Two-Phase Protocol for Dupuytren's Contracture Management: Cord Thermal Weakening & Release (CTWR) with Adjuvant Radiotherapy (CTWR-AR)

Lev Neymotin, PhD
N5Digital, Inc.

Abstract
This paper proposes a **two-phase integrated treatment protocol** for Dupuytren's contracture that combines **Cord Thermal Weakening & Release (CTWR)** — a targeted, ultrasound-guided heating technique to mechanically neutralize contractile cords — with **Adjuvant Radiotherapy (CTWR-AR)** — a post-release low-dose radiotherapy protocol to suppress myofibroblast activity and reduce recurrence risk. CTWR offers precise, immediate, single-session cord release without the immune or spread risks of enzyme injection, while CTWR-AR adds biological control of disease progression. A detailed procedural description for each phase is presented, followed by a comparative review of CTWR against standard collagenase injection.

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1. Background & Rationale
Dupuytren's contracture is a chronic fibroproliferative disorder of the palmar fascia involving abnormal myofibroblast activity and collagen deposition. Cords shorten over time, causing finger flexion deformity. Current treatments — surgery, percutaneous needle fasciotomy, collagenase injection (CCH), and early-stage radiotherapy — each have limitations:

- **Surgery**: Effective but invasive; long recovery; recurrence 20–50%.
- **CCH injection**: Minimally invasive but costly; recurrence up to 50% in 3–5 years; risk of skin tears, tendon rupture, allergic reaction.
- **Early-stage radiotherapy**: Effective in preventing progression, but rarely used once contracture is established.

The proposed two-phase approach is designed to:

1. **Mechanically eliminate contracture** in any stage by precision heating and rupture (CTWR).
2. **Biologically suppress residual fibroblast activity** to prevent recurrence (CTWR-AR).

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2. Phase 1: Cord Thermal Weakening & Release (CTWR) Protocol
Purpose
To selectively weaken Dupuytren's cord collagen by controlled heating to ~65–70 °C for 5–10 s at depth, immediately followed by mechanical manipulation to rupture the cord with minimal collateral injury.

Patient Selection

- Moderate to severe contracture with well-defined cords.
- Exclude patients with:
    - Local infection over the treatment site.
    - Severely compromised skin quality over the cord.
    - Severe neuropathy or ischemia of the hand.

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3. Equipment Options
Heating Probes / Energy Sources — must allow *precise, localized heating* at target depth:

1. **Radiofrequency (RF) probe** — monopolar or bipolar; built-in thermocouple for real-time temperature control.
2. **Microwave ablation antenna** — rapid collagen heating; often water-cooled to protect skin.

3. **Diode laser fiber** (1470 nm, 200–400 µm) — tuned to collagen absorption; can be introduced via fine needle.
4. **High-Intensity Focused Ultrasound (HIFU)** — *experimental*; non-contact heating limited by hand anatomy and bone shadowing.

Guidance: High-frequency linear ultrasound (12–18 MHz) for precise cord targeting and safety. Portable MSK ultrasound units are widely available and **not excessively expensive**, often costing less than a high-end laptop.

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4. Targeting & Guidance

Ultrasound guidance means the operator visualizes the cord and the probe tip in *real time* on the screen:

- Cord: appears as a bright, fibrous band.
- Probe tip: visible as a bright dot/line.
- Guidance allows precise positioning within or alongside the cord, avoiding nerves, vessels, and tendons.

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5. Pre-Procedure Preparation

1. **Anesthesia**: Local infiltration or digital nerve block without epinephrine.
2. **Cord tensioning**: Gentle extension via splint or assistant to make cord taut.
3. **Sterile prep**: Antiseptic solution; sterile gel/probe cover for ultrasound.

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6. Heating Phase

Goal: Achieve irreversible collagen denaturation at ~65–70 °C for 5–10 s in the cord's core.

Steps:

1. **Cord localization**: Trace entire cord on ultrasound; choose thickest, tightest segment for heating.
2. **Entry planning**: Select site for straight access while avoiding critical structures.
3. **Local anesthesia**: Infiltrate just above cord.
4. **Device insertion under ultrasound**: Advance probe/fiber to cord midpoint; tip visualized continuously.
5. **Tissue separation if needed**: Hydrodissect with saline if nerve/vessel proximity is <3 mm.
6. **Controlled heating**:
    - RF: 65–70 °C for 5–10 s.
    - Microwave: low-power pulse ~5 s.
    - Laser: short pulses totaling 5–8 s.
    - Thermometry used if available; otherwise follow calibrated power-time curves.
7. **Monitoring**: Watch for cord shrinkage, echotexture change; stop if sharp radiating pain occurs.
8. **Probe removal**: Under ultrasound, confirm no bleeding or tissue irregularity.

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7. Immediate Manipulation Phase

- Immediately extend treated finger(s) to rupture the now-brittle cord.
- If rupture is incomplete, repeat heating at remaining segment(s).

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8. Post-Procedure Care

- Light dressing for 24 h.
- Begin gentle motion exercises within 1–2 days.
- **Optional**: Proceed to CTWR-AR within 1–2 weeks for recurrence prevention.

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9. Safety Measures

- Maintain ≥3 mm clearance from neurovascular structures.
- Avoid skin temp >45 °C; stop if deep pain persists after heating.

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10. Documentation & Monitoring

- Record pre/post joint angles.
- Document device type, power, duration, temperature.
- Follow-ups: 1 week, 1 month, 3 months, 1 year.

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3. Phase 2: Adjuvant Radiotherapy After CTWR (CTWR-AR)

Purpose

To destroy residual active fibroblasts/myofibroblasts in the treated fascia, reducing recurrence risk.

Indications

- Completed CTWR with full or partial rupture.
- High-risk for recurrence (multiple nodules, early onset, aggressive history).

Timing

Start **7–14 days** after CTWR — inflammation subsides but fibroblasts remain in radiosensitive phase.

Radiation Modality

- **Orthovoltage X-rays** (120–150 kV) — standard in Europe.
- **Electron beams** (3–6 MeV) — depth-tuned to fascia.

Field Definition

- CTWR-treated zone plus 1–2 cm margin.
- Shield non-target fingers/wrist.

Dose & Fractionation

- **Total**: 30 Gy in two identical series.
- **Series 1**: 5 × 3 Gy (Mon–Fri).
- **Interval**: 6–12 weeks.
- **Series 2**: Repeat 5 × 3 Gy.

Procedure Steps

1. **Consultation**: Review CTWR outcomes, skin status, explain RT goals.
2. **Simulation & Planning**: Hand positioned flat, immobilized in thermoplastic mold; field defined with lead cutouts or electron applicator.
3. **Delivery**: Orthovoltage: 1–2 min/session; Electron beam: 2–3 min/session.
4. **Between series**: Maintain gentle stretching; monitor acute reactions.

Biological Effects

- DNA damage → loss of fibroblast replication.
- Cytokine modulation → reduced inflammation.
- Fibroblast senescence → stable, non-contractile cells.

Side Effects

- **Acute**: Mild redness, dryness, itching.
- **Late**: Hypopigmentation, skin thinning, telangiectasia.
- **Rare**: Secondary skin cancer (<0.5% lifetime risk in older adults).

Monitoring

- Weekly during treatment.
- At 6 weeks, 6 months, 1 year, then annually ×5 years.

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4. Comparative Review: CTWR vs Collagenase Injection (CCH)

Precision & Control

- **CTWR**: Direct ultrasound visualization and heating confined to cord.
- **CCH**: Palpation-based injection; enzyme spread less controllable.

Single-Session Efficiency

- **CTWR**: Cord weakened and ruptured same day.
- **CCH**: Requires return visit 1–2 days later.

Risk Profile

- **CTWR**: No immune reactions; minimal swelling.
- **CCH**: Allergic reaction risk; frequent swelling/bruising; rare tendon rupture.

Cost

- **CTWR**: Capital device + low-cost disposables.
- **CCH**: Proprietary enzyme ~$3–4k/vial in US.

Recurrence Prevention Integration

- **CTWR**: CTWR-AR planned seamlessly from Phase 1 ultrasound mapping.
- **CCH**: Radiotherapy possible but requires separate mapping.

Summary Table:

Feature	**CTWR**	**CCH**
Mechanism	Collagen denaturation & rupture	Collagen enzymatic cleavage & rupture
Guidance	Ultrasound, precise	Mostly palpation
Time to rupture	Immediate	1–2 days
Sessions	One	Two
Immune risk	None	Present
Swelling/bruising	Minimal	Common
Cost per treatment	Low consumable	High drug cost
Recurrence control	Integrates with CTWR-AR	Needs separate planning

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5. Potential Impact

The CTWR + CTWR-AR protocol could:

- Provide precise, controllable release in all stages.
- Minimize systemic risk and skin/tendon injury.
- Reduce recurrence via combined mechanical and biological control.
- Offer cost-efficient long-term management.

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6. Next Steps

1. **Bench & cadaver testing** — validate heating parameters, safety margins.
2. **Pilot clinical trial** — compare CTWR-AR vs CCH in moderate/severe cases.
3. **RCT** — evaluate recurrence rates, function, patient satisfaction.