Hyperbaric oxygen therapy in free flap surgery: is it meaningful?

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ABSTRACT

BACKGROUND

Hyperbaric oxygen therapy is a recognised modality of treatment with applications in plastic surgery. This modality of treatment works by providing higher oxygen delivery to tissues. The benefits of this modality of treatment in free flap surgery were studied.

METHOD

A randomised prospective study was done. Ten patients undergoing free tissue transfer by microvascular technique were studied. These patients were randomised into two groups. In Group 1 the patients were subjected to hyperbaric oxygen therapy postoperatively for seven days. Group 2 served as the control group. Patients in this group were not subjected to hyperbaric oxygen therapy. Patients were evaluated up to 14 days postoperatively. The flaps were evaluated for any flap loss, presence of venous congestion in the flap, flap oedema, and completeness of healing at the flap site.

RESULTS

No significant difference was found in terms of flap survival, time to resolution of venous congestion, resolution of oedema, and period of postoperative recovery.

CONCLUSION

Routine use of hyperbaric oxygen therapy does not result in better survival of free flaps.

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Key Words: free flap; hyperbaric oxygen therapy

INTRODUCTION

Reconstructive surgery frequently involves transfer of tissue from available (donor) locations to (recipient) areas of need. Such transfer may be a non-vascularised transfer (graft) or a vascularised tissue transfer (flap). The survival of the tissues being

transferred is predicated on the assured nourishment of these tissues throughout the process of transfer. Pedicled flaps used in reconstructive surgery retain an attachment to the donor site that carries the circulation to the flap (the pedicle). Pedicled flaps therefore are usually from the same region and have restrictions with regard to dimensions, tissue composition and 'reach' of the flap. By contrast, free tissue transfer by microvascular technique (free flap) is free from these restrictions. In this technique tissue as required is harvested along with its supplying vessels from a donor site. At the recipient site the tissue is revascularised by anastomosis of the flap vessels to recipient vessels that have been identified in the defect. Today, transfer of chosen composite tissue to a defect from a distant site by free micro-vascular technique is considered 'standard of care' in many reconstructive surgical situations. The operative technique requires involves vascular anastomoses and requires special instrumentation, operative magnification, and training.

Oxygen is the most critical of the nutritive needs of tissue being transferred. The amount of oxygen carried by reversible binding to each molecule of haemoglobin is fixed. The amount of oxygen dissolved in plasma is proportional to the partial pressure of oxygen over the plasma. This can be increased many fold by the use of hyperbaric oxygen therapy (HBO). HBO appears to facilitate wound healing by a variety of actions.¹ Oxygen at 300 kPa increases oxygen tension both in arterial blood and tissue. This improves the cellular oxygen supply by raising the tissue-cellular diffusion gradient. The hyperoxia has potential benefits including improved angiogenesis.² The formation of collagen matrix is essential for angiogenesis and is facilitated by HBO. Further HBO decreases abnormal capillary permeability and decreases arteriovenous shunting in flaps. This results in improved flap perfusion. Also, HBO produces improved leucocyte function, killing of anaerobes and prevention of free radical injury.

Several studies have shown improved skin graft take upon hypoxic beds when HBO was used. The use of HBO in the situation of partial or total flap failure is rational and evidence based.^{3–6} Most of the evidence-based publications on the effects of HBO on flaps has been with experimental studies in animals. In these studies cryoprotection against ischaemia was found to be potentiated by HBO. HBO was seen to be synergistic with steroids, heparin, leeching and pentoxifylline when these were used to improve flap survival.^{7–9}

To date, though numerous studies (mostly in experimental animals) attest to the use of HBO in free flaps.^{9–16} There appears to have been no study which has prospectively studied the effects

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of on free tissue transfer in a clinical setting. In this study the effects of HBO on free flaps was investigated as a prospective randomised trial.

MATERIALS AND METHOD

The study was a prospective randomised trial. Ten patients undergoing free tissue transfer by microvascular technique were included in this study. These patients were randomised into two groups by random chit method.

Group 1: These patients were subjected to hyperbaric oxygen therapy postoperatively starting from first postoperative day to at 2.5 atmospheres absolute for one hour daily for seven days.

Group 2: This group served as the control group. Patients in this group were not subjected to hyperbaric oxygen therapy.

Inclusion Criteria

All patients who presented with a major defect for reconstruction at INHS Asvini during the period of study were considered for reconstruction by free flap technique. Cases were selected for reconstruction by free flap technique only if:

1. Conventional techniques were considered inapplicable or suboptimal.
2. The patient was fit to undergo up to 12 hours of anaesthesia and surgery.

The choice of flap was based on the nature of defect and available free flap options. The details of age and sex of the patients are given in Tables 1 and 2, respectively. The indications for the procedure are summarised in Table 3 and both groups of patients are comparable.

The free flaps used were latissimus dorsi muscle flap, anterolateral thigh flap, gracilis muscle flap, radial forearm flap and osteocutaneous fibular flap. The flap details are summarised in Table 4.

Table 1 Age distribution of cases in the study (surviving flaps).

Age group (yr)	Number of patients (n=8)	
	Group 1	Group 2
20–29	–	1
30–39	1	–
40–49	–	1
50–59	2	1
60–69	–	–
70–79	1	1
Total	4	4

Table 2 Sex distribution of cases in the study (surviving flaps) (n=8).

Sex	Group 1	Group 2
Male	4	2
Female	–	2

Harvest of the flaps was by standard technique. The average operating time was nine hours (5–14 hours) and the average period of warm ischaemia was three and a half hours (One and half to seven hours). All microvascular work was done using operative magnification and standard technique. All arterial and venous anastomoses were end to end only. A single artery and a single vein were anastomosed in all cases; 9–0 and 10–0 round bodied micropoint sutures were used as appropriate. At completion of anastomosis a single dose of heparin was given. All cases received low molecular weight dextran infusion for three days postoperatively. Postoperatively the flaps were monitored by recording colour, warmth, turgor, speed of capillary re-filling after blanching by pressure, quality of bleeding on pricking, and Doppler evaluation of arterial and venous anastomoses.

RESULTS

All flaps in both groups were evaluated for the following findings:

1. Any flap loss
2. Flap oedema
3. Venous congestion
4. Period of postoperative recovery

Flap loss was defined as an unviable segment of tissue of any size in the flap. One flap each in Groups 1 and 2 failed to survive

Table 3 Aetiology of defects reconstructed by free tissue transfer (all cases) (n=10).

Nature of defect	Group 1	Group 2
Postcancer excision	2	2
Electrical burns	1	–
Road traffic accident	1	2
Industrial accident	1	–
Postinfectious loss	–	1
	5	5

Table 4 Details of free flaps done (n=10) (all cases).

Location of defect	Flap used	Flap size	Group
Face	ALT	10 × 14 cm ²	2
R upper limb	LD	23 × 13 cm ²	1
L ankle and foot	LD	18 × 10 cm ²	2
R ankle	Gracilis	17 × 6 cm ²	1
Tongue	ALT	6 × 4 cm ²	1*
R leg	Gracilis	15 × 6 cm ²	2
Mandible, FOM	Fibular	12 × 8 cm ² , osteocutaneous	2*
		9 cm bone	
R hand	Radial forearm	10 × 8 cm ²	1
Mouth	Radial forearm	7 × 8 cm ²	1
L leg	LD	14 × 11 cm ²	2

*These cases were excluded from the analysis. ALT: anterolateral thigh flap; LD: latissimus dorsi muscle flap; FOM: floor of mouth.

Table 5 Data regarding flap oedema.

Group 1		Group 2	
Case	Duration to resolution of oedema (d)	Case	Duration to resolution of oedema (d)
1	3	1	1
2	0	2	3
3	0	3	1
4	1	4	0
Average = 2 days		Average = 2.5 days	

Table 7 Period of postoperative recovery.

Group 1		Group 2	
Case	Duration to postoperative recovery (d)	Case	Duration to postoperative recovery (d)
1	6	1	14
2	11	2	5
3	8	3	9
4	9	4	7
Average = 8.5 days		Average = 8.75 days	

Table 6 Data regarding venous congestion.

Group 1		Group 2	
Case	Duration to resolution of venous congestion (d)	Case	Duration to resolution of venous congestion (d)
1	0	1	0
2	1	2	1
3	0	3	1
4	0	4	0
Average = 0.25 days		Average = 0.5 days	

beyond 24 hours of surgery. These patients were excluded from the analysis since flap loss had occurred even before HBO was exhibited to the case group. The remaining eight flaps survived in toto.

Thus, the difference in terms of flap survival was not clinically significant. Though the numbers are small to be subjected to statistical analysis, certain conclusions can be derived. Table 5 shows the data regarding flap oedema. The difference between the groups is not significant. Table 6 shows the data regarding venous congestion. In both groups venous congestion had settled before the case group was given HBO, the difference therefore is not significant. Table 7 shows the period of postoperative recovery. This was defined as the period to complete epithelialisation and cessation of all discharge. The results in both groups are not different.

DISCUSSION

Several well-documented animal studies have established better survival of skin grafts and composite grafts with postoperative HBO.¹⁷ Similarly, superior survival of pedicled flaps, particularly failing flaps has also been reported. There is no published clinical trial for the effects of HBO on free flaps in the clinical setting, though studies on experimental animals show superior flap survival.

Our study though small failed to establish any significant benefit to free flaps by the use of HBO. We theorise the reasons for

the same as discussed below. It is known that the survival of skin and composite grafts in the first 48 hours postengraftment is based entirely on imbibition of serum with its contained nutrients (including oxygen) from the wound bed.¹⁸ It is understandable therefore that this phenomenon is markedly benefited by HBO. In the classic random pattern pedicled flap where vascular connections are divided on three sides of tissue and maintained on one side (the pedicle) the circulation is unphysiological and inefficient until re-orientation of blood flow occurs. Blood flow at the base of the flap may be reduced to 25% of the original and at the tip to 5% of the original flow. Further, a considerable amount of this blood flow may be non-nutritive owing to opening up of arteriovenous shunts.¹⁸ HBO increases the amount of oxygen carried per mL of blood and is reported to close off arteriovenous shunts.² Thus, HBO is of definite value in the management of a failing pedicled flap. HBO has also been shown to reduce venous congestion in the pedicled flap as long as total venous occlusion has not occurred.

Free flap tissues are harvested along with the artery principally perfusing these tissues and the corresponding draining vein. Circulation in a free flap is thus oriented physiologically and more efficient and reliable than in the pedicled flap. Thus (except in case of technical failure) venous congestion is less, and arteriovenous shunting and oedema are similarly less. Thus tissues transferred by this technique have superior oxygenation (except during the period of ischaemia which follows after harvest and before completion of vascular anastomosis and restitution of blood flow). HBO therefore has probably not much benefit to offer in the healthy free flap.

This hypothesis could possibly be validated to some degree by measurements of transcutaneous oxygen tension over the flap; however, this was not available at the time of the study.¹⁹ The present study is very small; a larger study would be required to fully establish the place of HBO in free flap surgery.

CONCLUSION

In this study no obvious benefit was found from the use of hyperbaric oxygen postoperatively in cases of free tissue transfer in terms of flap survival, resolution of oedema, venous congestion or period of postoperative recovery. The study suggests that

routine use of hyperbaric oxygen therapy in cases undergoing free tissue transfer is not indicated. However, this series is small and would require further study for validation.

CONFLICTS OF INTEREST

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REFERENCES

- Kindwall EP, Gottlieb LJ, Larson DL. Hyperbaric oxygen therapy in plastic surgery: a review article. *Plast Reconstr Surg* 1991;88: 898–908.
- Committee Report. *Undersea and Hyperbaric Medical Society*. 1996 Hyperbaric Oxygen Therapy.
- Ulkür E, Yüksel F, Açikel C, Celiköz B. Effect of hyperbaric oxygen on pedicle flaps with compromised circulation. *Microsurgery* 2002; 22:16–20.
- Manson PN, Narayan KK, Im MJ, Bulkley GB, Hoopes JE. Improved survival in free skin flap transfers in rats. *Surgery* 1986;99:211–215.
- Ramon Y, Abramovich A, Shupak A, et al. Effect of hyperbaric oxygen on a rat transverse rectus abdominis myocutaneous flap model. *Plast Reconstr Surg* 1998;102:416–422.
- Zamboni WA. Applications of hyperbaric oxygen therapy in plastic surgery. In: *Handbook on Hyperbaric Oxygen Therapy*, Oriani G, Marroni A, Wattel F, eds. New York: Springer Verlag, 1996.
- Esclamado RM, Larrabee WF Jr, Zel GE. Efficacy of steroids and hyperbaric oxygen on survival of dorsal skin flaps in rats. *Otolaryngol Head Neck Surg* 1990;102:41–44.
- Yücel A, Bayramiçli M. Effects of hyperbaric oxygen treatment and heparin on the survival of unipedicled venous flaps: an experimental study in rats. *Ann Plast Surg* 2000;44:295–303.
- Nemiroff PM. Synergistic effects of pentoxifylline and hyperbaric oxygen on skin flaps. *Arch Otolaryngol Head Neck Surg* 1988;114:977–981.
- Tai YJ, Birely BC, Im MJ, Hoopes JE, Manson PN. The use of hyperbaric oxygen for preservation of free flaps. *Ann Plast Surg* 1992;28:284–287.
- Nemiroff PM, Merwin GE, Brant T, Cassisi NJ. Effects of hyperbaric oxygen and irradiation on experimental skin flaps in rats. *Otolaryngol Head Neck Surg* 1985;93:485–491.
- Stevens DM, Weiss DD, Koller WA, Bianchi DA. Survival of normothermic microvascular flaps after prolonged secondary ischemia: effects of hyperbaric oxygen. *Otolaryngol Head Neck Surg* 1996;115:360–364.
- Zamboni WA, Roth AC, Russell RC, Smoot EC. The effect of hyperbaric oxygen on reperfusion of ischemic axial skin flaps: a laser Doppler analysis. *Ann Plast Surg* 1992;28:339–341.
- Kaelin CM, Im MJ, Myers RA, Manson PN, Hoopes JE. The effects of hyperbaric oxygen on free flaps in rats. *Arch Surg* 1990;125:607–609.
- Edwards RJ, Im MJ, Hoopes JE. Effects of hyperbaric oxygen preservation on rat limb replantation: a preliminary report. *Ann Plast Surg* 1991;27:31–35.
- Richards L, Lineaweaver WC, Stile F, Zhang J, Zhang F. Effect of hyperbaric oxygen therapy on the tubed pedicle flap survival in a rat model. *Ann Plast Surg* 2003;50:51–56.
- Zhang F, Cheng C, Gerlach T, Kim DY, Lineaweaver WC, Buncke HJ. Effect of hyperbaric oxygen on survival of the composite ear graft in rats. *Ann Plast Surg* 1998;41:530–534.
- Paletta CE, Pokorny JJ, Rumbolo P. Skin Grafts In: *Plastic Surgery* 2nd ed, Mathes SJ, ed. Saunders Elsevier 2006:309–10.
- Zamboni WA, Roth AC, Russell RC, Nemiroff PM, Casas L, Smoot EC. The effect of acute hyperbaric oxygen therapy on axial pattern skin flap survival when administered during and after total ischemia. *J Reconstr Microsurg* 1989;5:343–347; discussion 349–350.