Technical reports

Maintenance of negative-pressure wound therapy while undergoing hyperbaric oxygen therapy

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Key words
Wounds, hyperbaric oxygen, treatment, equipment, safety

Abstract
(Chong SI, Tan MK, Liang W, Kim SJ, Soh CR. Maintenance of negative-pressure wound therapy while undergoing hyperbaric oxygen therapy. Diving Hyperb Med. 2011;41(3):147-50.)
Background: Both negative pressure wound therapy (NPWT) and hyperbaric oxygen therapy (HBOT) are useful modalities in the treatment of problem wounds. However, none of the commercially available portable negative-pressure devices have been certified safe for use in a recompression chamber. Thus, the NPWT device is removed while the patient undergoes HBOT. The purpose of this study is to demonstrate that wound negative pressure can be effectively and safely maintained during HBOT.
Patients and methods: In a small, prospective, randomised crossover trial, we used commonly available clinical materials to connect the NPWT suction tubing to the negative suction generating device in the hyperbaric chamber. Six patients each underwent one HBOT session with continuous NPWT and one HBOT session without concurrent NPWT. We assessed the patient's pain score, the amount of exudate aspirated by the NPWT during HBOT, and the appearance of the wound dressing after each session was assessed in a blinded manner.
Results: There were no differences in pain scores between the two HBOT sessions. The amount of exudate aspirated during HBOT with NPWT ranged from 5 to 12 ml. Five of the six patients had a better appearance scoring of their dressing when NPWT was maintained during HBOT ($P = 0.006$).
Conclusion: We successfully demonstrated a simple design that allows the maintenance of NPWT during HBOT without causing additional pain, and with continued extraction of exudate. The maintenance of NPWT during HBOT also allowed the dressing to be maintained undisturbed.

Introduction

Negative pressure wound therapy (NPWT) has been widely utilised to manage problem wounds. The mechanism of action lies in its ability to maintain a negative-pressure environment over the wound bed. This is achieved by creating a bio-occlusive environment connecting the wound to a negative-pressure generating device, thereby promoting angiogenesis while reducing exudation.[1]

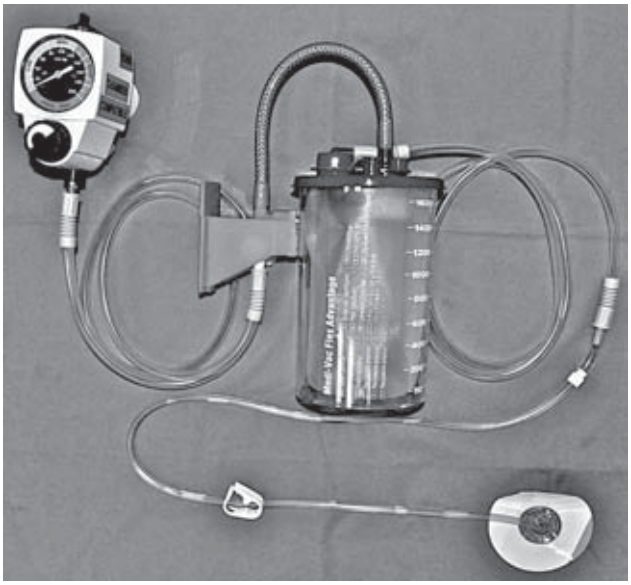
Hyperbaric oxygen therapy (HBOT) has been used as an adjunctive therapy for the management of problem wounds. These include ischaemic, diabetic and irradiated wounds, as well as compromised grafts and flaps.[2] Patients with diabetic wounds generally receive an average of 30 to 40 daily HBOT while those with necrotizing soft tissue infections generally receive an average of 3 to 10 sessions.[3-5] Some of these wounds are simultaneously dressed using NPWT. Based on their mechanism of action, there are reports that suggest the concurrent use of both treatments improves clinical outcomes in patients.[6,7]

However, none of the commercially available, portable, topical negative-pressure devices has been certified as safe for use in a recompression chamber. They contain lithium-based batteries that may be a potential fire hazard in a hyperbaric environment.[8] As a result, the NPWT system is interrupted and the device removed while the patient undergoes HBOT.

Interruption of NPWT frequently leads to pooling of exudates/blood within the wound and the loss of an intact airtight seal. This may lead to increased costs and increased discomfort by requiring the reinforcement or reapplication of the NPWT dressing system following each session. The displacement of dressing and the shearing forces generated as the fluid collects between the wound and the dressing may potentially disturb the wound bed and inhibit healing.[9] The pooling of fluids in the wound bed also theoretically increases the risks of infection and bacterial colonisation. These problems are particularly obvious for patients with large wounds with high exudation, when it is difficult to apply NPWT, such as large diabetic ulcers or wounds due to necrotizing soft tissue infections.

We aim to demonstrate that negative pressure can be effectively and safely maintained during HBOT using readily available materials, which will provide uninterrupted

Figure 1
Overview of system to maintain NPWT during HBOT; using widely available materials and components, the TRAC pad tubing is connected to a regular suction canister that is attached to a wall suction device



exudate removal and preserve the integrity of the NPWT dressing.

Materials and methods

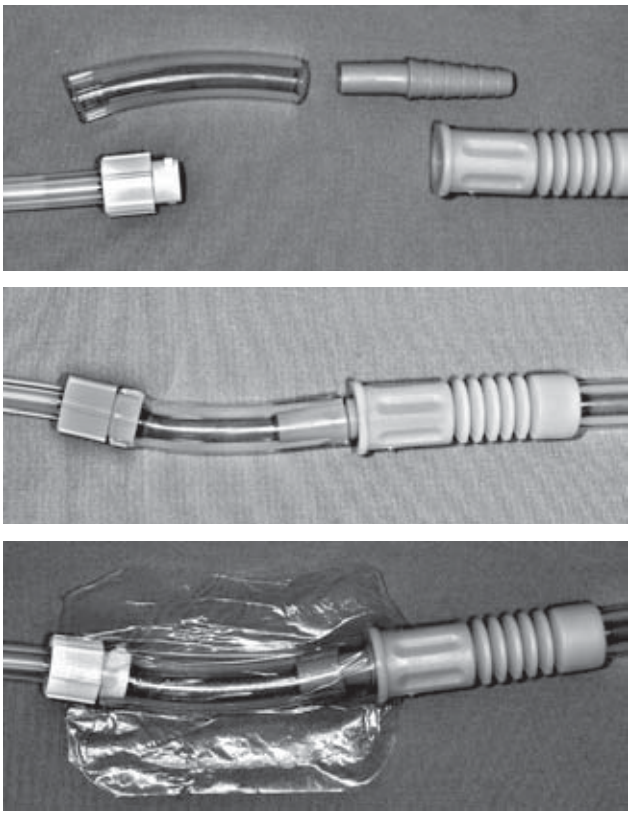
NEGATIVE-PRESSURE DEVICE FOR USE IN HBOT

Commonly available clinical materials were used to quickly and simply connect the suction tubing from the NPWT to the negative suction generating device in the hyperbaric chamber. Figure 1 shows how NPWT was maintained during HBOT. The TRAC pad tubing is connected to a regular suction canister that is attached to the wall suction device. The suction pressure which is generated by the pressure difference between the chamber and the external environment is controlled in two stages. The first stage consists of a continuous vacuum regulator unit (Ohmeda Medical, Low Vacuum model with suction range 0–200 mmHg), which allows a variable setting within predefined limits set by the chamber manufacturers (Hyperbaric Health) and the hospital Biomedical Engineering Department. The second stage consists of an adjustable pressure release valve which entrains air into this circuit to keep the pressures within an acceptable range (–50 to –400 mmHg).

The following components are assembled to form an airtight connection to the device:

- end of T.R.A.C.® Pad;
- rubber tubing with two cuts fashioned at 180^{O} apart;
- rubber connection from a naso-gastric tube;
- suction tubing.

Figure 2
Key to the setup is the connection between the TRAC pad and standard suction tubing; the TRAC pad tubing is not designed to couple with suction tubing; however, a simple modification using a short length of tubing and a connector sandwiched between two pieces of Tegaderm™ transparent dressing ensures an air-tight seal.



The key components are detailed in Figure 2. Key to the setup is the connection between the TRAC pad and a length of regular suction tubing. Unlike the other connecting parts of the setup, the TRAC pad tubing is not designed to couple with suction tubing. However, a simple modification using a short length of tubing and a connector sandwiched between two pieces of Tegaderm™ transparent dressings allows us to ensure an air-tight seal between the TRAC pad and suction tubing. For each HBOT involving the maintenance of NPWT, the attending nurse ensured that the negative pressure remained within a narrow 10 mmHg range from the target therapeutic pressure of –120 mmHg, and the pressure was recorded regularly during the treatment.

STUDY DESIGN

We conducted a small, prospective, randomised crossover trial on six patients referred for HBOT between October and December 2010. Prior to the commencement of the study, the team had tested the technique on mannequins. Ethics approval was obtained from the SingHealth IRB. Following informed consent, patients enrolled in the study. The patients' wounds were all small (< 100 cm^2) lower limb

Table 1
Demographics, wound details and exudate volumes of each patient; DM – diabetes mellitus

Age	Sex	Co-morbidities	Location of wound	Size of wound (cm)	NPWT aspiration (ml)
67	F	DM, hypertension	Post-total knee arthroplasty	8 x 4	5
50	M	DM	Right heel	5 x 8	7
43	M	DM	Right foot	8 x 6	10
56	F	DM	Right shin	4 x 7	5
61	M	DM	Left heel	8 x 8	10
56	M	DM	Left foot, post-ray amputation	9 x 7	12

wounds due to diabetes mellitus, complicated by peripheral vascular disease and poor microcirculation, and being treated with NPWT. All six patients were assessed as fit to undergo HBOT.

For one HBOT, NPWT was maintained throughout the treatment, while for the other the NPWT was discontinued during HBOT. Randomisation was performed using sealed envelopes that were opened by the principal investigator before the start of the first HBOT session. Each HBOT session consisted of 90 minutes breathing 100% 0_2 at 243 kPa. Patients were randomised to either having the NPWT interrupted or maintained for the first study HBOT session. For the second study HBOT session, the opposite intervention was instituted in the same patient.

ASSESSMENT PARAMETERS

The wound dressing was assessed by three independent assessors who were blinded as to which study arm the patient was randomised. Their grading was based on digital photographs of the NPWT dressing system taken at the end of each HBOT session to give an 'Appearance Score'. The assessments for all the treatments were made at a single sitting. The scoring system used to grade the state of the dressing was:

1 dressing intact with good seal;
2 dressing slightly soaked with some leak;
3 dressing soaked with seal leak and requiring reinforcement;
4 dressing soaked and requiring whole dressing change.

The median appearance scores between the study and control arms were analysed with the Mann-Whitney U test for significance.

The volume of exudate removed by the NPWT during the HBOT session was recorded at the end of the treatment. Pain or discomfort was assessed on a 1–10 analogue scale on three occasions during the HBOT session: at the start, one hour into and at the end. A pain score greater than seven for more than 5 minutes was a trigger for aborting the trial.

Results

Table 1 shows the demographics, wound details, pain scores and amount of exudate drained during the HBOT with NPWT. The target suction pressure of –120mmHg was achieved and maintained for all patients during the treatments. Five of the six patients had a better wound appearance score with maintenance of negative pressure than in the control arm (Z score = –2.76, P = 0.006). There was no difference in pain score between the study and control arms.

Discussion

Problem wounds can be a challenge to manage, often resulting in high costs for the patient, increased nursing demands, higher risks for complications and prolonged hospital stay. Both NPWT and HBOT have been proven to have beneficial effects in the management of problem wounds. However, the incompatibility of the negative pressure devices with a hyperbaric environment has excluded their continuous use during HBOT, with potentially disadvantageous effects on wound healing.

We have described a simple, safe technique using readily available materials, that allows the maintenance of NPWT while a patient undergoes HBOT, without causing additional pain and allowing exudate to be drained during the treatment. The maintenance of NPWT during HBOT also allows the dressing to be maintained and may potentially avoid additional nursing work such as reinforcing or changing of the dressing. However, the synergistic effects of HBOT and NPWT cannot be demonstrated by this study and further studies are required to clearly demonstrate any benefits of HBOT and continuous NPWT on non-healing wounds.

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