Comfort Cast

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Abstract
During the four to twelve weeks that patients wear orthopedic casts, the limb contained develops an aggravating itch. The itching is a direct response to the lack of airflow and buildup of body salts and dead skin under the cast. Existing technologies to alleviate itching can deliver or pull air through the cast but none are widely used because they are not lightweight, portable or handheld. The proposed design concept, Comfort Cast, consists of a perforated sleeve worn prior to the casting of the injured limb and an external air source that does not require the use of a power outlet. The aerating sleeve is made of heat-sealed polyethylene sheets with air channels and small perforations that will be wrapped around the patient’s limb. The external gas source consists of a high pressure CO$_2$ gas tank with an adjustable flow knob. Supporting data and analysis show that this inexpensive system effectively reduces the moisture in the cast environment by injecting gas flow under the cast to deliver cooling itch relief to the patient. In the future, this design will be tested on an actual patient to gain more support from orthopedic professionals and the prospective users.

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Figure 1 - Comfort Cast
The Need for Project

Each year, over 6.8 million Americans are treated for bone fractures using orthopedic casts. Most of the people that wear casts for these injuries develop uncomfortable itches caused by lack of airflow and buildup of moisture under the cast. (Rep 1.1) The goal of this Capstone research project is to design a device that will inject gas flow under the cast to deliver cooling itch relief to the patient. The benefits of this design solution will be its full integration into the existing cast. The system is composed of two major parts: an aerating sleeve worn prior to casting and an external gas supply unit. The early integration system will deliver a cool, even flow of gas under the cast to reduce the moisture in the environment therefore minimizing skin breakdown, which is the primary cause of itching.

The Design Project Objectives and Requirements

Design Objectives

This project focuses on the design of a lightweight, hand-held, device that can eject a stream of gas to provide a steady flow of cooling relief to a casted patient as shown in Figure 3. The key objective is to evenly distribute the cooling gas over the casted limb until the itching sensation is relieved. (Rep 2.2) The proposed design solution, called Comfort Cast will be completely portable. The device must also be applicable for a multitude of cast geometries.

Design Requirements

The system will weigh no more than 5 lb. in total. Due to the limited intra-cast space—approximately 0.3 in. between limb and the cast inner diameter—the perforated sleeve must be extremely thin yet flexible, durable and comfortable. (Rep 1.2) The gas source cannot require electrical power, and must be small enough to be incorporated into a handheld housing. For the patient’s safety, the source must be regulated such that the flow entering the air sleeve falls within the cooling range of 20 – 60 LPM.

The amount of time required for gas flow to cool a limb is predictably arbitrary. Each person has different levels of skin sensitivity and irritability. Therefore, the product must be over-engineered to fit the needs of those at either end of the spectrum. At minimum, the gas source should easily supply cooling flow for up to 2 minutes.
Design Concepts Considered

After developing several prototypes, three final bladder designs were chosen for further refinement and final testing. Compressed CO₂ tanks met all requirements needed for the air source.

Figure 4 - Tube Design

Tube Design

The first concept involves a sleeve with several perforated tubes placed on the broken limb prior to casting as shown in Figure 4. The tubes run parallel to the limb and connect to gas distributing cuffs at each end. (Rep 6.2.1) One cuff is fitted with a barbed connection to provide easy connectivity to a gas source. The sleeve is then wrapped in a soft, stretchable material that will allow the user to feel comfortable for an extended period of wear. Although the hole size and spacing were varied to determine the optimal design, no further prototypes were created due to poor performance of the overall design.

Bladder Design

The second concept is a sleeve constructed from two layers of polyethylene that are heat-sealed together. Multiple channels are for a very thin membrane to be created for an under cast application as shown in Figure 5. The sleeve is fitted with an inlet tube that can be easily connected to a gas source when needed. Several prototypes of this design were created by varying hole size & spacing, channel width, and overall dimensions. (Rep 6.2.2) After further testing it was determined that heat-sealing a porous fabric into each channel helped the airflow drastically. As idealized in concept one above, the sleeve will be wrapped in a soft, stretchable material allowing for full user comfort. Based on performance and comfort, only three final prototypes were kept for further refinement and testing.

Gas Source

To provide the user with cooling itch relief a high pressure gas source is needed to push gas into the thin area between the skin and cast. Small electric air pumps were unable to provide adequate flow to either of the two sleeve designs due to their inability to overcome high pressure gradients. Compressed gases such as oxygen, helium and nitrogen were ruled out due to safety and availability reasons. As a result, compressed CO₂ was considered due to its available high pressure and small size. (Rep 6.2.3) The compressed CO₂ also provides a cooling effect as it is released into the atmosphere. Two initial sizes of CO₂ tanks were chosen for initial testing; a 4 oz. tank to serve as a travel option and a larger 20 oz. tank for in-home use as shown in Figure 6.

Figure 5 - Bladder Design

Figure 6 – CO₂ Assemblies
**Recommended Design Concept**

Concealed CO₂ gas canister connected to a perforated polyethylene bladder to evenly distribute flow under the cast.

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**Design Description**

The final design selection for the sleeve prototype is constructed from two sheets of 4 mil thick polyethylene plastic that have been heat sealed into separate channels for even flow. The sleeve layout has 7 evenly spaced flow distribution channels that run parallel to the limb with a single distribution channel that runs perpendicular. (Rep 8) In these channels, there is a ¼” thick vinyl sponge material to prevent unintentional blockages and set the initial cast spacing. A tapered design contours to the arm geometry and will be available in varying sizes to fit all patients as seen in Figure 7. A vinyl inlet tube is sealed into the bladder using a two part epoxy.

The second half of the design consists of a cylindrical housing which contains a 4 oz. compressed CO₂ canister, a pressure regulator with a barbed outlet port and an adjustable knob to control the gas flow as seen in Figure 8. The user may connect the gas hose from the unit’s barbed outlet port to the air sleeve and administer a cooling gas flow by rotating the adjustable flow knob. An additional design which utilizes a 20 oz. CO₂ canister has also been implemented for a less portable but longer lasting solution.

**Experimental Investigations**

Intra-cast temperature measurements were conducted for performance standards. Three thermocouples were attached to a user’s arm at staggered locations beneath the aerating sleeve and mock fiberglass cast. After allowing the thermocouples to achieve steady-state temperature, the air flow was activated for 60 seconds, first at a flow rate of 40 standard cubic feet per hour (scfh) and in a second test at 60 scfh as shown in Figure 9. The resulting temperature differentials were 2.25° C and 2.71° C respectively; proving the effectiveness of the design.

**Key Advantages of Recommended Concepts**

Overall sleeve design has evolved incrementally from the initial bladder prototype. The final sleeve design is superior due to its enhanced flow distribution and form fitting shape. The inclusion of the vinyl sponge material prevents unintentional blockages and gives initial spacing guidelines for an orthopedic professional. Hole spacing, size,
The gas source design represents a self-contained, highly portable and inexpensive solution. A user may easily assemble and operate the air source with limited mobility. The entire device can easily be transported in a large pocketbook or backpack. Additionally, CO₂ represented the cheapest pneumatic solution for high pressure airflow.

**Financial Issues**

The cost analysis estimates the cost of all raw materials and equipment required to fabricate each prototype. Aside from performance testing, the team also conducted a prototyping cost analysis to narrow down the final design for the breathable sleeve and air/gas supply. The aerating sleeve prototypes consisted of the tube design ($12.00) and bladder design ($3.50). The huge price difference was one of the major reasons the tube design became the final design solution. (Rep 7.2) The gas supply varied in CO₂ assembly sizes of 4 oz ($87.78) and 20 oz ($98.00). To reduce cost, the patient would be able to rent the CO₂ assemblies of either a 4 or 20 oz.

**Recommended Improvements**

Mass production of Comfort Cast would make use of more efficient production methods. Custom hardware would be designed and sourced for the product. During the given project timeline, certain aspects were left unexplored due to schedule limitations. While the team opted for off-the-shelf hardware to be used in the prototype build, ideally Comfort Cast would be composed of custom components. (Rep 10) The first step towards improvement would be designing a custom regulator to handle the pressure and temperature conditions of the CO₂ canister output and a more compact housing.

Additionally, the current product manufacturing methods would be updated to drastically reduce cost & labor effort. The bladder design would be stamped with a custom heat-seal press. The air source housing would be injection molded and made of a lighter material.

Finally, an achievable goal is a handheld trigger so that a user may pulse the gas flow at their discretion, providing an easier means of activating the gas flow while conserving the CO₂ capacity and prolonging the run time. The team hopes to have a fully implemented, compact trigger mechanism by the final presentation.

![Figure 10 - Finalized Design Solution](image)