Comparison of four techniques for synoviocentesis of the equine digital flexor tendon sheath: A cadaveric study

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Keywords
Digital flexor tendon sheath, synoviocentesis, horse, palmar digital nerve, plantar digital nerve, anaesthesia

Summary
Objective: To compare four different techniques for synoviocentesis of the equine digital flexor tendon sheath (DFTS).
Methods: Fifteen inexperienced operators performed each of the following injection techniques on two cadaveric limbs: Proximal (at the proximal recess of the DFTS), Axial (axial to the proximal sesamoid bone), Base (at the base of the proximal sesamoid bone), and Distal (at the pastern). The number of attempts needed before the needle was assumed to be correctly positioned into the DFTS was recorded and 10 ml of methylene blue was injected. The limbs were dissected to determine the presence of methylene blue in the DFTS, the distance between the needle entrance point and the lateral palmar or plantar (digital) nerve, the degree of subcutaneous leakage and the distance between the border of the leakage zone and the lateral digital nerve.
Results: The Axial (29/30) and Distal (25/30) approaches had the highest numbers of successful injections. The median number of attempts was highest for the Axial approach. The distances from the injection point and from the border of the leakage zone to the lateral digital nerve were longer for Distal and Axial approaches.
Clinical relevance: In the hands of inexperienced operators, the Axial approach was the most successful technique for injection of the equine DFTS. Sparse subcutaneous leakage and larger distance to the nerve when using this technique might decrease the risk of inadvertent palmar or plantar digital nerve desensitisation when performing DFTS analgesia.

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Introduction

Synoviocentesis of the digital flexor tendon sheath (DFTS) is commonly performed in horses for both diagnostic and therapeutic purposes. Indications for DFTS synoviocentesis include septic and aseptic tenosynovitis, intrathecal contrast radiography, distension of the DFTS for tenoscopy, through-and-through needle lavage or therapeutic injection of anti-inflammatory agents.

Due to its anatomical localization, the DFTS is frequently involved in lacerations of the distal equine limb, hence being the most commonly affected synovial sheath (1, 2). Early and prompt identification of DFTS involvement is crucial in order to establish appropriate treatment. Reliable access to the DFTS is mandatory for either synovial fluid sampling or confirming communication between the DFTS and a laceration. Different techniques for synoviocentesis of the DFTS have been described. The most commonly used approaches are at the proximal recess of the DFTS and at the distal palmar or plantar aspect of the pastern between the proximal and distal digital annular ligaments (3, 4). The DFTS may also be approached abaxially, at its outpouching at the base of the proximal sesamoid bone, between the distal aspect of the palmar annular ligament, and the proximal aspect of the proximal digital annular ligament (4). Hassel et al. described a palmar-plantar axial sesamoidean approach, at the level of the midbody of the lateral proximal sesamoid bone, axially to the palpable palmar or plantar border of the lateral proximal sesamoid bone, through the palmar annular ligament (5). The choice of technique is determined by the experience and personal preferences of the operator. However the absence of distension, presence of a wound at the puncture site or compromised state of the surrounding tissues may prevent the use of a specific technique. In any case, the injection technique should be easy to perform and ensure an accurate access to the DFTS.

Aseptic tenosynovitis causing lameness can have several aetiopathogeneses, but it is

mostly secondary to longitudinal tears of the digital flexor tendons, tears of the manica flexoria, desmitis of the palmar annular ligament, tendonitis of the superficial digital flexor tendon and deep digital flexor tendon, rupture of the DFTS, or chronic synovitis of the DFTS of unknown origin (6–11). Intrasynovial analgesia has become a routine procedure in confirming lameness of the DFTS. Nevertheless, some controversy concerning the specificity of DFTS anaesthesia exists, suggesting that desensitisation of structures other than those intended may occur (4). Schneider et al. reported desensitisation of the foot after DFTS analgesia, probably related to the proximity of the palmar or plantar nerve to the injection site and to the size of the needle allowing subcutaneous leakage (12). In contrast, Harper et al. found no influence of DFTS analgesia on lameness caused by pain within the navicular bursa, distal interphalangeal joint or the sole (dorsal margin or heel region) (13). However, inadvertent skin desensitisation at the level of the heel bulbs was not assessed in their study.

To our knowledge, there is no study that compared objectively the four most commonly used techniques for intrasynovial injection of the DFTS. Therefore, the goals of the present study were: 1) to compare the accuracy and the ease of performing the four previously mentioned synoviocentesis techniques, and 2) to assess the risk of inadvertently influencing the palmar or plantar digital nerves by measuring the degree of subcutaneous leakage and the distance to the palmar or plantar digital nerve.

Materials and methods

Specimens

A cadaveric study was performed using a total of 120 distal equine limbs (60 forelimbs and 60 hindlimbs) from horses of different breeds, sizes and ages, collected at the slaughterhouse. Limbs were amputated at the level of the carpo-metacarpal or distal intertarsal joints and were examined to exclude the presence of any gross anatomical abnormalities or damage produced during the cutting process. The specimens were used fresh and the hair was clipped.

Injection techniques

▶Table 1 provides a detailed description of the four injection techniques, as presented to the operators. ▶Figure 1 illustrates the site of injection for each of the four previously mentioned injection techniques. All synoviocenteses were performed using a 20 gauge, 25 mm hypodermic needle and the position of the needle bevel was left to the discretion of each operator. For the Proximal and Axial injection techniques, the limbs were held in flexion in a proximal-distal orientation. For the Base and Distal techniques, each limb was lying flat on a table with the palmar or plantar aspect facing upwards (simulating a limb that is held up, parallel to the ground). Limbs were always held by the same person (MJ).

Experimental design

Fifteen inexperienced operators (final year veterinary students) were included in this study. The operators were provided with some anatomic slides and a written protocol for each of the four synoviocentesis techniques (▶Table 1). A video film demonstrating each technique was shown at

Table 1 Description of the four synoviocentesis techniques.

Description of the injection techniques	
Proximal: Proximo-lateral approach (3)	
Position:	Metacarpo or metatarsophalangeal joint slightly in flexion.
Insertion:	Needle inserted 1 cm proximal to the palmar annular ligament and 1 cm palmar or plantar to the lateral branch of the suspensory ligament.
Direction:	Needle directed slightly distal.
Depth:	Approximately 15 mm.
Axial: Palmar-plantar axial sesamoidean approach (5)	
Position:	Metacarpo or metatarsophalangeal joint flexed to a 225° angle.
Insertion:	Needle inserted at the level of the midbody of the lateral proximal sesamoid bone, through the palmar annular ligament, and 3 mm axial to the palpable palmar or plantar border of the lateral proximal sesamoid bone.
Direction:	The needle is inserted in the transverse plane and directed 45° from the sagittal plane, angled toward the central intersesamoidean region.
Depth:	Approximately 15 to 20 mm.
Base: Base of proximal sesamoid bone approach (4)	
Position:	Metacarpo or metatarsophalangeal joint in normal extended position.
Insertion:	Needle inserted in palpable indentation just distal to the lateral proximal sesamoid bone, between the distal aspect of the palmar annular ligament and proximal aspect of the proximal digital annular ligament, palmar or plantar to the neurovascular bundle.
Direction:	The needle is inserted in the transverse plane or slightly proximal (approximately 20°), perpendicular to the skin.
Depth:	Approximately 5 mm.
Distal: Palmar-plantar pastern approach (4)	
Position:	Metacarpo or metatarsophalangeal joint in normal extended position.
Insertion:	Needle inserted in the palmar or plantar aspect of the pastern region, in the outpouching of the digital flexor tendon sheath located between the proximal and distal digital annular ligaments.
Direction:	Needle directed in the sagittal plane, perpendicular to the skin.
Depth:	Approximately 5 mm.

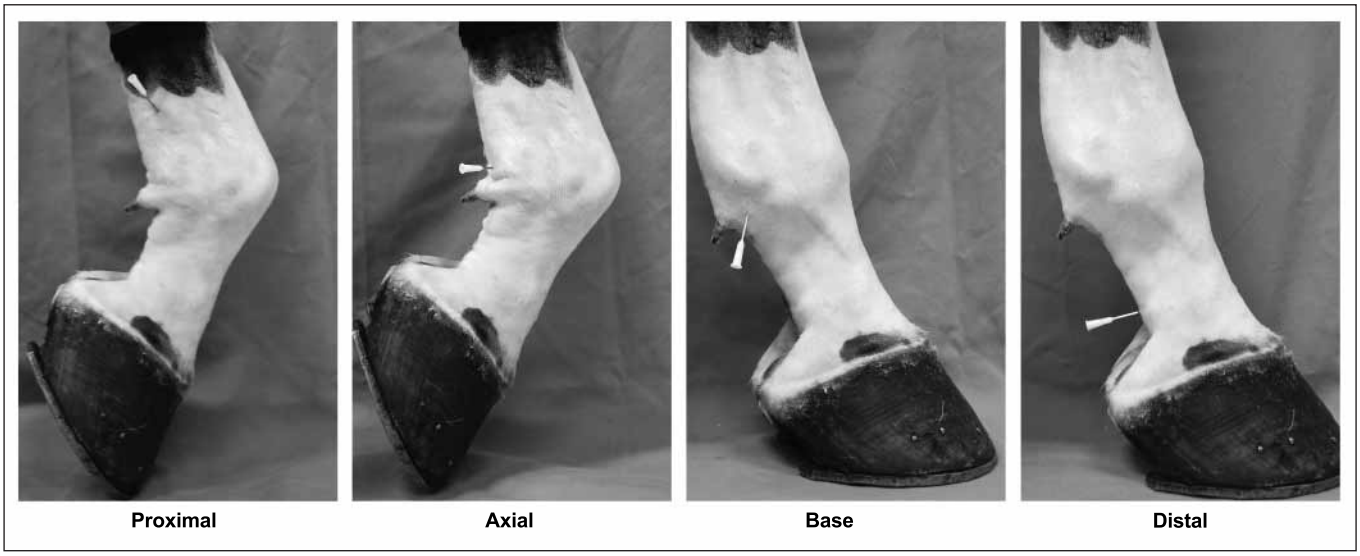

Fig. 1 Cadaveric limb illustrating the needle position for each of the four different injection techniques. For a detailed description of the injection technique see Table 1.

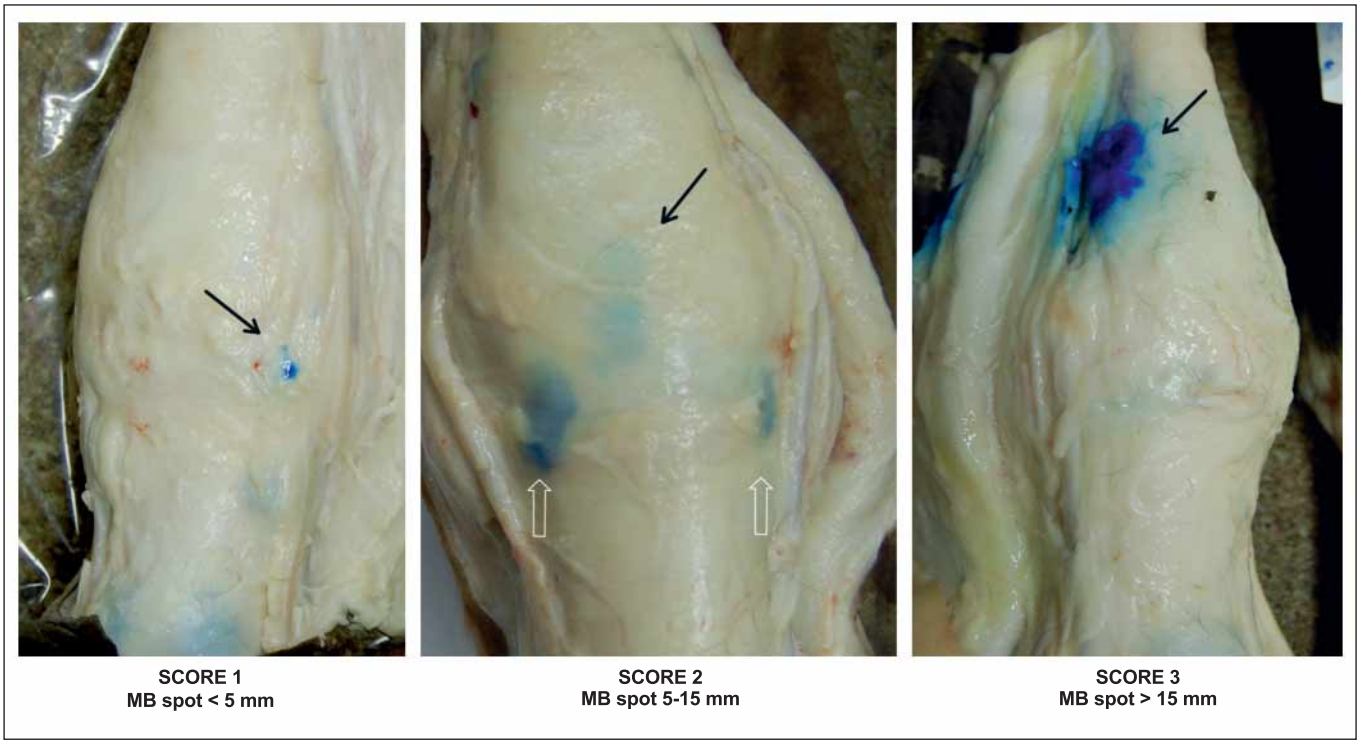

Fig. 2 Photographs of the limbs during anatomical dissection. Illustration of the different subcutaneous leakage scores (black arrows). Note the outpouchings of the digital flexor tendon sheath at the base of the proximal sesamoid bones (white arrows) which should not be interpreted as subcutaneous leakage. MB = methylene blue.

the start of the experiment (▶Video is available online at http://www.vcot-online.com). Each operator performed each injection technique on two cadaver limbs (one forelimb and one hindlimb). The order of limb and technique were randomly assigned. As each technique was performed, the main investigator (MJ) recorded the number of attempts needed before the needle was assumed to be correctly positioned into the DFTS. Any redirection of the needle was considered an attempt, even if the needle was not completely removed from the limb. There was no limit to the number of attempts allowed. When the operator considered the needle to be successfully inserted in the DFTS, 10 ml of methylene blue dye was injected. Criteria used by

the operators for assuming correct placement of the needle in the synovial space were adherence to the anatomical landmarks and protocol definition, palpable evidence of entrance into a potential space, obtaining synovial fluid into the needle hub and/or lack of resistance to fluid injection. The limbs were systematically dissected between one to three hours after the injection. The following parameters were recorded and compared between techniques: presence of methylene blue in the DFTS confirming correct intrathecal injection, the presence of methylene blue in the metacarpo or metatarsophalangeal joint indicating inadvertent intra-articular injection, the distance between the needle entrance point and the lateral palmar or plantar nerve, the degree of subcutaneous leakage (1 = minimal, with a methylene blue spot <5 mm; 2 = moderate, with a methylene blue spot 5 to 15 mm; 3 = severe, with a methylene blue spot >15 mm) and the distance between the border of the methylene blue leakage zone and the lateral palmar or plantar nerve (▶Fig. 2).

Statistical analysis

Statistical analysis was performed using a commercial software package[a] with statistical significance set at $p < 0.05$. As data were not normally distributed (Kolmogorov-Smirnov test and QQ-plot) and this could not be adequately resolved by transformation, non-parametric analyses were performed. The association between the different techniques and the number of successful injections was examined using chi-square analysis with Bonferroni adjustment for the individual contrasts. Forelimb and hindlimb values (attempts, score) were compared using Mann-Whitney rank sum test. The number of attempts, leakage score, and distance between the injection point and the border of the leakage zone to the palmar or plantar digital nerve were all compared using Kruskal-Wallis test with pairwise comparison using Dunn's test. Only limbs with correct intrathecal injection were included for subcutaneous leakage scoring and distances to the palmar or plantar digital nerve. Data are presented as median values and ranges.

[a] SPSS 17.0: IBM Corporation, Armonk, New York

Table 2 Comparison of four different techniques for synoviocentesis of the digital flexor tendon sheath in 120 equine cadaveric limbs (30 limbs for each technique) for accuracy and ease of performing.

Technique	Number successful injections in DFTS	Number attempts Median (range)	Penetration MP joint
Proximal	17 out of 30 (56%)[b]	2 (1-8)[b]	2 out of 30 (6%)
Axial	29 out of 30 (96%)[a]	3 (1-9)[a]	0 out of 30 (0%)
Base	19 out of 30 (63%)[b]	1 (1-4)[b]	0 out of 30 (0%)
Distal	25 out of 30 (83%)[a]	1 (1-6)[a]	0 out of 30 (0%)

Key: DFTS = digital flexor tendon sheath; MP = metacarpo or metatarsophalangeal joint. For the description of proximal, axial, base and distal see Table 1. Values in the same column with different superscript letters are significantly different ($p < 0.05$)

Table 3 Comparison of four different techniques for synoviocentesis of the digital flexor tendon sheath in 120 equine cadaveric limbs (30 limbs for each technique) for subcutaneous leakage and distance to the lateral palmar or plantar (digital) nerve.

Technique	D_N (mm) Median (range)	Leakage score Median (range)	D_{LN} (mm) Median (range)
Proximal	5 (0-25)[b]	2 (1-3)	0 (0-5)[b]
Axial	23 (5-110)[a]	1 (1-3)	18 (5-75)[a]
Base	15 (0-35)[b]	2 (1-3)	0 (0-20)[b]
Distal	30 (0-45)[a]	2 (1-3)	10 (0-30)[a]

Key: D_N = distance from the needle insertion point to the lateral palmar or plantar nerve; D_{LN} = Distance from the border of the methylene blue leakage zone to the lateral palmar or plantar nerve. Leakage score: 1 = minimal, with a methylene blue spot <5 mm; 2 = moderate, with a methylene blue spot 5 to 15 mm; 3 = severe, with a methylene blue spot >15 mm. For the description of proximal, axial, base and distal see Table 1. Values in the same column with different superscript letters are significantly different ($p < 0.05$)

Results

▶Tables 2 and 3 summarize the results for the different parameters.

The highest numbers of successful injections were recorded for the Axial (29/30) and Distal (25/30) approaches. The Axial approach was significantly more successful than the Proximal (*values presented as odds ratio [OR], confidence interval [CI]*; OR 22.2, 95% CI [2.7–184.9]) and Base techniques (OR 16.8, 95% CI [2.0–141.0]) ($p < 0.01$). No significant differences were observed between forelimbs and hindlimbs. On only two occasions was methylene blue observed in the metacarpo or metatarsophalangeal joint indicating inadvertent injection into this synovial structure. This occurred in one forelimb and one hindlimb, with different operators, both when using the Proximal approach.

The median number of attempts was highest for the Axial approach (3 attempts) with a significant difference when compared to the Base ($p < 0.01$) and Distal ($p < 0.001$) techniques (both 1 attempt). The Base technique required significantly more attempts in the forelimbs (median 2, range 1–4) compared to the hindlimbs (median 1, range 1–4) ($p < 0.05$).

When analyzing the distance from the injection point to the lateral palmar or plantar nerve, Distal and Axial injections occurred significantly further away from the nerve compared to Proximal and Base approaches ($p < 0.001$ for all comparisons except for Axial to Base: $p < 0.01$). The

median leakage score was lower for the Axial technique compared to the other three approaches but these differences did not reach statistical significance. Only for the Distal approach was the leakage score number significantly higher in the forelimbs (median 3, range 1–3) compared to the hindlimbs (median 1, range 1–3) ($p < 0.01$). When analyzing the distance from the border of the methylene blue leakage zone to the lateral palmar or plantar nerve, similar results were observed as those for the distance from the injection point to the lateral palmar or plantar nerve: methylene blue leakage spots observed after Axial and Distal injection were significantly further away from the palmar and plantar nerve than those obtained with the Proximal and Base techniques except for the comparison of Distal to Base ($p < 0.001$ for Axial to Proximal; $p < 0.01$ for Axial to Base and $p < 0.05$ for Distal to Proximal). No significant differences between forelimbs and hindlimbs could be identified for the distance from the border of the methylene blue leakage zone to the lateral palmar or plantar nerve.

Discussion

In the hands of inexperienced operators, the Axial and Distal techniques were superior compared to the Proximal and Base approaches in terms of accuracy of injection. Although the Axial approach took the highest number of attempts, there was only one non-successful injection with this technique. In clinical cases with distension of the DFTS, synoviocentesis at one of the synovial recesses of the DFTS (Proximal, Base and Distal techniques) becomes easier to perform as the presence of synovial fluid in the needle hub confirms correct needle location. It is therefore likely that in these clinical situations the rate of successful injection of the Proximal and Base techniques would have been higher compared to the results obtained in this study. However, clinicians should be able to inject the DFTS under any circumstance, even when distension of the DFTS is not present and the presence of synovial fluid in the needle hub cannot be used as a landmark to confirm accurate positioning of the needle. Since the Axial technique is not performed at one of the outpouchings of the DFTS, this might be the most suitable technique in case of absence of DFTS distension.

The inadvertent penetrations of the metacarpo or metatarsophalangeal joint (2 out of 120 limbs) with the Proximal technique may possibly be explained by the close anatomic proximity of the palmar or plantar recess of the joint capsule to the proximolateral synovial pouch of the DFTS. Although the chance of inadvertent penetration of the metacarpo or metatarsophalangeal joint is small, unintended intrasynovial analgesia or iatrogenic spread of infection when dealing with septic tenosynovitis may result. Placing the needle plantar to the neurovascular bundle should theoretically reduce the risk of inadvertent penetration of the metacarpo or metatarsophalangeal joint.

Although the median number of attempts were acceptable, in individual cases many attempts were needed to reach the DFTS. In our opinion, a lack of familiarity of the inexperienced operators with the anatomy of the area, together with the disadvantage of working with cadaver limbs could have played a role. Nevertheless, a large number of attempts increases the likelihood of inducing intrasynovial haemorrhage and damage to the tendons (14). Indeed, needle marks on the superficial or deep digital flexor tendons, or both, were frequently observed with any of the four described techniques during anatomical dissection, however substantial needle-induced trauma was not identified during gross dissection of the limbs. Hassel et al. previously suggested that damage to the abaxial region of the flexor tendons may occur when using the Axial technique (5). Unfortunately, similar to the study of Hassel, no detailed recording of iatrogenic damage to the soft tissue and flexor tendons was performed in the present study. Theoretically, one can expect a lower risk of tendon damage when using the Proximal, Base or Distal techniques compared to the Axial technique as with the latter there is very little free space between the flexor tendons, the palmar annular ligament and the proximal sesamoid bone in the fetlock canal. On the other hand, in many clinical situations where distension of the DFTS is present, the appearance of synovial fluid in the needle hub as a sign of correct needle placement into the DFTS would no longer result in further needle advancement with less chance of tendon damage. Nevertheless, further investigation should be performed in order to establish the degree of flexor tendon damage for each of the different injection techniques.

The difference in leakage score between the Axial and the other three techniques was not significant, but this might have been due to the lack of power. For the Axial technique, the injection is performed obliquely and through the hard fibrous palmar annular ligament, and we speculate that this may inhibit subcutaneous leakage of the injected fluid. Furthermore, the Axial and Distal techniques are performed in a more axial position which places the needle further away from the palmar or plantar digital nerve compared to the Proximal and Base techniques, both of which are performed more abaxially and thus closer to the neurovascular bundle. As suggested by Harper et al., with the Axial technique the combination of injecting further away from the palmar or plantar digital nerve together with a lower degree of subcutaneous leakage is likely to result in a reduced risk of inadvertent desensitisation of the palmar or plantar digital nerves when performing diagnostic analgesia (13). Nevertheless, this hypothesis should be confirmed in an *in vivo* study comparing the different techniques since in a clinical situation other elements may also play a role, like the compression that is routinely applied following injection over the site of needle entrance in order to avoid subcutaneous leakage. Also differences in tissue characteristics of the distal limb between cadavers and patients may influence the degree of subcutaneous leakage.

In conclusion, the results of the present study demonstrate that, in the hands of inexperienced operators, the palmar or plantar axial sesamoidean approach described by Hassel et al. is the most successful technique for injection of the equine DFTS in an *in vitro* situation, however it requires the highest number of attempts to achieve correct needle placement (5). Sparse subcutaneous leakage together with a relatively larger distance from the injection point to

the nerve both suggest a smaller likelihood of inadvertent desensitisation of the palmar or plantar digital nerves when performing analgesia of the DFTS during lameness examination.

Conflict of interest

None declared.

Online Supplementary Material

The video film shown to operators at the start of the experiment, and which demonstrates each of the four synoviocentesis techniques is available to view online at www.vcot-online.com.

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