Transient Altitude-Induced Compartment Syndrome Associated With Fiberglass Casts Using Waterproof Cast Padding

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Abstract

Changes in aircraft cabin pressure and its interplay with a fixed diameter fiberglass cylindrical cast and the closed air cells in waterproof cast padding may cause a transient altitude-induced compartment syndrome. In this case series, 2 patients reported transient compartment syndromes that resolved with aircraft decent. As proof of concept, this work displays photographic and video evidence showing the difference in air cell volume from experimental data in a vacuum chamber as well as real-world volume changes at cruise altitude in a commercial airliner. Transient altitude-induced compartment syndromes associated with fiberglass casts using waterproof cast padding are real and surgeons and patients should be advised of this potentially devastating complication.

Compartment syndrome is a potentially devastating complication of closed reduction and casting of pediatric forearm fractures. The incidence of compartment syndrome in this scenario is low (0%-1.04%).[1-4] One would expect that, after the acute traumatic swelling subsides, the likelihood of developing compartment syndrome would also decrease. However, compartment syndrome can nevertheless develop in patients who travel to high altitudes or fly on commercial flights after being treated with fiberglass casts with waterproof padding.

Changes in ambient pressure associated with changes in aircraft cabin altitude and the interplay with waterproof cast padding may cause transient altitude-induced compartment syndrome. This article reports this phenomenon and demonstrates through an experimental model the concept that waterproof casting material expands with decreased ambient pressure. Additional photographic evidence is presented to show the difference in air cell volume from experimental data in a vacuum chamber as well as real-life volume changes at cruise altitude in a commercial aircraft.

Case Reports

At a tertiary-care pediatric hospital, 2 patients with forearm fractures underwent closed reduction and casting with fiberglass casts under conscious sedation.

The patients were neurologically intact after reduction. Both were seen in clinic within 2 weeks after the original cast application with radiographic confirmation of maintained skeletal alignment. Three to 4 weeks after injury, they were given the option to pay out-of-pocket for a cast with waterproof padding. The patients' families elected to purchase the waterproof cast materials because of planned vacations that would include water play.

Each patient received a waterproof cast having a Procel Cast Liner (W. L. Gore & Associates Inc, Flagstaff, Arizona) applied in accordance with manufacturer instructions, which state that the material should be overlapped 50% and "wrapped around the wrist snugly."[5,6] This quilted polytetrafluoroethylene liner contains air-filled open-celled polyurethane padding (**Figure 1**).[6] Both patients remained neurologically intact and comfortable after cast application.

Shortly thereafter, they took commercial flights subject to Federal Aviation Regulations.[7] The families reported that the patients became irritable and reported pain, throbbing, and numbness distal to the cast. In each case, as the aircraft descended, the symptoms resolved. Neither patient had a permanent deficit on follow-up.

Figure 1. Procel Cast Liner (W. L. Gore & Associates, Inc, Flagstaff, Arizona).

Materials and Methods

To validate this anecdotal, 2-case evidence, we used materials readily available in most hospitals and sought photographic and video evidence. A waterproof quilted polytetrafluoroethylene cast liner was placed into a

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Figure 2. Cast liner in standard hospital wall-mounted bedside suction chamber at atmospheric pressure (A) and at full suction (B). Cast liner near sea level at major international airport (C) and at cruising altitude of 31,000 ft in a Boeing 757 (D). Note expanded volume of air cells.

bedside wall–mounted suction canister and was subjected to decreased atmospheric pressure to evaluate the volume of air cells under different pressures. The liner was also flown on a commercial airplane, and the volume was assessed photographically at real-world pressurized cabin altitude.

Results

The volume of the waterproof air cells changed with differential ambient pressure when placed in the standard hospital wall-mounted suction canister (**Figures 2A, 2B**). As pressure was decreased, the volume of air cells visibly increased. A video of this can be viewed online (www.amjorthopedics.com). The waterproof cast liner was photographed during flight at 31,000 ft in a pressurized Boeing 757 and before takeoff at an airport that is 9 ft above mean sea level.[8] The volume of the cast liner was increased at cruising altitude (**Figures 2C, 2D**).

Discussion

The volume of air cells in a waterproof cast liner changes with changes in ambient air pressure. The volume visibly increased at cruising altitude on a routine commercial flight, compared with volume near sea level. Modern pressurized aircraft cabin altitudes can reach as high as 8000 ft.[9] If these expanding air cells are contained in a fixed-volume rigid device surrounding fiberglass cast, the volume available for the injured limb is decreased. Even though these expanding gases are compressible, it is reasonable to assume that the extrinsic pressure applied on the limb by the air cells will increase, thereby increasing compartment pressure. Furthermore, data from a porcine model show that, simply by increasing the altitude in an experimental chamber, compartment pressures can be increased a mean of 2.7 mm Hg without a cast.[10] Therefore, we believe that this photographic evidence provides concept validation that using waterproof air cell cast padding filled with matter sensitive to the effects of changing pressure under a rigid cast can lead to transient altitude-induced compartment syndrome during routine air travel even at altitudes that are routine for pressurized commercial cabins.

Video. Air cell volume with varying visible change in pressure.

Along the same lines, the cast liner manufacturer is aware that certain environmental factors can affect air cell volume. In *Instructions for Use*,[6] the manufacturer states that "'some patients' fingers or toes may temporarily turn blue. This is a reaction to heat generated by the casting tape and its proximity to the skin. Once the extremity adjusts to the new environment of the cast and the casting tape has cooled, the patient's fingers or toes should return to normal color (10-15 minutes)." Increasing the temperature of the curing fiberglass and decreasing ambient pressure expand the air cells. Surgeons who use waterproof casts should be aware of this potential hazard, and bivalving or splitting casts should be considered in patients who are wearing waterproof casts and are considering air travel or travel to high altitudes.

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