Enhancement of Auricular Composite Graft Survival With Hyperbaric Oxygen Therapy

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Objective: To continue investigation regarding the efficacy of hyperbaric oxygen (HBO) therapy in improving survival of reattached auricular composite grafts.

Design: A prospective, randomized, double-blind study using 20 New Zealand albino rabbits randomized to a treatment or control group. The treatment group received 30 HBO treatments over 19 days following amputation and reattachment of composite auricular grafts. The control group received standard care. Ears were examined grossly and microscopically on postoperative day 21 to determine the percentage of graft survival.

Results: The mean percentage of graft survival for the 2 separate grafts (a larger 1.5 × 4.0-cm and a smaller 1.0 × 3.0-cm graft) in the treatment group was 26.5% and 27.9%, respectively. The mean percentage of graft survival for the larger and smaller graft in the control group was 9.7% and 14.0%, respectively. An analysis of variance test was used to evaluate this difference, which was found to be statistically significant (P = .001).

Conclusions: This study represents a continued investigation following a pilot study, which suggested some enhancement of composite graft survival with the use of HBO therapy in the rabbit ear. Both experiments have demonstrated a slight survival benefit using HBO therapy in auricular composite grafts in the rabbit model.

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FACEPLASTIC and reconstructive surgeons have long recognized the challenges set forth with the traumatically amputated auricle.1 Investigators have tried to improve survival with various pharmacological agents and surgical techniques.2-9 Microvascular anastomosis is ideal but is generally not a possibility owing to severe vascular and soft tissue destruction and small vessel size.10,11

Hyperbaric oxygen (HBO) therapy has several medical applications (eg, augmentation of wound healing, treatment of decompression sickness, and therapy for osteoradionecrosis). Hyperbaric oxygen therapy is believed to help prevent white cell–mediated damage related to reperfusion injury.12 It also helps promote angiogenesis and enhanced oxygen delivery to body tissues.12 Multiple studies have been conducted to further evaluate the use of HBO in tissue healing.12-17 McFarlane and Wermuth16 studied the effect of HBO in preventing necrosis in pedicle flaps and composite skin grafts. Their treatment groups received 1, 2, or 3 atm of absolute pressure.

Our initial pilot study18 demonstrated an enhanced mean percentage of graft survival with the use of HBO therapy. The design of the pilot study included 2 separate auricular composite grafts in the rabbit model, one at the tip of the ear and the other in the thicker base portion of the ear. In the present study, grafts of 2 different size were made only in the base portion of the ear. In both studies, after amputation and reattachment of the grafts, 10 rabbits received a series of HBO treatments, and 10 rabbits received routine postoperative wound care. The rabbits in the treatment group in both the present study and pilot study demonstrated a slightly improved graft survival.

We noted several problems with the rabbit as a model for these studies, but were encouraged by our initial findings, which prompted further investigation. Accordingly, this second study was undertaken to reconfirm the initial findings and to hopefully further define the role of HBO therapy in improving survival of auricular composite grafts.

RESULTS

For the covariables evaluated, no statistically significant differences were observed in reattachment time, right vs left ear, or surgeon. Regarding the composite graft measuring 1.5 × 4.0 cm, the percentage of graft survival for the rabbits receiving HBO treatments was 26.5%, while the percent-

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MATERIALS AND METHODS

The basic protocol used in the pilot study was repeated in the present study with a few significant design changes; this is a prospective, randomized, blinded, controlled study. Twenty adult New Zealand albino rabbits, weighing from 1.4 to 1.8 kg (3-4 lb), were obtained from an approved breeder. The rabbits were housed in a university-approved animal research laboratory and fed a standard rabbit diet. The Animal Care and Use Committee at the University of Missouri, Columbia, approved this investigation. Investigators participated in a training course in animal care, and guidelines were followed to ensure humane care of the rabbits.

Technicians from the university's Office of Laboratory Animal Medicine provided anesthesia support and monitoring. Xylazine hydrochloride (7 mg/kg) and ketamine hydrochloride (33 mg/kg) were administered subcutaneously as the preanesthetic agent. Isoflurane was used as the principal anesthetic agent. The eyes were shaved and then prepared with an iodine solution. The animals were brought to the operating room where their ears were measured and marked.

An independent assistant randomized the rabbits to (1) treatment and control groups, (2) right vs left ear to undergo amputation first, and (3) which size graft to be used in the right vs left ear. Two types of composite amputation and reattachment were performed on each rabbit with only 1 graft performed on each ear. One graft design was identical to that used in the pilot study, a vertically oriented, rectangular shape measuring 1.5 x 4.0 cm located near the base portion of the ear (Figure 1). The second composite graft used in this study was similar in shape and placement but measured 1.0 x 3.0 cm (Figure 1). In each ear, the excised segment was reattached using only 6-0 nylon skin sutures. The suture was used to reapproximate the epidermis and subcutaneous tissue on each side of the ear. No cartilaginous, through-and-through sutures or supportive dressing were used. Detachment time was recorded.

Buprenorphine hydrochloride (0.05 mg/kg) was given immediately following surgery and again 12 hours later for pain control. The rabbits were monitored until they adequately recovered from anesthesia. A protective collar that extended to the level of the ears was placed around each rabbit, and the death was believed to be secondarily to hyperthermia and not HBO.

*COMMENT*

Facial plastic and reconstructive surgeons have long recognized the challenges inherent to traumatically amputated auricle. Simple reattachment has often met with failure in survival of the detached portion. Hyperbaric oxygen therapy has several therapeutic applications. Twelve disorders are approved for the use of HBO. We have previously completed a pilot study investigating the efficacy of HBO therapy in improving survival of reattached auricular composite grafts in the rabbit. An enhancement in survival noted in the pilot study prompted this investigation to reconfirm this preliminary finding and better define a role for HBO therapy with respect to the traumatically amputated auricle.

In 2 separate studies we have now observed a slightly better composite graft survival in the group of rabbits receiving HBO treatments. In the rabbit model we have used composite grafts of fairly large size in an attempt to mimic the condition of a major human auricular avulsion injury.

age of graft survival for the control group was 9.7% (Figure 2). Regarding the composite graft measuring 1.0 x 3.0 cm, the percentage of graft survival for the treatment group was 27.9% and 14.0% for the control group (Figure 3). The percentage of graft survival between the treatment and control groups was significantly different (P = .001). As expected, the portion of the graft that survived was found adjacent to the anastomosis.

A single death occurred. A staff veterinarian examined the rabbit, and the death was believed to be secondary to hyperthermia and not HBO.

By the rabbits. Mupirocin (Bactoderm; Pfizer Inc, New York, NY) ointment was applied to the ears postoperatively.

Of the 20 rabbits, 10 were randomized to the control group, and 10 to the treatment group. The treatment group received 90-minute treatments of 100% oxygen at 2.0 absolute atmospheres. Treatments were administered 3 times a day for the first 2 days, twice daily for the next 7 days, and then only once daily for the next 10 days. Over 19 days, 30 treatments were administered; in the pilot study, 14 treatments were given over 10 days. Because the pilot study had suggested some survival benefit with HBO therapy, we believed that a more aggressive treatment regimen may show further enhancement of graft survival.

An HBO chamber had been constructed by the Science Instrument Technology Services at our institution. We consulted with the Division of Hyperbaric Medicine at our institution and various other facilities for advice regarding construction of the chamber and recommended treatment regimens used in this protocol. The chamber was constructed of stainless steal and Plexiglas (Rohm GmbH & Co KG, Darmstadt, Germany) with cylindrical design. Instrumentation included oxygen hose, an oxygen monitor, pressure gauge, venting device, safety pop-off valve, and flow regulators. The oxygen level within the chamber was continuously monitored by an oximeter to ensure that the chamber remained at 100% oxygen. Continuous pressure monitoring was accomplished with a pressure gauge. Experience at other centers reportedly has not shown oxygen toxicity to occur at these treatment levels.

On postoperative day 21, each ear was examined both grossly and microscopically. Nonviable tissue was debrided. The amount of graft that survived was measured and recorded. The surviving graft was compared with the initial area of graft harvested. The surviving graft area was then recorded as a percentage of the initial graft harvested. This same protocol was used and described in our pilot study. Calculations were then made to determine the total area and percentage of graft survival.

The Technology Integrated Services Division at the University of Missouri, Columbia, performed all statistical analysis using SAS statistical software (SAS Institute Inc, Cary, NC). The percentage of graft survival was the primary outcome variable. Covariables evaluated included reattachment time, right vs left ear, surgeon, and graft size used. These items were statistically analyzed using the SAS system. P < .002 was considered statistically significant.
Because the rabbit ear is quite different from that of a human, this is only a fair model at best. We had no success in survival using large composite grafts at the tip portion of the rabbit ear either with or without the use of HBO therapy in our previous study. We have found partial survival (involving tissue near the interface of reattachment) of large composite grafts in the base portion of the rabbit ear where both the cartilage and the soft tissue is thicker, which allows for a more satisfying apposition of tissues along the margins of reanastomosis. We believe that tissue in the base portion of the rabbit ear more closely resembles that of the human ear compared with tissue at the tip of the rabbit ear. Although we recognized the limits of the rabbit as a model comparable with the human auricle, we believe that the findings from this study give support to the use of HBO therapy in the treatment of reattached auricular composite tissue. We encourage further study of this subject.

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