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ULTRASOUND-GUIDED BRACHIAL PLEXUS BLOCK USING ARTICAINE 4% WITH EPINEPHRINE IN GOAT

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ABSTRACT

Block of brachial plexus is a regional analgesia commonly used for thoracic limb surgery in different animal species. Articaine HCl with epinephrine is indicated for local infiltrative anesthesia in both simple and complex dental procedures in humans. This study aimed to evaluate the effectiveness of articaine HCl with epinephrine for brachial plexus blockage in goats, using ultrasonography for guidance. The study involved two cadavers for anatomical exploration of the brachial plexus, as well as 18 adult goats of both sexes. A 7.5-9 MHz micro-convex transducer was employed to visualize the brachial plexus and guide the sterile needle to inject 4% articaine HCl with epinephrine. The used dose was 0.25 mL kg^{-1} (10mg/kg). The beginning and length of both motor and sensory impairments were registered following the injection. The results showed the onset times for motor and sensory blocks were 1.4 ± 0.45 min and 2 ± 0.41 min, respectively. The duration of motor and sensory blocks was 186.4 ± 13 min, and 176.4 ± 13 min, respectively. Importantly, the brachial plexus block was not associated with any catastrophic vascular injection, seizures, and paresthesia. Based on the findings of this study, it can be concluded that 4% articaine HCl with epinephrine is effective for brachial plexus blockage, especially when guided by ultrasonography.

Keywords: Articaine HCl, brachial plexus, epinephrine, ultrasonography.

INTRODUCTION

Regional anesthesia techniques, such as nerve blocks, are increasingly common in humans and animal surgeries. These methods are cost-effective and relatively safe, allowing surgical procedures on conscious animals. In ruminants, they help minimize risks of recumbency including bloat, regurgitation, hypoxemia, and myopathy (Rosario *et al.,* 1997; Marhofer *et al.,* 2005; Adami *et al.,* 2011 &Fonseca *et al.,* 2015).

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To successfully perform regional anesthesia blocks, it is essential to achieve optimal distribution of the local anesthetic around nerve structures. Ultrasound visualization has emerged as the most successful technique for improving the quality of nerve blocks. This method offers several advantages during nerve block procedures, such as the direct observation of nerves, surrounding anatomical structures, and the distribution of the local anesthetic during the injection procedure (Estebe *et al.,* 2000; Marhofer *et al.,* 2005; Adami *et al.,* 2014 & d'Ovidio *et al.,* 2014).

Real-time ultrasound visualization allows for precise needle placement, which minimizes the risks of complications such as intraneuronal or intravascular injections. In addition, ultrasound-guided blocks have the indirect effect of reducing painful muscle contractions, shortening block duration, speeding up sensory onset times, and improving overall block quality. This technique also has the potential to reduce the required dosage of local anesthetic, which is considered superior to traditional methods, such as the dependence on anatomical landmarks (blind technique) or nerve locator (nerve stimulator) techniques (Estebe *et al.,* 2000; Marhofer *et al.,* 2005; Casati *et al.,* 2007; Adami *et al.,* 2014 & d'Ovidio *et al.,* 2014).

The brachial plexus block is a safe and widely used method of providing anesthesia for the forelimb. As a result, various procedures, such as limb surgery, tumour removal, and wound management, are performed with reduced pain and discomfort (Huang *et al.,* 2004; Adami *et al.,* 2014 and Skarda & Tranquilli, 2007a&b).

Articaine HCl (carticaine) is a local anesthetic with intermediate action, characterized by a fast onset and moderate potency. Compared to other local anesthetic agents, Articaine 4% demonstrates a quicker clinical onset and a more profound duration of clinical activity. It is commonly used in dentistry for local infiltration and peripheral nerve blocks. Additionally, Articaine has proven effective for spinal, epidural, ocular, and intravenous regional anesthesia. It is considered a safe local anesthetic with a wide safety margin, which is attributed to its pharmacological properties. Articaine, like most local anesthetics, has vasodilatory properties that lead to its quick absorption into the systemic circulation from the injection site. To decrease the absorption and prolong the duration of action of articaine, adrenaline can be added in concentrations of 1:60,000, 1:100,000, or 1:200,000 (Oertel *et al.,* 1997; Malamed *et al.,* 2000; Malamed *et al.,* 2001; Yapp *et al.,* 2011; Snoeck, 2012 & Scully, 2014).

The study aimed to provide a comprehensive anatomical description of the brachial plexus in goats. It also aimed to evaluate the effectiveness of 4% Articaine HCl with epinephrine (Artpharmadent - Artpharma - Egypt) for brachial plexus block in goats, guided by ultrasonography.

MATERIALS AND METHODS

The current study was carried out according to the OIE standards for the use of animals in research and it has institutional ethical approval by the Veterinary Medical Research Ethics Committee (Soh.un.vet /00031 R1). The present study was conducted on 18 clinically healthy mature goats (9 females and 9 males) reared in the Veterinary Teaching Hospital, Assiut University. Two cadavers (one female and one male) were included in the study. The animals were aged 1-4 years and weighed 15-25kg.

Anatomical description

Anatomical investigation and description were performed on two cadavers. The animal's vascular system was flushed with physiological saline and then subjected to preservation by injecting 10% formalin through the right common carotid artery. These formalized goats were dissected systemically on both sides. The origin, course, and distribution of the brachial plexus were studied after 48 hours following embalming. The dissection began by making skin incisions. Then, the pectoralis superficialis and pectoralis profundus muscles were dissected at their origin on the sternum, and the brachiocephalic and trapezius muscles were dissected at the cranial border of the scapula. The serratus ventralis and rhomboideus muscles were dissected at their insertions near the dorsal border of the scapula, and the latissimus dorsi muscle at the caudal border of the scapula. The forelimb was then abducted to explore the axillary artery and brachial plexus. The adjacent nerves and blood vessels were dissected and identified (Fig. 1).

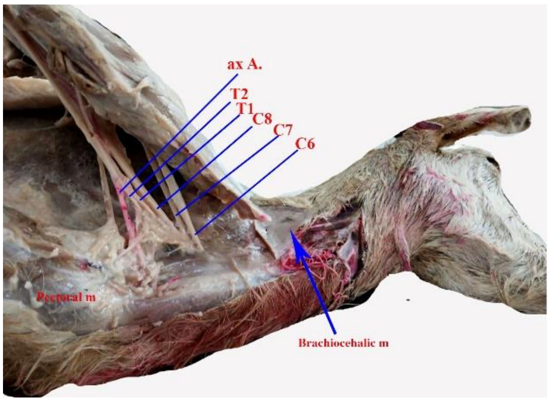

Figure 1: A photograph shows the ventromedial view of the right brachial plexus of a goat after the dissection of the pectoral and brachiocephalic muscles. The image shows the roots of the brachial plexus, which consist of the ventral branches of the sixth cervical to the second thoracic vertebrae (C6-C8 T1, and T2), positioned close to the axillary artery (ax A).

Ultrasound-guided blockade

Animals were fasted for 12 hours from food and for 6 hours from drinking. They were physically restrained and placed in right lateral recumbency on a surgical table for the regional block of the left-side brachial plexus. The skin over the cranio-lateral aspect of the first rib and around the shoulder joint was shaved, followed by scrubbing using 2% chlorhexidine gluconate and 0.5% alcoholic chlorhexidine for antisepsis (Fig. 2A). The brachial plexus block was performed under ultrasound guidance.

Ultrasound imaging was performed with A 7.5-9 MHz micro-convex transducer (Edan Dus 60, USA). The brachial plexus was identified by placing the ultrasound probe just cranial to the shoulder joint. The transducer's orientation was modified to preserve a transverse view of the brachial plexus by aligning the probe perpendicular to the 1st rib. The brachial plexus was also observed in a longitudinal plane by rotating the probe about 90 degrees from the transverse view. For tracing the plexus proximally and clear visualization of the blood vessels of the plexus, the transducer was shifted several centimeters dorsally until the blood vessel became visible (Fig.2B). Once the brachial plexus was visualized, A 20-gauge, 90mm spinal needle was inserted medial and dorsal to the transducer till the needle shaft could be visualized at the site of the brachial plexus then infiltration of articaine-epinephrine was performed (Fig.2C). Blocking achieved via infiltration of 0.25 mL kg^{-1} of an articaine with epinephrine (Artpharmadent - Artpharma - Egypt).

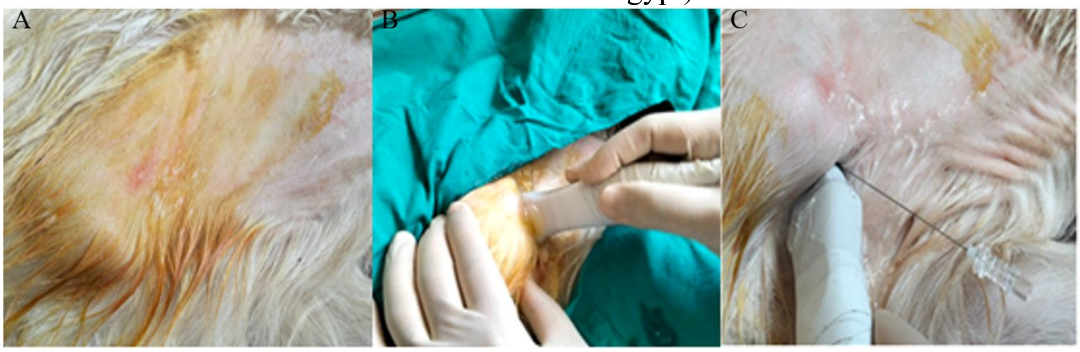

Figure 2: Ultrasound-guided brachial plexus blockade in goats. A- showed antisepsis preparation for the region surrounding the shoulder joint (black arrow). B- showed the position of the ultrasound transducer C- showed the position of the transducer and the needle direction.

Clinical Evaluation of Brachial Plexus Nerve Block

The onset and duration of complete analgesia (sensory block) of the forelimb were estimated. The analgesia was recognized by the absence of response to noxious stimuli. This was assessed using a pinprick test with a 25-gauge needle (superficial and deep) and through the pinching of the skin with mosquito artery forceps, which was closed to the first ratchet. Additionally, the autonomous zones associated with specific nerves in the thoracic limbs were tested. The cranial-lateral aspect from the point of the elbow to the claw was considered the sensory zone of the radial nerve. The medial aspect of the antebrachial region represented the autonomous zone of the musculocutaneous nerve. The autonomous zone of the ulnar nerve is located on the posterior or caudal aspect of the antebrachium and extends to the caudal aspect of the metacarpal region. The median nerve supplies sensation to the medial side of the carpus and the palmar surface of the digits**.** The efficacy of analgesia was assessed by performing pain tests every 30 seconds after the beginning of local infiltration. Responses to the stimuli were evaluated using a numerical rating scale (Table 1). The thoracic limb motor activity loss was assessed by observing the degree of abnormal gait during walking, as well as unusual clinical signs such as a dropped elbow and knuckling of the thoracic limb at the fetlock while standing. It was assessed as previously described by **Iwamoto *et al.* (2012)** and was scored using a three-point numerical rating scale (Table 1). The beginning of the return of sensory and motor responses of the thoracic limb was assessed and recorded from the time of injection of local anesthetics. All cases were evaluated by two investigators.

Table 1: Score of sensitive and motor effect (three-point numerical rating scale)**.**

Score	Sensitive response	Motor response
0	Normal response (response to gentle pinprick stimuli at the skin surface)	Normal gait while walking and no abnormal clinical signs while standing.
1	Diminished response (no response to a needle stabbed into the skin)	Goats can walk while bearing mild to moderate weight and show no abnormal signs while standing.
2	No response (no response to a needle stabbed through the skin)	Goats can walk but is barely able to bear weight while walking, and shows abnormal signs while standing

Statistical *analysis*

All statistical analyses were accomplished using SPSS version 25.0 from IBM, based in Armonk, NY. The results were presented with a mean and standard deviation (SD) for variables that fit the bell curve of normal distribution. In contrast, for the rambunctious data that refused to conform, in the present study, the media was used along with the interquartile range (IQR). To determine whether our data was playing nice or behaving oddly, the Shapiro-Wilk test to check for normality was employed. When the data was amenable to parametric testing, that approach was embraced; however, when faced with non-normal datasets, non-parametric tests were employed. For key metrics like the onset of pain relief, and the duration of paralysis, data were expressed as mean, standard deviation (SD), and standard error (SE). for anesthetic and locomotor scores, the median, SD, and percentiles (25th, 50th, and 75th), along with the full range from minimum to maximum values were achieved. The duration of sensory and motor block did not follow a normal distribution, so we applied the Wilcoxon Signed-Rank test for our statistical comparisons. In the present study set a threshold for significance was set at a p-value of less than 0.05, marking the levels of statistical relevance with a clear line in the sand.

RESULTS

Anatomical considerations

The brachial plexus is formed from the ventral branches of the 6th to 8th cervical nerves and the 1st and 2nd thoracic nerves. The plexus roots pass between the scalenus muscles to the craniomedial side of the shoulder joint. It supplies the skin and the muscles of the thoracic limb, parts of the shoulder girdle, and the thoracic wall. It is located medial to the shoulder joint, closely associated with the axillary artery and vein cranial to the first rib. It was covered laterally by the subclavius and supraspinatus muscles, slightly above the shoulder joint (Fig. 1). The plexus branches into the following branches: suprascapular, subscapular, musculocutaneous, radial, median, ulnar, axillary, dorsal thoracic, lateral thoracic, pectoral, and long thoracic nerves.

Ultrasound-guided Blockade of the Brachial Plexus

The brachial plexus was visualized as a bright, echogenic structure located near the pulsating, anechoic axillary artery, creating a striking contrast in the vivid landscape of the ultrasound image (Fig. 3A). Ultrasound scanning guided a precise needle direction toward the brachial plexus and confirmed the injection of local anesthetic solution around the nerve (Fig. 3B). The anesthetic solution had appeared as anechoic zone around the brachial plexus nerves. The US allowed accurate identification of the vascular structures with decreased risk of intravascular injection. No complications were reported, such as intravascular injection, vascular injury, seizures, persistent paresthesia, ongoing motor loss, or lasting sensory loss.

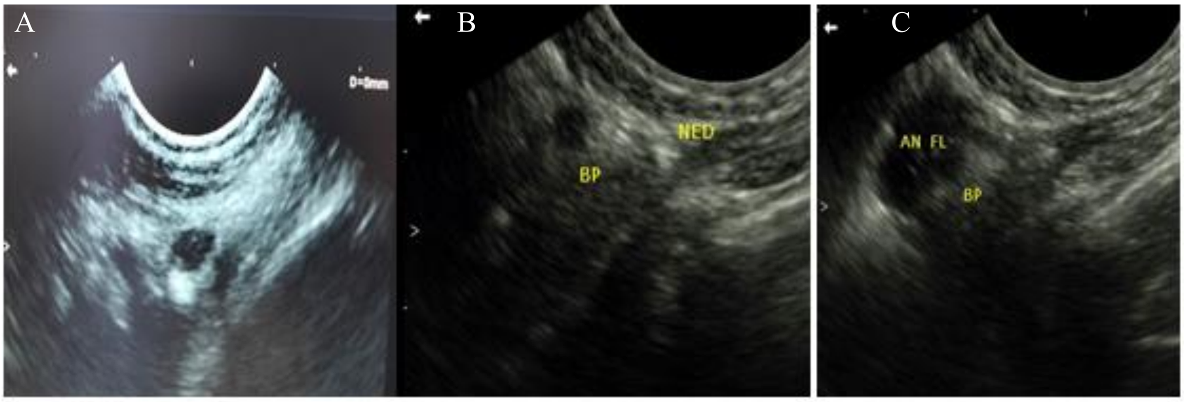

Figure 3: Transverse scan using US showed the brachial plexus as appeared echogenic structure close to the axillary blood vessel. B. Transverse scan just before injection showed the needle (NED) appeared as an echogenic line close to the brachial plexus (BP). C. Transverse scan during injection of articaine HCl, making a halo radiolucent zone encircle the BP.

Clinical Evaluation of Brachial Plexus Nerve Block

Motor inhibition signs appeared earlier than sensory inhibition signs, and their duration was longer, as recorded in Table (2). The sensory inhibition scores gradually increased by 2 min, reaching their peak analgesic effect at 3 min post-injection. It was statistically significant compared to the baseline (before the blockade) with a *p*-value of less than 0.05. This peak of analgesia was maintained until 180 min (P=0.046). However, the sensory inhibition score declined at 200 min (P=1). The motor inhibition scores increased earlier than the sensory scores, starting at 1 min. The peak of motor blockade was achieved at 2 min (P=0.015) and continued until 180 min, after which the motor blockade score began to decline at 200 min (P=0.157). The recovery of all goats was complete and uneventful, with no neurological problems. The results of the sensory inhibition score and motor blockade score were statistically analyzed, and the median values (minimum-maximum) are expressed in Table (3).

Table 2: Onset and duration of sensory and motor blockage.

Articaine hydrochloride (4%) with epinephrine	Time recorded (mean ± SD)
Onset time of sensory block (min)	2 ± 0.41 min
Onset time of motor block (min)	1.4 ± 0.45 min
Duration of sensory block (min)	176.4 ± 13 min
Duration of motor block (min)	186.4 ± 13 min

[SD – Stander deviation \ min – minute]

Table 3: The median, minimum and maximum scores of sensitive and motor response from zero time before injection to the end of the study at 200 min. P< 0.05 was considered statistically significant according to the baseline.

Time/sensory & Motor response	0 min	1 min	2 Min	3 min	100 min	120 min	140 min	160 min	180 min	200 min
Sensory response median (minimum-maximum)	0(0-0)	0(0-0)	2 (1-2)	2(2-2)	2(2-2)	2(2-2)	2(2-2)	2(2-2)	1(1-1)	0(0-0)
P value	1.00	1.00	0.317	0.38*	0.008*	0.008*	0.008*	0.015*	0.046*	1.00
Motor response median (minimum-maximum)	0(0-0)	1(0-1)	2(1-2)	2(2-2)	2(2-2)	2(2-2)	2(2-2)	2(2-2)	1(2-1)	0(1-0)
P value	1.00	0.83	0.015*	0.008*	0.008*	0.008*	0.008*	0.014*	0.034*	0.157

DISCUSSION

The findings of the present study showed that the brachial plexus extends as a large band of nervous tissue. Its caudal boundary is in contact with the superior surface of the first rib, positioned cranial to the acromion and dorsal to the scalenus medius muscle. Additionally, it is located medial to the pulsating axillary artery. Similar findings have been reported in Bengal and Zaraibi goats (Sultana *et al.,* 2011& Hassan *et al.,* 2024). Blocking of the brachial plexus provides complete desensitization of the thoracic limb and avoids risks associated with epidural and general anesthesia (Adami *et al.,* 2011; Fonseca *et al.,* 2015; Ansón *et al.,* 2017 & Atiba *et al.,* 2019).

The present study verified the importance of ultrasound in regional anesthesia. It enabled the inspectors to display the relationship between the tip of the spinal needle and the nerve, along with the surrounding anatomical structures and the spread of the local anesthetic solution around the brachial plexus nerves. Moreover, this approach helps to avoid complications associated with blind techniques, such as intraneural and intravascular injections. There is consistency between these findings and those previously recorded (Casati *et al.,* 2007; Iwamoto *et al.,* 2012; d'Ovidio *et al.,* 2014; Atiba *et al.,* 2019; Castillo-Zamora and Castillo-Peralta, 2022 & Chiba *et al.,* 2022). According to these studies, ultrasound was associated with reducing painful muscle contractions, minimizing dose and drug volume, and providing faster sensory onset time and longer block duration of action. In this study, 0.25 mL of articaine with epinephrine per kg was administered for brachial plexus block in goats. The same volume of the drug was also administered for anesthesia in sheep and dogs. This dosage was sufficient to achieve a good regional anesthetic effect (Wenger *et al.,* 2005; Campoy *et al.,* 2008; Ghadirian & Vesal, 2013; Akasaka & Shimizu, 2017 & Imani Rastabi *et al.,* 2018). The effectiveness can be attributed to the diffusion of the local anesthetic from the perineural space to the neural tissue, which primarily depends on the volume and concentration of the injected drug (Taylor & McLeod, 2020 & Chen *et al.,* 2023).

In the present study, the axillary artery appeared as a circular, anechoic structure with a thick echogenic wall and the brachial plexus was identified as an echogenic structure with multiple discontinuous lines adjacent to the anechoic blood vessel. Similar findings have been reported during ultrasound guidance for brachial plexus blockade in donkeys (Atiba *et al.,* 2019), calves (Iwamoto *et al.,* 2012), dogs (Campoy *et al.,* 2010), and cats (Ansón *et al.,* 2017).

Concerning the use of potentiated articaine HCl for a block of the brachial plexus in goats, our results showed a long duration of action ranging from 180 to 200 min. The addition of epinephrine decreased the absorption of articaine from the site of injection. The duration of local anesthesia is influenced by various factors, including the type, concentration, and volume of the anesthetic drug, the nerve localization, and the type of the desensitized nerve. Articaine hydrochloride has a high lipid solubility, and this may increase its distribution at the site of action, which may lead to its rapid absorption into systemic circulation from the site of injection. To reduce the absorption and to prolong the duration of action of articaine, adrenaline or epinephrine was added (1:60,000, 1:100,000, and 1:200,000) (Malamed *et al.,* 2001; Yapp *et al.,* 2011; Snoeck, 2012; Malamed, 2014 &Lasemi *et al.,* 2015). The current study demonstrated that the use of epinephrine with articaine resulted in a rapid onset of anesthesia, typically ranging from 1.5 to 2 min. These findings were consistent with those reported in previous studies in humans and rabbits (Miyoshi et al., 2000; Costa *et al.,* 2005; Nizharadze *et al.,* 2011 &Malamed, 2014). The fast action of articaine may be attributed to its concentration (4%), and its high lipid solubility (Malamed, 2014 & Lasemi *et al.,* 2015).

The outcomes of the present work showed that sensory inhibition scores had shorter durations than motor inhibition scores. The motor inhibition score was achieved rapidly and increased significantly compared to the sensory inhibition score. These findings were in agreement with those recorded previously (Iwamoto *et al.,* 2012; Ghadirian & Vesal, 2013; Imani Rastabi *et al.,* 2018 & Atiba *et al.,* 2019). When local anesthesia is administered to mixed peripheral nerves, researchers have observed that the motor block begins sooner and lasts longer than the sensory block. This observation is attributed to the somatotopic organization of nerve fibers within these nerves. The local anesthetic diffuses along a concentration gradient, starting from the outer layer (the mantle) and moving toward the inner core. As a result, the motor nerve fibers, which are located closest to the outer mantle, are the first to be affected. This leads to skeletal muscle paralysis occurring before the sensory block sets in. During recovery, however, the process reverses. The core of the nerve, where the vascular supply is concentrated, allows for a quicker removal of the anesthetic. Consequently, the sensory block tends to dissipate more rapidly than the motor block (Skarda & Tranquilli, 2007a, b).

CONCLUSION

Briefly, using articaine hydrochloride 4% with epinephrine for brachial nerve block produces rapid and moderate duration of analgesia for the thoracic limb in goats, in addition to longed motor paralysis. Ultrasonography is an important guide for brachial nerve block to avoid accidental penetration of adjacent blood vessels.

CONFLICT OF INTEREST

There are no conflicts of interest associated with this publication.

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تخدير الضفيرة العضدية باستخدام الأرتيكيين ٤٪ مع الإبينفرين تحت توجيه الموجات فوق الصوتية في الماعز

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في مختلف أنواع الحيوانات يستخدم تخدير الضفيرة العضدية بمثابة مسكن موضعي في جراحة الارجل الامامية. يُستخدم ايضا الأرتيكيين هيدروكلوريد مع الإبينفرين للتخدير الموضعي في إجراء جراحات الأسنان البسيطة والمعقدة فى الانسان. تهدف هذه الدراسة إلى تقييم مدى فعالية الأرتيكيين هيدروكلوريد ٤٪ المدموج مع الإبينفرين في تخدير الضفيرة العضدية فى الماعز، من خلال تقنية التصوير بالموجات فوق الصوتية. وقد تضمنت الدراسة تحليل جثتين لاستكشاف البنية التشريحية للضفيرة العضدية، بالإضافة إلى ١٨ ماعزًا بالغًا من الجنسين. تم استخدام جهاز السونار بتردد يتراوح بين ٧,٥ و٩ ميجاهرتز لتصوير الضفيرة وتوجيه الإبرة المعقمة لحقن الأرتيكيين هيدروكلوريد بتركيز ٤٪، مضافًا إليه الإبينفرين. استخدام جرعة من المخدر تقدر ب١٠ مليجرام لكل كيلوجرام من وزن الحيوان (٠,٢٥ مل/كجم). تم تسجيل الوقت اللازم لبداية ومدة التخدير الحركي والحسي للأرجل بعد عملية الحقن. أظهرت النتائج أن زمن بدء التخدير الحركي بلغ 0.45 ± 1.4 دقيقة بينما كان زمن بدء التخدير الحسي 0.41 ± 2 دقيقة. واستمر التخدير الحركي لمدة 13 ± 186.4 دقيقة، في حين كانت مدة التخدير الحسي (13 ± 176.4) دقيقة. ومن الجدير بالذكر إلى أن استخدام تقنية تخدير الضفيرة العضدية لم تسجل اى آثار جانبية مثل وخز الأوعية الدموية القريبة، أو نوبات صرع، أو شعور بالتنميل. وبناءً على النتائج التي تم الحصول عليها من هذه الدراسة، يمكن الاستنتاج بأن استخدام الأرتيكيين هيدروكلوريد بتركيز ٤٪ مع الإبينفرين يُعتبر فعالاً في تخدير الضفيرة العضدية، وبالأخص عند حقنه تحت توجيه الموجات فوق الصوتية.