Ultrasound-guided approach to the cervical articular process joints in horses: a validation of the technique in cadavers

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Abstract:

Objectives: To compare accuracy of the ultrasound-guided craniodorsal (CrD) approach with the dorsal (D) approach to the cervical APJs, and to evaluate the effect of transducer, needle gauge, and operator experience.
Methods: Cervical APJs from 14 cadaveric neck specimens were injected using either a D or CrD approach, a linear (13 MHx) or microconvex transducer (10 MHz), an 18 or 20 ga needle, by an experienced or inexperienced operator. Injectate consisted of an iodinated-contrast and methylene-blue mixture. Time taken for injection, number of redirects, and retrieval of synovial fluid were recorded. Accuracy was assessed using a scoring system for contrast seen on computed tomography (CT).
Results: Both approaches performed comparably with 89.7% (D; 61 of 68) and 89.0% (CrD; 57 of 64) of injections intra-articular on contrast CT. No significant effect of approach, transducer or needle gauge was observed on injection accuracy, time taken to perform injection, or number of redirects. The 18 ga needle had a positive correlation with retrieval of synovial fluid. A positive learning curve was observed for the inexperienced operator.
Clinical relevance: Both approaches to the cervical APJs were highly accurate. Ultrasound-guided injection of the cervical APJs is an easily-learnt technique for an inexperienced veterinarian. Either approach may be employed in the field with a high level of accuracy, using widely available equipment.

Introduction

Ultrasound-guided injection of the cervical articular process joints (APJs) is indicated for horses showing a variety of clinical signs including neck pain and stiffness, ataxia and paresis, forelimb lameness and abnormal head carriage (1). Cervical vertebral diseases include degenerative or inflammatory disease, osteochondrosis of the cervical APJs, or narrowing of the vertebral canal (1, 2). Intra-articular injection techniques have potential for both diagnostic and therapeutic applications (1, 2, 3).

Two ultrasound-guided injection techniques of the cervical APJ have been reported, cranial (4) and dorsal (2, 5) approaches. To date, only the dorsal approach has been validated. Nielsen *et al*. (2003) described a cadaveric study of 60 APJs from 8 specimens, using a dorsal approach (2). Seventy-two percent were found to be intra-articular, with a further 17 % intra-capsular. It has been shown in human cervical zygapophysial joint blocks that intra-articular diffusion of injectate can occur across an intact anterior capsule (6), thus an intra-capsular injection may be sufficient to achieve a diagnostic or therapeutic outcome in the horse (2). As it is unknown whether the APJ capsule in man and the horse are comparable in terms of thickness and composition, this proposed mechanism of diffusion across an intact capsule may not apply to the horse. The cranial approach has been described whereby the transducer is orientated parallel to the long-axis of the neck, in alignment with the vertebral column (4). In this technique an 18 ga needle is introduced cranial to the transducer and is directed into the joint space. In a retrospective study of 59 horses with cervical APJ arthropathy, treated with intra-articular corticosteroids using this technique, 71.2% of cases returned to normal function or had improved performance, as reported by the owner (1). Whilst this demonstrates the clinical usefulness of the technique and highlights its diagnostic value, it does not provide information on the accuracy. A third technique, the 'craniodorsal' approach, exists but has not yet been described nor validated in the literature. In humans, accuracy of cervical intraarticular injections has been reported to be up to 90 %, with arthrography used as confirmation of intra-articular location (6), thus there is still scope for improvement in the technique in the horse. Further investigation is warranted to ascertain which approach provides maximum accuracy, in order to achieve an optimal diagnostic or therapeutic outcome in practice.

The aim of this study was to describe and validate the previously unreported craniodorsal (CrD) approach to the craniodorsal synovial recess of the cervical APJ in the horse and to compare it to the previously reported dorsal (D) approach. The secondary aim was to evaluate the effect of the ultrasound transducer (linear 13 MHz or microconvex 10 MHz), needle gauge (18 ga or 20 ga), and operator experience (experienced or inexperienced), on accuracy of injection. We hypothesised that compared to the dorsal approach; the craniodorsal approach to the APJs would result in a higher accuracy (defined as successful intra-articular injection). We hypothesised that a microconvex transducer, and 18 ga needle, would result in improved accuracy and faster injection times, compared to a linear transducer, and 20 ga needle, respectively. We also hypothesised that the learning curve would be steep for an inexperienced operator and that the experienced operator would be more accurate overall.

Methods and Materials

Neck Specimens

Cadaveric neck specimens were harvested from 14 adult horses euthanized for reasons other than lameness, neck pain or ataxia. The specimens were from adult horses (5 geldings, 9 mares). Horses were estimated to weigh 420 - 650 kg. Specimens were obtained from 5

Thoroughbreds and 9 Irish Sport Horses. The necks were transected at the first thoracic vertebrae, with heads left intact, within 24 hours of death.

Procedure

Specimens were initially placed in right lateral position. The hair was clipped and the skin prepared for ultrasonographic examination. Cervical APJs were identified using either a linear high frequency (13 MHz) or a microconvex (10 MHz) ultrasound transducer[a]. The following variables were randomly selected for each joint (by coin toss): operator (authors XX or XX); approach (CrD or D); transducer type (linear or microconvex) and needle gauge (18 ga or 20 ga). A new randomisation procedure (coin toss) was performed for each ‘new’ joint; e.g. the combination of operator / approach / transducer type / needle gauge was randomly assigned for each individual joint, until every combination had been performed once on each joint. If a combination was obtained which had previously been performed, the coin was tossed again until a previously unperformed combination was obtained. Joints were injected sequentially from cranial to caudal, using a ~~a mixture of~~ 1.5 ml iodinated contrast material solution (Ioversol 300 mg/ml)[b] ~~and 0.5 ml of 1 % methylene blue solution~~[e]. Each joint was injected only once. For each injection the following parameters were recorded: time taken from needle touching skin to withdrawal of the stylet, number of redirection attempts, and whether synovial fluid was obtained on aspiration. Redirection was defined as withdrawal of the needle in order to alter its course. After injection of the APJs from C2 - C7 (5 APJs) on the left side were performed, the process was repeated in the contralateral (left lateral) recumbency. When APJs on both sides had been injected, computed tomography (CT) examination was performed.

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Dorsal approach to the cervical APJ

After identifying the APJ, the transducer was oriented perpendicular to the long axis of the neck. With dorsal to the right of the screen, the image was adjusted until the joint space was at its widest and most accessible. ~~Using a 'free-hand' technique a~~A spinal needle (9 cm, 18 or 20 ga) was introduced dorsal to the transducer along its long-axis into the joint space (Figure 1; Figure 2 (a)).

If the angle of approach of the needle did not match the joint angle, the needle tip would encounter bone, necessitating redirection of the needle. Once satisfied that the needle tip was seated in the joint, the stylet was removed and an empty 2 ml syringe was attached to the needle for aspiration to check for the presence of joint fluid. The ~~1.5 ml~~ contrast ~~/ dye mixture~~solution was instilled into the joint. If injection was met with resistance the needle was withdrawn marginally and/or rotated 180 degrees until no resistance was encountered. In the case of negative joint fluid aspiration, if the operator was satisfied that the needle tip was seated in the joint, the contrast solution was instilled into the joint. The stylet was replaced prior to withdrawal to minimise drag of injectate through the soft tissues.

Craniodorsal approach to the cervical APJ

Once the APJ was identified and the optimal image obtained (as described above), the transducer was rotated 45 degrees cranially (counterclockwise for the left side and clockwise for the right) and advanced cranially to visualise the cranial aspect of the APJ. The image was manipulated to visualise the joint space at its widest. ~~As above, a "free-hand" technique was employed, using a spinal needle (9 cm, 18 or 20 ga).~~ A spinal~~The~~ needle (9 cm, 18 or 20 ga) was inserted craniodorsal to the transducer (Figure 1) and directed under ultrasound control so that the angle of approach matched the joint angle, allowing the needle to pass freely into the joint space. Injection was performed as described above for the D approach (Figure 2 (b)).

Assessment of injection

CT images for all necks were acquired in lateral recumbency with the same multi-slice helical CT scanner[cd]. Scans were made in helical acquisition mode with a slice thickness of 6 mm and a pitch of 1.5. Technical settings were 120 kV, 280 Eff mAs, 0.75 s tube rotation time, a 455 mm field of view and a 512 × 512 matrix. The images were reconstructed at 3 mm slice width and a reconstruction increment of 2 mm at a high frequency reconstruction algorithm (WL 450 WW 1500).

Multiplanar reconstructions and two-dimensional image sequences were produced using commercially available DICOM viewing software[de].

~~Following CT examination, the specimens were dissected to facilitate examination of the distribution of the methylene blue injectate, and to compare its location with that of the contrast on CT.~~

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Data Analysis

The CT images were analysed individually by 4 authors (XX, XX, XX, XX) and then scored as a consensus. Each APJ was scored using the protocol found in Table 1 (see also Figure 3 (a) – (c)). ~~Specimen dissection was performed by a single, blinded, author (XX).~~ Scores, timings and number of redirection attempts were recorded for each of the 2 transducers utilised, operators performing the injection, for each approach, and both needle gauges.

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~~Dissection findings were assigned a score of 1 if methylene blue was seen intra-articularly within the APJ (‘hit’), or 0 if no methylene blue was seen within the APJ (‘miss’).~~

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Initial exploration of the data used summary statistics, univariable and bivariate plots. Association between the primary outcome of interest, CT score, and potential predictors was assessed using ordinal regression (treating the score as a ranked sequence) and linear regression (making the assumption that the scores were approximately evenly spaced on a scale). Scores were also dichotomised onto scores 1– 2 being a 'miss' and 3 – 64 a 'hit'. This outcome was analysed using logistic regression. In all regression models a random error term was included for the horse as multiple trials were conducted on each horse neckpelvis. Initial regression models included all potential predictor covariates in an aim to adjust estimates of associations of interest for variation in other covariates. Models were simplified by stepwise removal of covariates to minimise AIC (Akaike information criteria), a parameter-count penalised measure of model fit. Final significance of covariates was tested using a likelihood ratio test (LRT). Further multivariable models were used to assess the association between covariates and secondary outcomes including retrieval of synovial fluid (SF), time to complete the procedure and number of needle redirections. Poisson regression was used for the redirection count data and time was log transformed to produce normally distributed model residuals as time measurements were highly right skewed. Critical significance was set at $p < 0.05$. The R Statistical Software system was used for statistical analysis[ef].

Results

Fourteen neck specimens (140 APJs) were included in the study. Eight APJs were discarded: improper sectioning led to fractured caudal APJs in 2 and subcutaneous gas precluded ultrasonic imaging of caudal APJs in 6. One hundred and thirty two APJs were evaluated. Each APJ/needle gauge/transducer combination was injected by each operator at least once. Results of the CT scoring system are shown in Table 1. Table 2 summarises the number of injections performed for each APJ, laterality, needle gauge, transducer and operator. The proportion of intra-articular injections as seen on contrast CT is shown in the right-hand column as hit/miss.

One hundred and eighteen injections (89.4 %) were intra-articular, resulting in contrast seen within the APJ on CT. Synovial fluid was obtained on aspiration for 56 (42.4 %) of the injections, with no synovial fluid obtained in 76 (57.6 %). The mean time taken to perform the injections was 51.7 seconds (range 3-390 seconds, sd 51.45). The mean number of redirects for each injection was 2.6 (range 0-14, sd 2.01).

Ordinal regression showed that APJ site ($p = 0.013$) was significantly associated with injection score. In the ordinal regression model operator, transducer, approach, needle and laterality were not significant predictors of score and AJP site remained significant when these covariates were forced back into the final model. Interestingly, the C2-C3 articulation had the highest number of injection scores of 1 compared with the other articulations, with none of the C5-C6 articulations having an injection score of 1. AJP site alone was also the statistically significant predictor when score was treated as a numerical outcome ($p = 0.005$). Exploratory analysis suggested that operator was correlated with injection score. However operator was not a significant predictor of numerical or ranked score in the multivariable models. When correlation between needle gauge and the likelihood of achieving an injection score of 5 (i.e intra-articular with needle reflux) was assessed, no significant association was found ($p = 0.15$ LRT).

When injections scores were re-categorised as either a 'hit' (intra-articular contrast seen on CT, score ≥ 3) or 'miss' (no intra-articular contrast seen on CT, score ≤ 2), ~~facet~~ APJ ($p = 0.035$ LRT) and operator ($p = 0.046$ LRT) were found to have statistically significant effects.

Needle gauge was found to have a significant association with retrieval of synovial fluid (p = 0.013 LRT, SF retrieval less likely with 20 ga needle) and was the only significant predictor in the multivariable model of SF retrieval. The effect was robust to inclusion of ~~facet~~ APJ and operator in the model. Needle gauge was not found to have significant effects on time taken to perform injections (p = 0.47), thereby rejecting our null hypothesis that the 18 ga would have a faster injection time compared to the 20 ga. ~~h~~However, a higher number of needle redirects was associated with use of a 20 ga needle (p = 0.004).~~.~~

Use of the microconvex transducer ~~M~~ was associated with a significantly shorter procedure time (p = 0.03, 23% shorter time) and fewer redirects (p = 0.003, 28% fewer redirections), thereby partially confirming our null hypothesis that the microconvex transducer would result in improved accuracy and faster injection times, compared to a linear transducer.

Regarding the effect of approach, no significant effect was seen on either time taken to perform injections (p = 0.92) nor number of needle redirects (p = 0.16). These findings reject our null hypothesis that the CrD approach would result in higher injection accuracy.

The CrD approach, in combination with an 18 ga needle, and a linear transducer, was found to have the highest mean injection score both on raw numerical score (mean 4.84) (Table 3) and on numerical score using a multivariable ordinal regression model to correct for any effect of facet and operator.

The results were compatible with a positive learning curve for the inexperienced operator (XX) (see Figure 4). Overall, the experienced operator obtained an injection score of 3 or higher ("hit") on CT in 95.4 % of cases, whilst for the inexperienced operator, an injection score of 3 or higher ("hit") on CT was obtained in 83.6 % of cases.

Discussion

This study describes two ultrasound-guided approaches (D and CrD) to the craniodorsal recess of the cervical APJ of 14 equine cadavers and evaluated the success of injection on contrast CT. Taking the presence of intra-articular contrast material as a successful injection attempt, any injections scoring 3 or higher can be considered successful. By this definition, 89.7% of D approaches, and 89.0% of CrD approaches were successful, with the total accuracy for both approaches combined being 89.4 % (118 / 132 injections intra-articular on contrast CT). This study demonstrates the high level of accuracy of intra-articular cervical APJ injections performed via both the dorsal and craniodorsal approaches. This is a marked improvement on the previously reported success rate of 72 %, which may in part be attributable to more modern technology providing improved image quality (2). The CrD approach allowed the craniodorsal joint margins to be clearly visualised. This approach is advantageous as the angle allows visualisation of the needle as it enters the joint, passing between the dorsal articular APJs of the adjoining vertebrae (Figure 2 (c) & (d)). Conversely, when approaching the APJ from a D position the needle can be impeded from accessing the joint space by the angulation of the APJ, by periarticular osteophytes or a prominently positioned cranial APJ (Figure 2 (a) & (b). Thus it is possible that both the D and CrD approaches performed comparably in the present study as the specimens were pathology free, and that the CrD approach may be more accurate for injection of diseased APJs.

The accuracy of injection was not significantly different depending on the ultrasound transducer used, although use of the microconvex transducerr ~~r M~~ was associated with a 23%

shorter procedure time and 28% fewer redirects. Image quality was good for both transducer types for all included APJs. The results showed that injection of the C2-C3 articulation resulted in a greater proportion having a score of 1 (miss) (n = 7) compared to other APJs which had fewer scores of 1 (e.g. the C5-C6 articulations had no scores of 1). The more superficial location and steeper dorsoventral angulation of this C2-C3 articulation required an altered angle of approach, with less depth of tissue available for redirection of the needle. In addition, the joint outpouching of the C2-C3 articulation has been shown to have a smaller volume than the more caudal articulations (7). These anatomical characteristics unique to the C2-C3 articulation could explain the reduced accuracy observed at this site.

The authors subjectively found the 18 ga needle easier to visualise and redirect within tissue compared to the 20 ga, which may account for the higher number of needle redirects associated with the use of the 20 ga. Furthermore, the 18 ga needle was found to be significantly associated with the retrieval of synovial fluid. The authors had anticipated that the 18 ga needle would have a higher incidence of needle tract contrast reflux, however the results did not support this, finding no significant effect of the needle gauge on the likelihood of obtaining an injection score of 5. Therefore, the authors advocate the use of an 18 ga needle for ultrasound-guided injection of the cervical APJs.

Although the experienced operator obtained an injection score of 3 or higher ("hit") on CT in 95.4 % of cases, compared to 83.6% of cases for the inexperienced operator, it was not possible to draw conclusions regarding operator experience with only two operators involved in the study. Therefore it was not possible to accept nor reject the null hypothesis that "the learning curve would be steep for an inexperienced operator and that the experienced operator would be more accurate overall".

Cervical APJ injections are frequently undertaken in equine practice for investigation of clinical signs of neck pain, obscure forelimb lameness or neurological deficit(s) associated with the lower cervical region (1, 2). A response to corticosteroid injection is often used as confirmation of the diagnosis (1). To avoid misinterpretation of this response it is imperative that injections are accurate. The clinical importance of intra-articular versus periarticular injection for therapeutic efficacy has yet to be established. It has been speculated that periarticular deposition of corticosteroids in proximity to the joint may be sufficient to treat osteoarthritis (6). However, as joint effusion, capsular fibrosis and periarticular bone remodelling are implicated in the clinical signs and as the synovial response is proportionate to the dose of corticosteroid, intra-articular injection is preferable (1, 8, 9). In addition, site of injection may have a significant influence on anti-doping testing regimens for competition horses (10). Despite replacing the stylet prior to withdrawal of the needle in this study, 48 of 132 injections (36.4 %) scored a 5 suggesting that inadvertent periarticular deposition of some injectate may be unavoidable.

It is important to be aware of potential risks associated with this procedure, and measures available to minimise them. It is theoretically possible to push the needle all the way through the APJ, resulting in the needle contacting the nerve root ganglia, or deposition of injectate at the nerve root ganglia. Although epidural injection of corticosteroids has previously been described as a treatment for nerve root impingement caused by enlargement of cervical APJs, needle penetration resulting in traumatic injury to the nerve roots is possible and thus should be avoided (11). The CrD approach may be advantageous in this respect, avoiding both the dorsal and ventral rami of the cervical nerves [12, 13]. There is also a risk of inadvertent penetration of blood vessels in this area, for example the vertebral artery which lies ventral to the APJ (11, 12). Thus the authors recommend that the needle should not be advanced more than 1 cm following penetration of the joint capsule and to aspirate prior to injection.

As this was a cadaveric study, it did not directly simulate the conditions encountered when injecting a conscious, standing animal. However, the above described techniques are performed routinely in our hospital without complications. In a conscious animal, adequate plane of sedation and restraint are essential to ensure patient compliance.

Conclusion

Ultrasound-guided injection of the cervical APJs is an easily-learned technique. Given that high levels of accuracy can be achieved using either the D or CrD approaches, and with either the linear or microconvex transducers, this technique may be employed by the equine practitioner with equipment commonly used in the field.

Manufacturers' Details

[a]Sonosite M-Turbo, Bothwell, Washington, USA.

[b]Ioversol 300mg/ml; Mallinckrodt UK Commercial Ltd, Hampshire, UK.

~~[e] Merck KGaA, Damstadt, Germany.~~

[dc]SOMATOM Sensation 4, Siemens Healthcare GmbH, Germany.

[de]Osirix, Pixmeo, Geneva, Switzerland.

[fe] R Software, R Foundation for Statistical Computing, Vienna, Austria. URL https://www.r-project.org/.

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Figure 1: Image showing transducer position for dorsal and craniodorsal approaches relative to the long-axis of neck (represented by red line). The yellow line represents the transducer angle for the dorsal approach, at approximately 90° to the long-axis. The green line represents the transducer angle for the craniodorsal approach, at approximately 45° degrees to the long-axis. Relative needle positions for the two approaches are represented by the white asterisk.

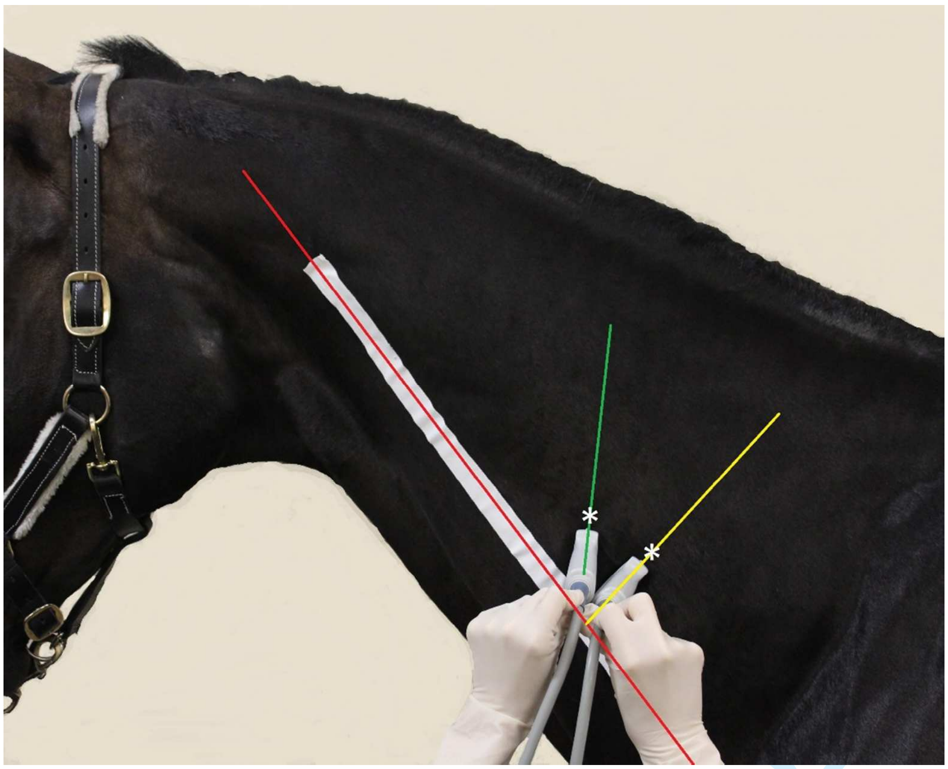

Figure 2 (a – d): Ultrasound images (a, c), and CT images (b, d) showing needles *in situ* for intra-articular injection of the cervical APJs. Ultrasound image (a) shows US-guided injection using the dorsal approach, an 18 ga needle (arrowheads), and a linear transducer, with the corresponding transverse CT image of a C2-C3 APJ (b). Ultrasound image (c~~b~~) shows US-guided injection using the craniodorsal approach, an 18 ga needle (arrowheads), and a microconvex transducer, with the corresponding transverse CT image of a C5-C6 APJ (d).

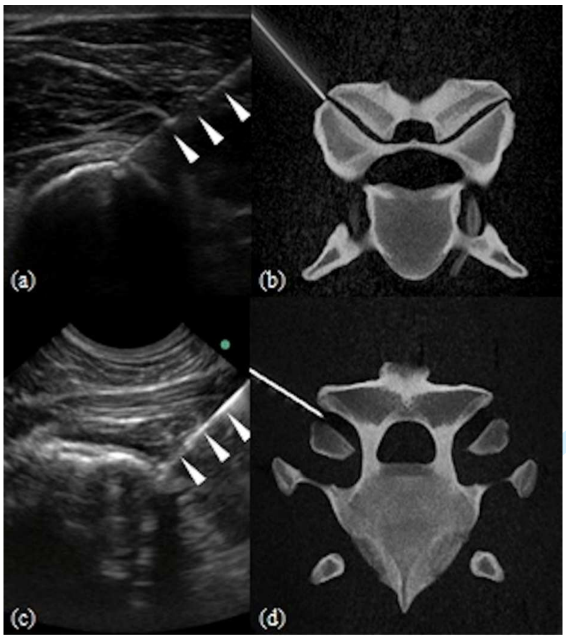

Figure 3 (a – c): Transverse contrast CT images depicting quantitative scoring system. Image (a) of a C4-C5 APJ, arrow demonstrates a Score 1, arrowhead a Score 3; image (b) of a C2-C3 APJ, arrow demonstrates a Score 2, arrowhead a Score 6; image (c) of a C3-C4 APJ, arrow indicates a Score 4, arrowhead a Score 5.

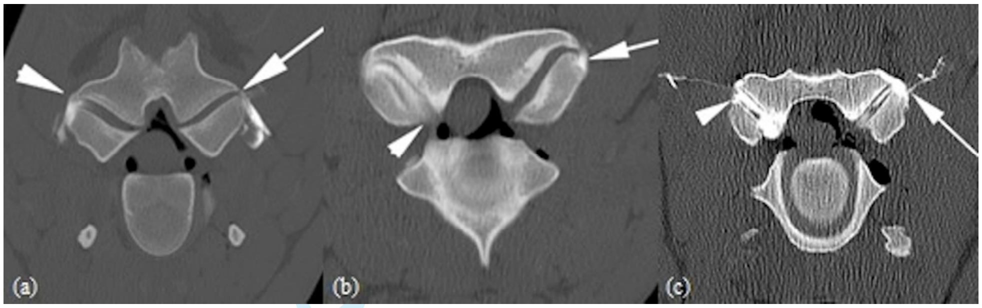

Figure 4: Graph depicting learning curves of both experienced (XX) and inexperienced (XX) operators, as shown by mean score (and SEM) obtained by each operator for each consecutive neck specimen (horse number).

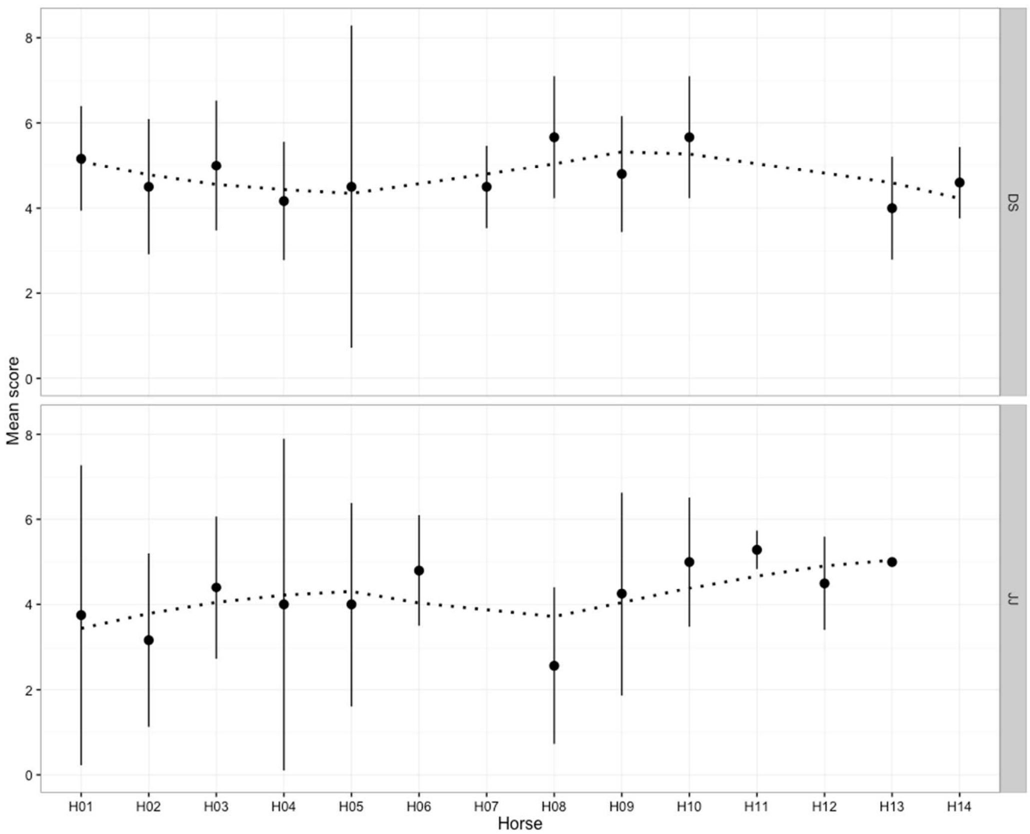

Figure legends

Tables

Table 1. Contrast CT quantitative scoring system for evaluation of injection accuracy, with categorical ‘hit’/’miss’ categories shown for each score (‘hit’ if contrast intra-articular on CT, ‘miss’ if no contrast intra-articular), and number of injections obtained for each score.

Score	Description	Hit/Miss	Number of injections
6	All intra-articular	Hit	38
5	Intra-articular with needle reflux	Hit	48
4	Intra-articular & intra-capsular	Hit	5
3	Intra-articular, intra-capsular & extra-capsular	Hit	27
2	Intra-capsular & extra-capsular	Miss	1
1	All extra-capsular	Miss	13

Table 2. Number of injections and proportion of ‘hit’/’miss’ (‘hit’ if contrast intra-articular on CT, ‘miss’ if no contrast intra-articular) for each articular process joint (APJ), laterality, needle gauge, operator, transducer (linear or microconvex; L or M, respectively) and approach (dorsal or craniodorsal; D or CrD, respectively). each APJ, laterality, needle gauge, operator, transducer and approach.

		Number of Injections Performed	**Contrast CT (Hit/Miss)**
APJ	**C2-C3**	28	21/7
	C3-C4	33	31/2
	C4-C5	32	29/3
	C5-C6	18	18/0
	C6-C7	21	19/2
Laterality	**Left**	66	58/8
	Right	66	60/6
Needle gauge	**18**	66	61/5
	20	66	57/9
Operator	**XX**	65	62/3
	XX	67	56/11
Transducer	**L**	65	56/9
	M	67	62/5
Approach	**D**	68	61/7
	CrD	64	57/7

Table 3. Mean contrast CT scores for the eight highest-scoring combinations of approach (CrD and D; craniodorsal and dorsal, respectively), needle gauge, and transducer (L and M; linear and microconvex, respectively).

Approach	**Needle Gauge**	**Transducer**	**Mean Score**
CrD	18	L	4.84
D	18	M	4.65
CrD	18	M	4.54
CrD	20	M	4.50
D	18	L	4.24
CrD	20	L	4.21
D	20	M	4.21
D	20	L	4.13