern to predict block failures and also to avoid a type II statistical error. Ideally, parity and nature of labour (spontaneous/induced/augmented) should have been controlled, as the progression of labour and the intensity of pain may be a confounding factor while assessing quality of analgesia and local anesthetic consumption. The loss-of-resistance technique should also have been standardized as, theoretically, the injection of a larger volume of air into the epidural space could interfere with the electric current distribution. Nevertheless, in our study, the catheter was flushed with saline before the baseline EEST, therefore creating a fluid medium between the tip of the catheter and the nerve root. Finally, the investigator evaluating the contraction pattern and the sensory block was not blinded to the EEST results, leading to a potential assessment bias.

In conclusion, the ESST seems to be an efficient tool to confirm the epidural catheter placement in the epidural space; however, it cannot be used to predict the consumption or spread of local anesthetic solutions during epidural analgesia for labour.

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Conflicts of interest None declared.

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