TREAT-NMD Activity A07: Accelerate preclinical phase of new therapeutic treatment development

Work package 7.4: Develop standardised protocols and procedures for harmonising and accelerating pre-clinical studies (including standardised data analysis)

SOP Title  Measuring Isometric Force Decrement after Eccentric Contraction in Vivo

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1. OBJECTIVE

Dystrophin serves to buttress the muscle cell membrane. In the absence of dystrophin, the membrane is prone to tearing during minimal exercise. Dystrophic muscles are particularly prone to injury subsequent to eccentric (lengthening) contractions.\(^1\) As an example, mdx mice have near-normal absolute force measurements but demonstrate greater-than-normal force decrement after eccentric muscle contractions.\(^2\) We have previously shown that GRMD dogs also have a greater-than-normal force decrement with eccentric contractions.\(^3\)

2. SCOPE AND APPLICABILITY

As discussed in the GRMD tibiotarsal joint force protocol, phenotypic variation in affected dogs confounds statistical analysis, necessitating larger group sizes to show significance. With localized treatments, the effect of phenotypic variation is less of a concern because the untreated opposite limb can serve as the control. With systemic treatments, baseline measurements should be established prior to treatment so that each dog serves as its own control. Evaluation of the force decrement incurred due to eccentric muscle contraction offers another option by which each dog can be used as its own control.

3. CAUTIONS

Dogs must be anesthetized. A nerve stimulator, specialized, custom-made stereotactic frame, and servomotor are required. See METHODS and EVALUATION AND INTERPRETATION OF RESULTS (below) for guidance on interpretation.

4. MATERIALS

Separate personnel are utilized for anesthetic management and force measurements. Dogs are anesthetized and positioned in dorsal recumbency with one of the pelvic limbs placed in a custom-made stereotactic frame such that the hip (coxofemoral), knee (stifle), and hock (tibiotarsal) joints are all at 90° angles (see GRMD tibiotarsal joint force protocol and Figure 1). In an initial study, eccentric contractions were induced in flexor muscles of the cranial tibial compartment by stimulating the sciatic trunk in the mid-thigh area.\(^3\) This caused contraction of both the tibiotarsal joint flexors and extensors. Because the extensors are more powerful, eccentric (lengthening) contractions were induced in the flexors.
More recently, we have developed a technique whereby the common peroneal nerve is stimulated while simultaneously extending the tibiotarsal joint with a servomotor (Aurora Scientific, Ontario, Canada) coupled to a lever arm. The servomotor extends (lengthens) muscles of the cranial tibial compartment. Movement of the lever arm is controlled by use of a computer and customized LabView software (Aurora Scientific). Before beginning the experimental contractions, isometric forces from single twitches are measured. The common peroneal nerve is stimulated with optimally-positioned percutaneous electrodes (Model S48 Solid State Square Wave Stimulator, Grass Instruments, Quincy, MA, USA). Voltage is adjusted until twitch force \( (P_t) \) reaches a maximum. To maximally activate the muscles of interest, stimulation voltage is 50% greater than necessary to achieve \( P_t \). Stretches are performed 10 times, once every 5 sec. Following a 4 minute rest, the series of 10 stretches is repeated. Thus, the muscles of the cranial tibial compartment are repeatedly stretched to induce mechanical damage.

5. METHODS

1. Anesthetic protocol (Note, in a preliminary study, mean alveolar concentration [MAC] values for isoflurane did not significantly affect force measurement values [Schueler RO, Koch J, Kornegay JN, unpublished data]).

20-30 minutes prior to anesthesia induction:
- Pre-anesthetic agents:
  - Atropine sulfate (0.04 mg/kg, IM)
  - Acepromazine maleate (0.02 mg/kg, IM) for dogs weighing greater than 5 kg
  - Butorphanol tartrate (0.4 mg/kg, IM)

Anesthetic induction:
- Anesthetic agents:
  - Propofol (up to 3 mg/kg, IV – slowly!) for dogs weighing greater than 5 kg
  - Isoflurane or sevoflurane (to effect, inhaled) (avoid masking down)

Anesthetic monitoring:
  During anesthesia, ECG, heart and respiratory rate, blood pressure, end tidal \((E_t)\text{CO}_2\), and saturation of hemoglobin by peripheral oxygen \((\text{SpO}_2)\) are monitored continuously with a pulse oximeter (Cardell Multiparameter Monitor 9405, Minrad International, Inc, Orchard Park, NY). These values, as well as capillary refill time and anesthetic setting, are recorded every 15 minutes.

Anesthetic recovery:
  Monitor affected and carrier dogs closely during anesthetic recovery until fully awake and in sternal recumbency.
  - Naloxone (up to 0.4 mg/kg, SQ) for rapid recovery; given in ½ dose increments \((1^{st} \text{ dose given while the dog is still intubated and breathing } \text{O}_2; 2^{nd} \text{ dose, if necessary, after extubated and/or if respiration drops below 7 breaths per minute})\)
2. Position the dog in dorsal recumbency.

3. Measure the tibiotarsal joint angle (see SOP D.2.2_003 Measuring Tibiotarsal Joint Angle to Assess Contractures In Vivo).

4. Calibrate the force transducer before each measurement.

5. Place one of the pelvic limbs in a stereotactic frame such that the hip (coxofemoral), knee (stifle), and hock (tibiotarsal) joints are all at 90° angles (see GRMD tibiotarsal joint torque force protocol).

6. Palpate the common peroneal nerve just distal to the head of the fibula as it courses across the bone. Paired stimulating and reference 27-gauge monopolar needle electrodes are placed subcutaneously on either side of the nerve (Figure 1A). The electrodes are optimally positioned and the voltage is adjusted until twitch force (Pt) reaches a maximum. To maximally activate the muscles of interest, stimulation voltage is 50% greater than necessary to achieve Pt (generally, supramaximal pulses of 150 V are applied). An electromyography (EMG) unit (TE42, Teca Corp, Pleasantville, NY, USA) can be used to record electrical activity in tibiotarsal joint flexor muscles (cranial tibialis and long digital extensor) to ensure proper needle placement. Eccentric contractions are induced using square wave pulses of 100 μsec duration in a tetanic run for 1 sec at a frequency of 50 Hz. The contraction is held isometric at the optimal fiber length (Lo) for the first 900 msec. In the final 100 msec, the muscles of the cranial tibial compartment are stretched by the servomotor at a rate of 0.7 muscle lengths/sec, such that the muscles are stretched to 107% of Lo. Stretches are performed 10 times, once every 5 sec. Following a 4 minute rest, the series of 10 stretches is repeated. Thus, the muscles of the cranial tibial compartment are repeatedly stretched to induce mechanical damage. Force is recorded by the computer software. Contraction-induced injury is quantified by the force deficit (Pd), which is defined as the percent difference between maximum isometric force (Po) before and after exercise (in this case, eccentric stretches). Force deficit is expressed as a percent change of the initial value of Po, using the following equation:
6. EVALUATION AND INTERPRETATION OF RESULTS

Based on results from mdx mice, we expect that GRMD dogs will have a greater decrement in force following eccentric contractions of muscles of the cranial tibial compartment. Preliminary findings suggest that GRMD dogs may exhibit as much as an 85% decrement following 10 stretches (Figure 1). This contrasts with a force deficit of only 13% following two sets of 10 eccentric contractions in a normal dog. However, data must be collected systematically from normal and dystrophic dogs and correlated with histologic markers such as Evans blue dye exclusion before definitive conclusions can be drawn.

Potential Advantages/Disadvantages of the Methodology

Advantages
As with the tibiotarsal joint force method, this technique allows serial, non-invasive evaluation of contractile force. The effects of phenotypic variation are offset because the force decrement is individualized for each dog.

Disadvantages
Instrumentation is more expensive and must be customized. Muscles of the cranial tibial compartment may undergo functional hypertrophy subsequent to initial injury. Thus, it is not clear that functional test results will accurately predict overall response to treatment.

Force deficit ($P_d$) = $[P_o - P_{o\ after\ stretch}/P_o] \times 100$
7. REFERENCES

muscles from mdx mice to damage induced by contractions with stretch. J MusRes
3. Childers MK, Okamura CS, Bogan DJ, Bogan JR, Petroski GF, McDonald K,