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Peripheral nerve stimulator improves efficacy of the proximal paravertebral block in sheep

[*O estimulador de nervo periférico melhora a eficácia do bloqueio paravertebral proximal paravertebral proximal em ovelhas*]

I.M. *Costa*[1], M.A. *Oliveira*[2], B.P. *Floriano*[3], C.J.X. *Abimussi*[4]

[1] Graduate, Faculdade de Medicina Veterinária de Araçatuba (FMVA – Unesp) – Araçatuba, São Paulo, Brasil
[2]Graduate, Universiddadde de Tuiuti, Tuiuti, PR, Brasil
[3]Centro de Ciências Rurais (CCR), Universidade Federal de Santa Maria, UFSM, Santa Maria, Rio Grande do Sul, Brasil
[4]Escola de Veterinária, Universidade Federal de Minas Gerais, UFMG, Belo Horizonte, Minas Gerais, Brasil

ABSTRACT

The purpose of this study was to compare the efficacy of proximal paravertebral anesthesia in sheep using a peripheral nerve stimulator and compare it to the Cambridge technique. Eight Santa Inês sheep, five females and three males aged 2 years and weighing 13kg were enrolled in the study. Right proximal paravertebral anesthesia was carried out using 2% lidocaine without vasoconstrictor, injected in the spaces between T13-L1, L1-L2 and L2-L3, with and without the aid of a peripheral nerve stimulator in two procedures with an interval of 7 days between treatments, which comprised: ST (stimulator treatment: 3mg kg^{-1} of lidocaine 2%) and CT (Cambridge control treatment, 6mg kg^{-1} of lidocaine 2%). Cardiorespiratory variables were recorded before the treatment (baseline, T_B) and then at 15, 30, 45 and 60 minutes (T_{15}, T_{30}, T_{45} and T_{60}, respectively) following local anesthesia. Effectiveness of the regional anesthesia was assessed by means of mechanical skin clamping at a point between the iliac crest and the lowest border of the last rib. Data were tested for normal distribution using the Shapiro-Wilk test and compared using Kruskal-Wallis followed by Dunn post-hoc test. Duration of the blockade was analyzed using a Kaplan-Meyer survival curve. Analyses were performed under 5% significance. ST took significantly longer and had greater success and greater duration. Positive response to skin clamping in CT was obtained in seven animals at T_{15} and one at T_{45}, whereas in ST, one animal responded to skin clamping at T_{15}, two at T_{30}, four at T_{45} and one at T_{60}. Duration was significantly longer in ST compared to CT according to the Kaplan-Meyer analysis. No changes were seen in cardiorespiratory variables throughout the study. In conclusion, the peripheral nerve stimulator increases the success of proximal paravertebral anesthesia using a lower dose of 2% lidocaine in healthy sheep.

Keywords: regional anesthesia, large animals, ruminant, lidocaine

RESUMO

O objetivo deste estudo foi comparar a eficácia da anestesia paravertebral proximal em ovinos, com o uso de estimulador de nervos periféricos, comparando-a com a técnica de Cambridge. Oito ovinos da raça Santa Inês, cinco fêmeas e três machos, com idade de dois anos e peso de 66±13kg, foram incluídos no estudo. Foi realizada anestesia paravertebral proximal direita com lidocaína a 2% sem vasoconstritor, injetada nos espaços entre T13-L1, L1-L2 e L2-L3, com e sem o auxílio de estimulador de nervo periférico, em dois procedimentos com intervalo de sete dias entre os tratamentos, que consistiram em: TE (tratamento com estimulador: 3mg kg-1 de lidocaína 2%) e TC (tratamento controle Cambridge, 6mg kg-1 de lidocaína 2%). As variáveis cardiorrespiratórias foram registradas antes do tratamento (basal, TB) e depois, aos 15, 30, 45 e 60 minutos (T15, T30, T45 e T60, respectivamente) após a anestesia local. A eficácia da anestesia regional foi avaliada por meio de pinçamento mecânico da pele, em um ponto entre a crista ilíaca e a borda inferior da última costela. Os dados foram testados para

Corresponding author: mv.isabelamariano@gmail.com
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distribuição normal usando-se o teste de Shapiro-Wilk, e comparados usando-se Kruskal-Wallis, seguido pelo teste post-hoc de Dunn. A duração do bloqueio foi analisada por meio de uma curva de sobrevivência de Kaplan-Meyer. As análises foram realizadas com 5% de significância. O TE demorou significativamente mais tempo e teve maior sucesso e maior duração. A resposta positiva ao pinçamento cutâneo no TC foi obtida em sete animais no T15 e em um no T45, enquanto no TE, um animal respondeu ao pinçamento cutâneo no T15, dois no T30, quatro no T45 e um no T60. A duração foi significativamente mais longa no TE em comparação com o TC, de acordo com a análise de Kaplan-Meyer. Não foram observadas alterações nas variáveis cardiorrespiratórias ao longo do estudo. Em conclusão, o estimulador de nervo periférico aumenta o sucesso da anestesia paravertebral proximal, usando-se uma dose menor de lidocaína a 2% em ovelhas saudáveis.

Palavras-chave: anestesia regional, animais de grande porte, ruminantes, lidocaína

INTRODUCTION

General anesthesia is usually the choice for small ruminants requiring full immobility (Hall *et al*., 2001). However, lateral recumbency can cause diaphragm compression by abdominal organs, thereby decreasing functional residual capacity in the lungs. Yet, during ruminant anesthesia there is the possibility of ruminal reflux which can obstruct the respiratory system and/or cause severe pneumonia (Nóbrega Neto, 2008). To avoid this complication, local anesthesia techniques are widely used with or without sedation to allow surgical intervention of the abdominal cavity of ruminants (Musewe *et al*., 1979; Desmecht *et al.*, 1997). In addition, local anesthesia has the lowest cost among anesthetic techniques used in large animals, regarding both materials and drugs used (Massone, 2011).

Proximal paravertebral block (PPB) is also known as Cambridge, Farquharson or Hall technique and comprises desensitization of the dorsal and ventral branches of the last thoracic nerve (T13 branch) and two first lumbar nerves (L1 and L2 branches) at the level of their emergence from the intervertebral foramina (Hall *et al*., 2001; Greene, 2003; Weaver *et al*., 2005; Skarda & Tranquilli, 2007; Edmondson, 2008; Dyce *et al*., 2002). The efficacy of the blockade is highest with PPB compared to distal paravertebral anesthesia (Pasquini *et al*., 1989). The use of PPB for rumenotomy and cesarian section desensitizes the 13^{th} thoracic nerve and first, second and third lumbar nerves and can be done quickly using low volumes of local anesthetics (Garcia, 2017).

The nerves targeted by PPB are spinal nerves T13, L1 and L2, which result in desirable anesthesia for surgical approach to the flank with the animal standing and awake. The block is usually easier to perform in slender or younger animals, since location of the transverse processes of the vertebrae involves palpation of the bones (Natalini, 2007).

Peripheral nerve stimulators for regional blocks have been increasingly used with results showing high rate of success in humans and dogs (Fanelli *et al*., 1999; Mahler and Adogwa, 2008) due to the precision of the technique, allowing injection of local anesthetics closest to peripheral nerves, which results in efficient blockade with lower volumes of anesthetic solution (Rodríguez *et al*., 2004).

Peripheral nerve stimulators are also associated with lower incidence of traumatic complications (Fanelli *et al*., 1999) because there is no direct contact between needle and nerve (Desmecht *et al*., 1997). The stimulator generates a low frequency current of short duration, usually 1-2 seconds. The needles are disposable and are available with or without insulation in several gauges and lengths. Insulated needles, on the other hand, concentrate the current on its extremity, thereby focusing the stimulus on the nerve close to it and improving accuracy of its location (Mahler & Adogwa, 2008).

Nearly all techniques of local anesthesia can be performed with the aid of a peripheral nerve stimulator to improve location of nerves and the success rate of the block (Rodríguez *et al*., 2004).

However, most studies have been performed on humans or small animals and, to date, no studies have been found addressing the use of a peripheral nerve stimulator for proximal paravertebral anesthesia in small ruminants. Therefore, the purpose of this study was to compare the efficacy of PPB using a peripheral nerve stimulator and a lower dose of 2% lidocaine with the standard Cambridge technique using a higher dose of 2% lidocaine in sheep. The hypothesis was that the use of a peripheral nerve stimulator would result in more efficient anesthesia using the lower volume of lidocaine, demonstrated by onset and duration of the blockade.

MATERIAL AND METHODS

This study has been approved by the local Ethics Committee for Animal Usage (Protocol No. 021/2018). Eight Santa Inês sheep, five females and three males aged 2 years and weighing 64±14kg at the first day and 69±13kg at the second day were enrolled in the study. Exclusion criteria comprised any abnormalities in physical examination and complete blood count.

All animals participated in two experimental treatments, with an interval of 7 days between each treatment. The treatments were drawn using pieces of paper in a bag. Treatments comprised right proximal paravertebral block (PPB) using the standard Cambridge technique as a control (CT) for comparison with the same technique using a peripheral nerve stimulator (ST). The order of the treatments for each subject was randomized. Both treatments involved injection of 2% lidocaine (Lidovet®, Rio de Janeiro, Brazil) without epinephrine, at 6mg kg^{-1} in CT and 3mg kg^{-1} in ST. The total volume of the doses was equally divided in three parts to be injected in the spaces between T13-L1, L1-L2 and L2-L3. The hair from the last rib to the iliac crest was clipped the day before the experiment. Animals were not fasted for this experiment because there was no sedation or recumbency involved.

At the day of the experiment animals were submitted a physical restraint and after 30 minutes, the physical examination was performed (baseline, T_B), which comprised heart rate (HR) in beats.$minute^{-1}$ with a stethoscope, respiratory rate (f_R) in breaths.$minute^{-1}$ while observing thoracic movement and rectal temperature (RT) in ºC using a thermometer and skin clamping. The same variables were recorded after local anesthesia at 15, 30, 45 and 60 minutes (T_{15}, T_{30}, T_{45} and T_{60}, respectively). The technique for PPB in each treatment group was performed by the same anesthetist, as follows:

Cambridge technique (CT): after identification of the spaces between T13-L1, L1-L2 and L2-L3, a 22 G (8.5cm long) Tuohy needle was introduced in the parasagittal margin of L1. Upon reaching the transverse process of L1, the needle was angled cranially and aspired to prevent intravascular puncture prior to injection of lidocaine. The same technique was used on vertebrae L2 and L3.

Peripheral nerve stimulator technique (ST): after identification of the spaces between T13-L1, L1-L2 and L2-L3, a 22-G (10cm long) insulated needle coupled to a peripheral nerve stimulator (Stimuplex®, BBraun, Germany) was inserted at the parasagittal margin of L1. Upon entering the skin, the stimulator was configured to 1mA, 2 Hz and 1 second of stimulus duration. The needle was advanced until a muscular response was elicited (flank muscles contraction). The configuration was then changed to 0.5 mA to verify proximity to the nerve. If the muscle response was lost, the needle was advanced slightly further cranially until the muscles were again activated. The final current was set at 0.3mA with a positive muscular response, however, there was an absence of stimulus with 0.2mA to confirm that the tip of the needle was not inside the nerve. The syringe was aspirated, then lidocaine was injected. The same technique was used to locate the nerves at L2 and L3.

To assess the efficacy of the block, a Kocher hemostat was used on the skin, closed at the first ratchet, at a midpoint between the distal aspect of the last rib and the iliac crest at the right flank (Fig. 1) for 5 seconds by an evaluator who was unaware of the treatment performed on the animal. Despite the material used being traumatic, it was not enough to cause any injury to the animal. The muscular and behavioral responses obtained at each time point were compared to a previous skin clamping at baseline, which resulted in lowering the hips in most animals. However, a mild response (i.e. gaze at the flank) has not been considered positive. If the animal showed a positive response on T15, the evaluation was interrupted.

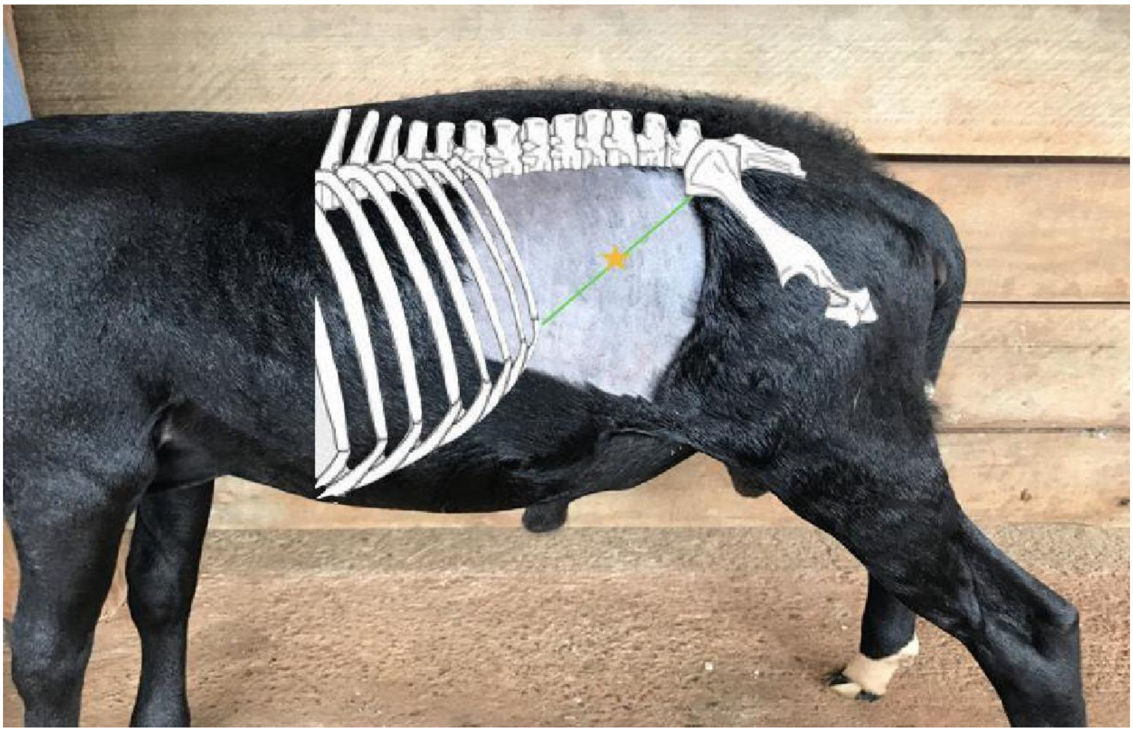


Figure 1. Right flank of a sheep demonstrating the midpoint (*yellow circle*) between the distal border aspect of the last rib and the iliac crest used to assess the efficacy of proximal paravertebral anesthesia by skin clamping using a Kocher hemostat.

Data were initially tested for normality using the Shapiro-Wilk test and then compared among treatments and time points using Kruskal-Wallis test followed by Dunn post-hoc test. The duration of the blockade was assessed using a Kaplan-Meyer survival curve. A chi-square test was performed to assess the relationship between time to perform the block and physical status (thin *versus* fat) or use of the peripheral nerve stimulator. Analyses were performed using a commercial software (GraphPad Prism 6.01) and significant differences were considered when p<0.05.

RESULTS

The techniques used to perform PPB in this study were successfully completed with the aid of physical restraint without any complications. The time to complete the blocks, from injection at the first point (T13-L1) to the last point (L2-L3) was 6 ± 3 minutes and 13 ± 6 minutes for CT and ST, respectively and there was no significant relationship between time and physical status (thin *vs.* fat animals) (p=0.5510). However, significance was found between time and type of technique (blind technique *vs.* guided by the peripheral nerve stimulator) (p=0.0389).

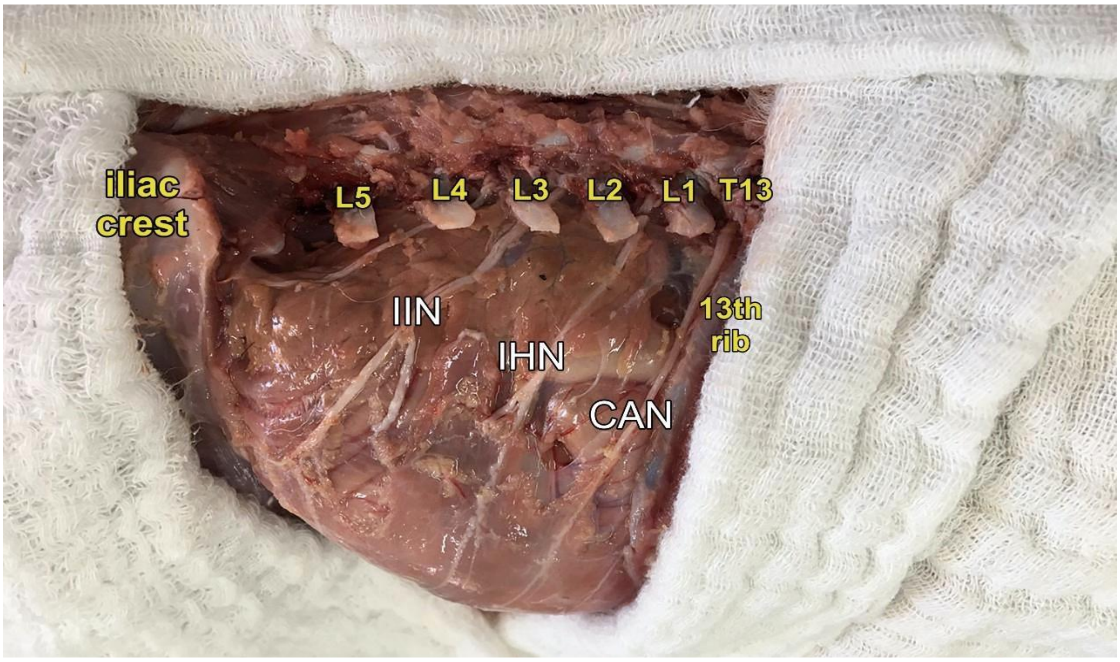
Cardiorespiratory variables and rectal temperature did not differ between groups and remained stable throughout the evaluation period (Table 1). The mechanical response to the electrical stimulus varied from contraction of the external abdominal oblique muscle (costoabdominal nerve T13), the external and internal abdominal oblique muscles (iliohypogastric nerve, L1) and the transversus abdominis muscle (ilioinguinal nerve, L2) (Fig. 2).

In CT, only one animal showed relaxation of flank muscles (Fig. 3), which persisted up to T_{30}, whereas in ST, two animals showed relaxation of the flank until T_{15}, four until T_{30} and one until T_{45}. In response to skin clamping, all animals lowered their hips at baseline. The positive response to skin clamping in CT was obtained in seven animals at T_{15} and one at T_{45}, whereas in ST, one animal showed positive response to skin clamping at T_{15}, two at T_{30}, four at T_{45} and one at T_{60} (Fig. 4).

Table 1. Median (minimum-maximum) of physiologic variables from eight sheep subjected to proximal paravertebral anesthesia without (CT) or with the use of a peripheral nerve stimulator (ST) at baseline (T_B) and at 15, 30, 45 and 60 minutes (T_{15}, T_{30}, T_{45} and T_{60}, respectively)

Variable	Treatment	Time					p-value
		T_B	T_{15}	T_{30}	T_{45}	T_{60}	
HR (beats.minute^{-1})	CT	142 (92-172)	112 (80-128)	118 (108-128)	122 (120-124)	118 (112-124)	0.9819
	ST	134 (116-172)	110 (80-120)	100 (80-120)	100 (92-108)	104 (104-104)	
f_R (breaths.minute^{-1})	CT	40 (24-80)	34 (24-60)	34 (28-64)	42 (36-48)	44 (40-48)	0.3883
	ST	56 (40-76)	41 (32-68)	47 (28-72)	40 (32-44)	36 (36-36)	
RT (°C)	CT	38,9 (38.5-40.0)	39,4 (38.7-40.0)	39,2 (38.5-39.6)	39,6 (39.4-39.7)	39,7 (39.6-39.7)	0.6614
	ST	39.2 (38.6-39.9)	39.5 (39.0-40.0)	39.5 (38.9-39.8)	39.4 (38.8-39.8)	39.2 (39.2-39.2)	

*Variables do not differ among treatments of time points according to Kruskal-Wallis test. HR, Heart rate; f_R, respiratory rate; RT, rectal temperature.



Figuree 2. Dissection of the right flank of a precocious lamb for anatomical identification of the target nerves blocked with proximal paravertebral anesthesia, demonstrating the last rib (13th rib), the transverse processes of thoracolumbar vertebrae and the iliac crest (*yellow*), and the three target nerves (*white*). CAN, Costoabdominal nerve; IHN, iliohypogastric nerve; IIN, ilioinguinal nerve.

Figure 3. Right flank of a sheep demonstrating complete relaxation of the abdominal muscles (*arrow*) following proximal paravertebral anesthesia using a peripheral nerve stimulator.

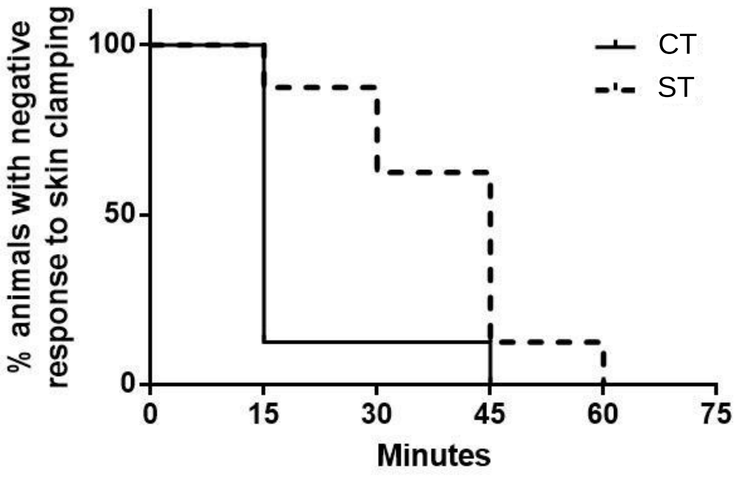


Figure 4. Percentage of sheep showing effective right proximal paravertebral blockade assessed through skin clamping at the right flank following blind injection (CT) or injection using a peripheral nerve stimulator (ST) over 60 minutes. Groups differ significantly according to Kaplan-Meyer survival analysis ($p<0.01$).

DISCUSSION

The different times to perform PPB using the two techniques in this study can be explained by minor difficulties regarding correct identification of the spinal nerves with the use of the peripheral nerve stimulator, which takes longer to be accomplished with the animals under physical restraint. Also, subjects were under semi-intensive regimen and thus had a high body score at the time the experiment was performed, which hindered identification of the transverse processes, although no statistical significance was found regarding thin *vs.* obese animals. Massone (2003) discusses that nutritional status and muscle development sometimes leads practitioners to choose the inverted L block over paravertebral anesthesia.

Valverde & Sinclair (2017) describe the combination of local anesthesia with physical or chemical restraint as to effectively produce desirable and less expensive anesthesia in large species. However, the choice between physical or chemical restraint relies upon species, behavior, and the technical abilities of the anesthetist. These conditions were not an issue in this study with the use of the peripheral nerve stimulator in ST, since electrical stimulation aided the correct identification of spinal nerves and resulted in more effective blockade using a lower dose compared to the blind technique. The same has been reported by Koschielniak-Nielsen *et al*. (1997) and Imbelloni *et al*. (2001) in humans, with lower incidence of technical errors and neuropathy caused by trauma by the needle.

In this study, execution of the blocks in all subjects was done by the same anesthetist, who had extensive experience with regional blocks in domestic animals, with the purpose of increasing the success of the technique at the shortest time possible. Interestingly, however, Eifert *et al*. (1994) refer that peripheral nerve stimulators can be operated by inexperienced practitioners with good success rate in humans. The authors reported that 85% of the successful brachial plexus blockades had been performed by inexperienced anesthetists using a peripheral nerve stimulator. In the present study, comparison of the technique performed by experienced or inexperienced professionals was not part of the objectives, and thus it is not possible to assume that the results would be the same without previous experience.

The maximum current used to locate peripheral nerves was standardized at 1mA according to manufacturer recommendations and its reduction to 0.3mA allowed confirmation of the proximity between needle and nerve, so that lidocaine was injected as close to the target nerve as possible, as described by Eifert *et al.* (1994) in humans. The authors refer that injection of local anesthetics should be done when a positive response is elicited at 0.5mA or less to ensure correct dispersion of the solution around the nerve bundle, since the use of 0.6mA for injection resulted in less effective blockade compared to 0.5mA.

Ruminants usually tolerate well the manipulation for local anesthesia under physical restraint, which poses an interesting alternative to general anesthesia for many procedures. However, local anesthesia in these cases should be highly effective to ensure success of the surgery without any suffering to the animals. In this sense, monitoring cardiorespiratory variables is an important tool to verify the success of local anesthesia together with tests of local sensitivity. In this study, none of the physiological variables showed any significant changes during skin clamping, thereby confirming the success of the blockade.

Regarding positive responses to the electrical stimulus, proximity with the costoabdominal nerve (T13) resulted in contraction of the external abdominal oblique muscle, while the iliohypogastric nerve (L1) resulted in contraction of both external and internal abdominal oblique muscles, and the ilioinguinal nerve (L2) resulted in contraction of the transversus abdominis muscle. Studies addressing muscular responses to electrical stimulation of these nerves in large animals remain scarce, which makes this an interesting description for further studies using the same technique in small ruminants.

After completion of the blocks, it was possible to observe gradual relaxation of the abdominal muscles at the flank in both groups. However, the duration of this relaxation was significantly longer in ST compared to TC (Fig. 4), which demonstrates the higher success rate of correctly locating the nerves with the aid of a peripheral

nerve stimulator. Moreover, the better results in ST were also obtained using half the dose used in CT. This highlights the importance of correct nerve location for better success of the technique, lower cost and lower incidence of risks related to nerve trauma or toxicity of local anesthetics, as discussed by Andrés (2005) regarding brachial plexus block in humans. Successful block of peripheral nerves allows surgical manipulation of patients while awake, thereby providing cardiovascular stability, which would be impaired by general anesthesia (Garcia, 2017), in addition to better quality of recovery from anesthesia.
The main limitation of this study was performing local anesthesia without any sedation. The authors believe that the time of execution of the block would have been shorter had restraint been more effective. However, the results were still satisfactory even with this limitation, and future studies using the same technique in sedated animals might evidence even more interesting results to contribute with small ruminant anesthesia worldwide.

CONCLUSION

The results of this study allow the conclusion that the use of a peripheral nerve stimulator improves the success of proximal paravertebral anesthesia using lower volumes of 2% lidocaine in healthy sheep.

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