THERMAL MASSAGING TOURNIQUET

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OBJECTIVE & MOTIVATION

This project aims to develop a thermal, massaging tourniquet to improve vein dilation for peripheral intravenous (PIV) access, optimizing success in pediatric and small-vein cases by mitigating risks of failed attempts and automating proven venodilation techniques.

BACKGROUND

Peripheral intravenous (PIV) insertion treats a range of conditions by delivering fluids and medications into the bloodstream. A **tourniquet** constricts blood flow and aids vein access, but non-standardized techniques like **heat** and **massage** are often used in conjunction for hard-to-access veins. Failed attempts cause pain, anxiety, and delays, with pediatric and small-vein patients at higher risk of distress and complications.

DESIGN REQUIREMENTS

PERFORMANCE

Requirement	Target
Blood Flow Constriction	40–90 mmHg
Increase in Vein Cross-Sectional Area	~ 37 %
Vein Depth From Skin Surface	0.3–1.5 cm
Vein Access Area	2 cm^2

QUALITY

Requirement	Target
Product life	7 years
Usage duration	15 min

SAFETY

Requirement	Target
Temperature limit	98.5–122 °F

COST

Requirement	Target
Prototype budget	200 USD

DESIGN DESCRIPTION

DEVICE COMPONENTS

(1) SLEEVE MOUNT
Secures the arm in position with foam-padded supports, ensuring stability and comfort

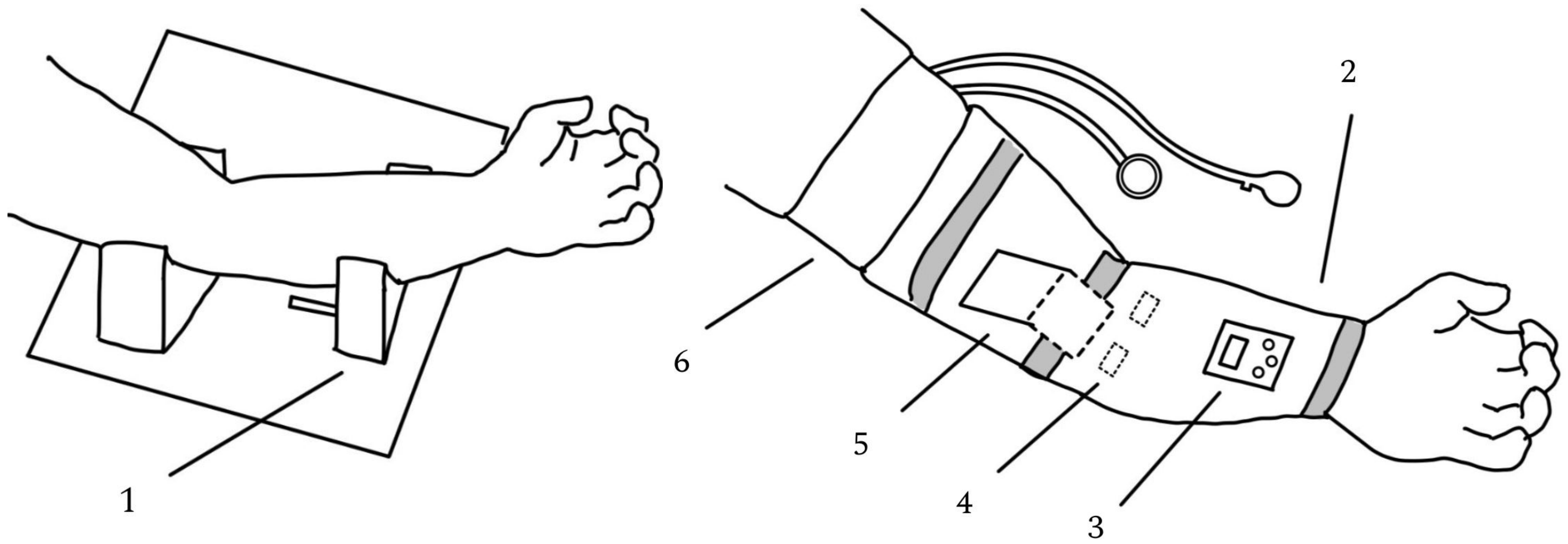
(2) EXTERIOR SLEEVE
Made of nylon and spandex for durability, flexibility, and hypoallergenic properties

(3) CONTROL & POWER SOURCE
Features an on/off switch and separate buttons for heat and massage, allowing independent activation for precise control

(4) MASSAGING MOTORS
Provides targeted vibration below the vein access region

(5) HEATING FILAMENT
Delivers safe, controlled heat embedded above the cubital fossa

(6) TOURNIQUET CUFF
Applies compression using a durable and adjustable blood pressure cuff



DESIGN EVALUATION

VENODILATION OPTIMIZATION USING HEAT, VIBRATION, AND COMPRESSION

INTRODUCTION

Assess various combinations of heat, vibration, and compression to identify the optimal technique that produces the largest increase in vein size and enhances venodilation.

METHODS

Test 1: Control
Test 2: Tourniquet only
Test 3: T, Heat (5 min)
Test 4: T, Massage only
Test 5: T, M, Heat (5 min)
Test 6: T, M, Heat (10 min)

APPARATUS

Ultrasound imaging, tourniquet, heat pack, and massage gun

RESULTS AND DISCUSSION

Software was used to estimate the cross-sectional area by detecting color changes and mapping the vein circumference in *Figure 1A*.

The results in *Figure 2* indicate that the optimal test condition is a combination of a tourniquet, heat, and massage, where the vein dilated by **67.5%** compared to the tourniquet only.

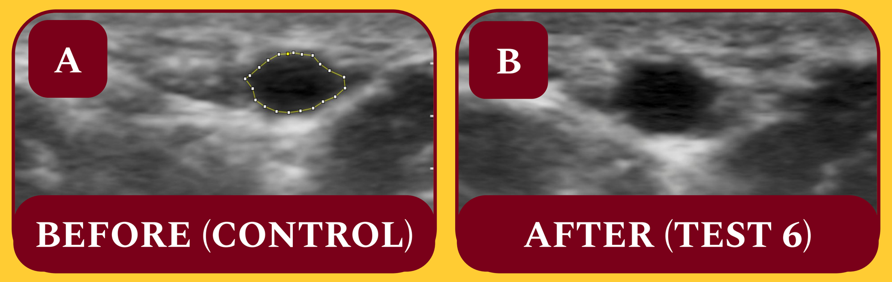


FIGURE 1 Comparison of control (*A*) and Test 6 using tourniquet, heat, and massaging (*B*).

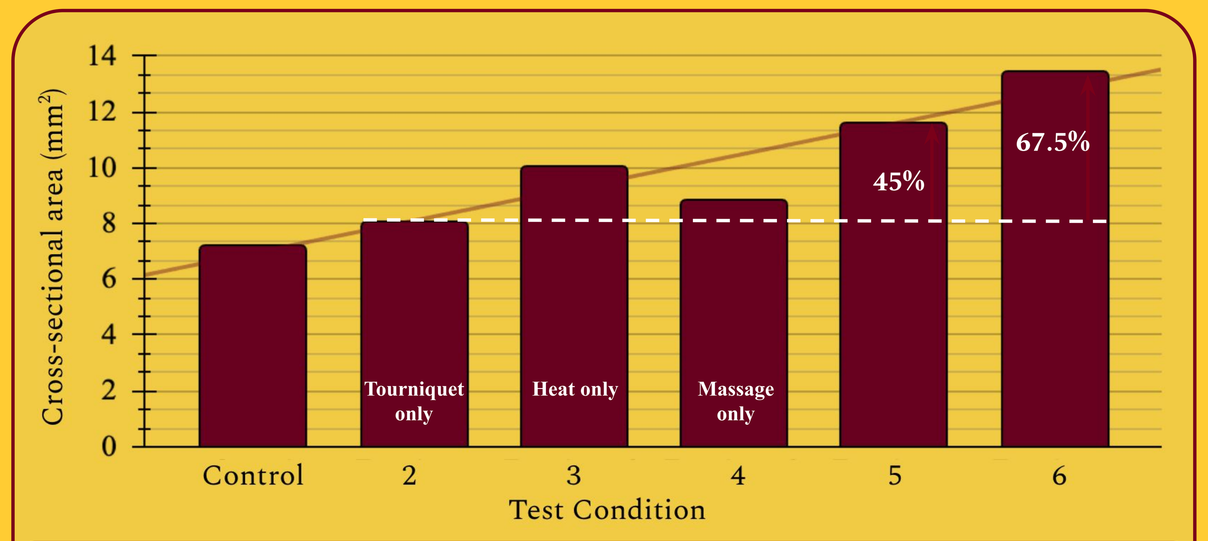


FIGURE 2 Cross-sectional area of the cephalic vein for each test condition as described in *METHODS*.

PERFORMANCE TESTING OF THE PROTOTYPE THERMAL MASSAGING TOURNIQUET

INTRODUCTION

Evaluate the performance of the prototype thermal massaging tourniquet in achieving venodilation and validate its design requirements.

METHODS

Test the prototype on three settings: 5, 10, and 15-minute operation
Ultrasound imaging was used to record vein dilation.

RESULTS AND DISCUSSION

Results show that the **10-minute heat** setting was optimal for venodilation, as the 15-minute test yielded less vein dilation. The prototype achieved a **50.9%** increase in cross-sectional vein area, exceeding the performance target at **37%**. The 15-minute setting provides flexibility for situations where additional time is required during PIV preparation or in cases of delayed insertion.

FIGURE 3 Comparison of 5, 10, and 15-minute heat setting on the prototype.

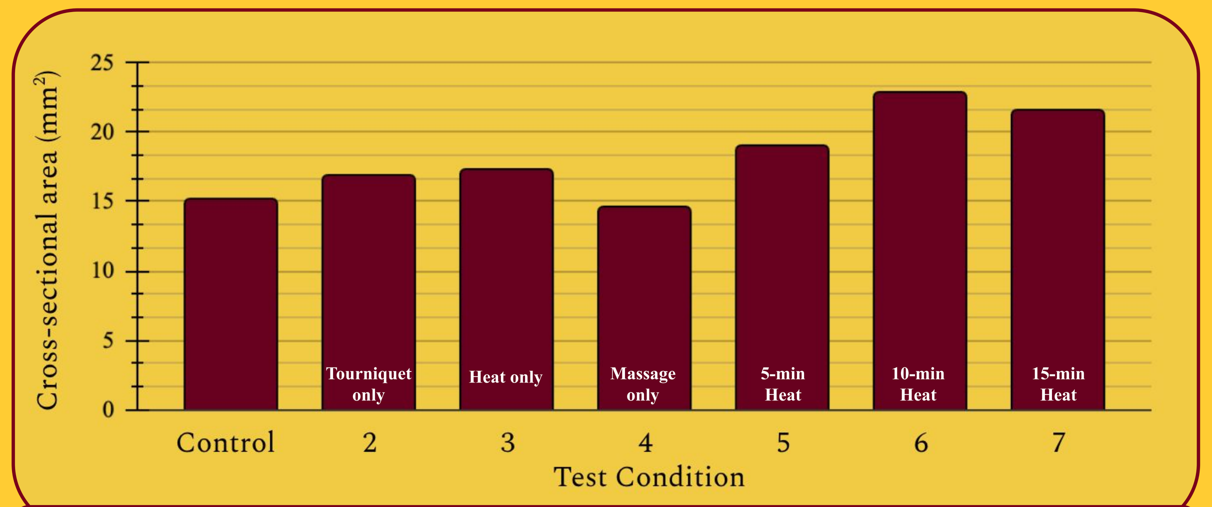


FIGURE 4 Cross-sectional area of the cephalic vein for each test condition

HEAT FLOW SIMULATION: 2D TRANSIENT CONDUCTION TO A VEIN

INTRODUCTION

Simulate the cross-sectional transient heat flow in the arm at the venous injection site, focusing on how heat propagates through various layers of tissue and interacts with the cephalic vein.

METHODS

- Model of heat flow to cephalic vein
- 2D boundary conditions: constant surface & body temperature
- Thermal properties: epidermis, dermis, and hypodermis layers

RESULTS AND DISCUSSION

Figure 5 shows that the cephalic vein reached **43°C (109°F)** after **5 minutes**. This simulation is relevant for ensuring the **safety** and **efficacy** of the tourniquet device. It helps define a safe temperature range and duration of heat exposure that would be required to obtain venodilation, as desired.

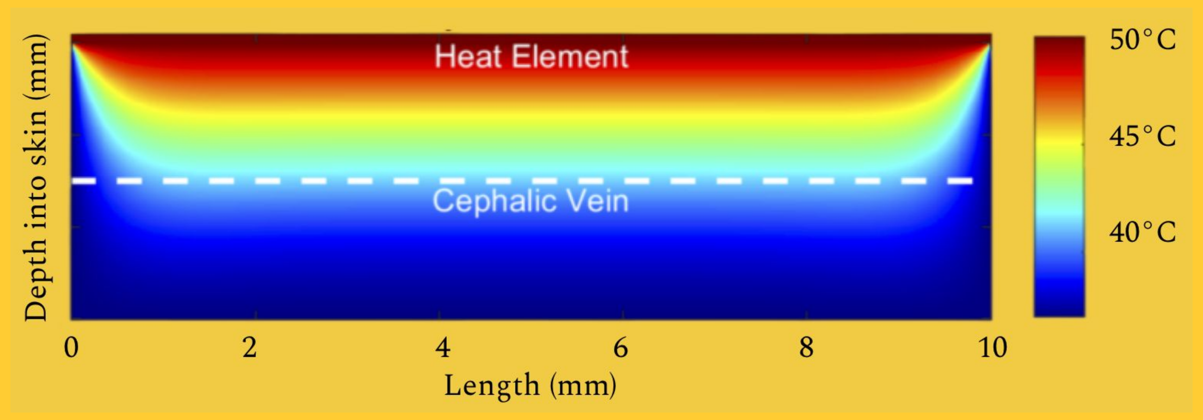


FIGURE 5. Final temperature distribution of the skin at 5 minutes of maintaining constant surface temperature from the heating filament.