Anaesthesia for microsurgery

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Summary

The data from a retrospective study of 32 anaesthetics administered for free-flap tissue operations are analysed. We suggest balanced analgesic-dominated general anaesthesia, supported wherever possible by continuous regional block. Special attention is paid to full control over the cardiovascular system and the haemodynamics, including the microcirculation and optimal rheological properties of the blood, as well as metabolic ability. Our results suggest that factors such as adequate infusion therapy guided by central venous pressure and urinary output and strict body temperature control, supplementary use of regional blocks and peri-operative use of dextran 40 (Rheomacrodex) can contribute significantly towards the overall success of free-flap surgery.

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Microsurgery has gained acceptance in many surgical specialties and offers a unique opportunity for the treatment of conditions otherwise surgically incurable. In plastic and reconstructive surgery the use of free-flap techniques has brought a new dimension to the repair of tissue defects. This is often a very effective one-stage procedure allowing the transfer of a relatively large mass of tissue including vessels, nerves, skin, subcutaneous tissue, muscle and bone, alone or in various combinations.

As in most microsurgical operations, the free-flap procedure is time-consuming and requires special skills of the surgical team as well as adequately controlled anaesthesia in a carefully selected and prepared patient. The factors which are of importance in free-flap surgery have not yet been fully elucidated. An understanding of these factors is vital for the success of these procedures. After careful study of our early results and related literature,[1,2] a standard anaesthetic protocol has been introduced at Tygerberg Hospital.

Patients and methods

Thirty patients have undergone 32 free-flap transfers in our institution since June 1981 (Table I). Five operations were performed in 1981, 10 in 1982 and 17 by September 1983. Most of the patients were young adults, their ages ranging from 13 to 53 years (mean 27,5 years, SD $\pm$ 11,7 years). They were all in the American Association of Anesthesiologists risk groups I and II. Some had been bedridden or immobilized for a long period because of the defect, such as in the case of non-union of a lower leg fracture. A high percentage of patients were heavy smokers, although this factor was impossible to quantify. There were 9 women and 21 men.

Causes of the defects were: trauma (acute and chronic) — 23 cases; infection and osteitis — 3; congenital facial abnormalities — 2; and carcinoma and sarcoma resections — 2.

Some of the patients were on medication such as antibiotics and mild analgesics. The latter may have had an effect on the clotting mechanism but this could not be quantified in a retrospective study and was not taken into consideration in analysis of the results.

Anaesthetic technique

After the initial period of orientation in this new field, the anaesthetic technique was standardized.

During the pre-operative preparation, particular attention was paid to the cardiovascular and pulmonary systems. The following investigations were performed routinely: ECG, chest radiography, and serum electrolyte measurements. Blood gas estimates and lung function tests were done if indicated. Four units of blood were routinely cross-matched. Premedication usually consisted of lorazepam (Ativan) 2,5 mg or a morphine-promethazine combination (Phenergan). Thiopentone 2 - 5 mg/kg or etomidate 0,15 - 0,2 mg/kg was used for induction. Pancuronium (Pavulon) 0,1 mg/kg was used initially and 0,03 - 0,05 mg/kg was used as a supplementary dose, titrated to maintain muscle relaxation during anaesthesia.

Nitrous oxide and oxygen in a ratio of 70:30 were used to vaporize enflurane or halothane in the initial period if needed. Fentanyl, morphine and/or ketamine were used initially to supplement and later to replace the inhalational agents. To avoid prolonged exposure to volatile agents, we used alphaxalone and alphadolone acetate (Alfathesin) as an infusion in the later stages of the procedure. A continuous epidural block was induced and maintained for 24 hours wherever possible and practical.

The patients were placed on a thick, soft sponge mattress with suitable padding for pressure points. They were all intubated and an endotracheal tube with a large-volume, low-pressure cuff was considered essential.

Two infusion lines were placed, one of which was for central venous pressure (CVP) monitoring. An arterial line was introduced into the radial or dorsalis pedis artery. A temperature probe was inserted into the oesophagus or rectum. The bladder was catheterized and urine output was recorded hourly. Slight-to-moderate positive end-expiratory pressure was used whenever possible for operations lasting longer than 8 hours. An oxygen analyser with high and low alarms was standard. A capnograph was used continuously to ensure normoventilation. An electric blanket maintained body temperature and, where applicable, a small water mattress was added to cover the chest and abdomen.

Millipore filters (40 μm) were introduced on all blood infusion lines. An in-line warmer was used for all the infusions and a hot-water humidifier was incorporated into the semi-closed breathing circuit.

ECG, peripheral pulse and intra-arterial pressure were routinely continuously monitored. The latter two were displayed as continuous digital read-outs as well as the usual

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TABLE I. LIST OF OPERATIONS IN CHRONOLOGICAL ORDER

Case	Age (yrs)	Sex	Type of transfer	Result
1	21	M	Fibula to leg	+
2	21	F	Latissimus dorsi to leg	+++
3	14	M	Bilateral inferior epigastric to neck	—
4	31	M	Crista iliaca to leg	++
5	21	M	Crista iliaca to leg	++
6	20	M	Crista iliaca to leg	+
7	27	M	Crista iliaca to leg	++
8	23	M	Crista iliaca to leg	+
9	50	M	Latissimus dorsi to scalp	+++
10	22	M	Latissimus dorsi to leg	+
11	33	F	Latissimus dorsi to face	++
12	22	M	Latissimus dorsi to leg	++
13	37	M	Latissimus dorsi to scalp	+++
14	13	M	Latissimus dorsi to leg	+
15	16	F	Latissimus dorsi to leg	+
16	22	M	Latissimus dorsi to leg	++
17	17	M	Crista iliaca to leg	+++
18	26	M	Scapula flap to arm	+++
19	25	M	Crista iliaca to leg	—
20	47	M	Crista iliaca to jaw	+++
21	13	F	Latissimus dorsi to face	+
22*	25	M	Crista iliaca to leg	+++
23	46	M	Crista iliaca to leg	++
24	22	F	Crista iliaca to leg	—
25	35	F	Crista iliaca to arm	+++
26*	22	F	Crista iliaca to leg	+
27	44	M	Crista iliaca to leg	++
28	26	F	Crista iliaca to jaw	+++
29	33	M	Crista iliaca to thigh	++
30	36	F	Crista iliaca to leg	++
31	19	M	Crista iliaca to hand	+++
32	53	F	Crista iliaca to jaw	+++

*Repeat operation for flap failure.
— = failed flap (total loss); + = slow healing, sepsis, partial loss; ++ = satisfactory; +++ = excellent.

tracings. The CVP was monitored continuously and recorded half-hourly. Blood gas, serum electrolyte and blood glucose levels and haematocrit were monitored regularly. The infusions consisted of crystalloids and colloids in a ratio of 3:1, altered to a ratio of 3:2 if any signs of oedema were detected. The volume infused was guided primarily by the CVP, which was maintained at a level of 15 - 20 cm H_2O and, secondly, by the urine production. The aim was to maintain urine flow at a minimum of 100 ml/h.

Results

The free-flap transposition operation is a long procedure.[1,2] The mean duration of anaesthesia was 9 hours 20 minutes (± 2 h 3 min) and mean duration of surgery 8 hours 45 minutes (± 1 h 53 min). In 3 patients the operation failed completely; 2 underwent successful reoperation at a later stage and the skin defect in the third was corrected with a split-skin graft. The remaining 29 operations were classified into three groups according to the results of the surgical procedure: group 1 — excellent, no need for secondary procedure to improve healing (10 patients); group 2 — satisfactory but minor wound inspection necessary (11 patients); and group 3 — slow healing, oedema, infection or marginal flap necrosis (8 patients).

The first two groups were combined for analysis of the results. The following factors were thought to have had a direct or indirect effect on the surgical result: (*i*) volume of infused fluid; (*ii*) urine output; (*iii*) intra-operative administration of dextran 40 (Rheomacrodex); (*iv*) body temperature during the operation; and (*v*) supplementary use of epidural block. The retrospective nature of the study prevented acquisition of complete data for each patient. This resulted in different group sizes for the statistical analysis.

An arbitrary scale was chosen to award points for the various abovementioned factors which may have been beneficial. In groups 1 and 2, only 5 patients out of 16 had 35 points or less, whereas in group 3, 6 out of 8 failed to collect more than 35 points. The good surgical result group had a higher total score, and the difference was not significant at the 5% level ($P = 0{,}055$; Fisher's exact test).

These factors were analysed separately with regard to the successful outcome of surgery. There was a significant difference ($P = 0{,}025$; Fisher's exact test) between the two groups in relation to the use of dextran 40. In groups 1 and 2, 13 out of 15 patients received dextran as against only 4 out of 8 in group 3. Other factors were not found to be significant when each was compared separately with the outcome of surgery.

Discussion

Infusion

The appropriate choice of fluids for infusion is of basic importance in this type of surgery. There is a need for physiological electrolyte solutions, plasma expanders and blood as well as substrates to cover metabolic requirements.[3,4] Oedema formation during microsurgery should be prevented because the integrity of the transplanted tissue depends on adequate oxygenation and substrate delivery. Oedema will interfere with these processes.

In the highly controversial sphere of fluid replacement for intra-operative loss it would seem logical to maintain a high intravascular colloid pressure. This can be achieved by infusion of colloid over and above the visual loss to maintain an effective osmotic gradient and prevent plasma protein dilution with a decrease in intravascular colloid osmotic pressure.[3]

Microcirculation

Optimal microcirculation during and after the operation is vital. This is produced by a combination of haemodilution and a moderately hyperdynamic circulation.[5] The haemodilution relies to some extent on dextran 40 infusion. Optimal oxygen delivery to the tissues is achieved at a haematocrit of 28 - 30%. At this level the rheological properties of blood ensure an optimal flow rate in the microvasculature.[5,6] The dextran 40 also decreases blood cell and platelet aggregation and sludging.[6] Integrity of the microcirculation is maintained and coagulation of the transplanted and anastomosed vessels is inhibited. The dextran 40 also expands the circulating blood volume and prevents leakage of fluids into the interstitial space. For a similar reason we use other colloids as well, such as stabilized human serum and fresh-frozen plasma.

A stable and slightly hyperdynamic circulation is considered essential during microsurgery. The aim was a normal or mildly elevated blood pressure and heart rate with a rate-pressure product of at least 10 000. A high urine output as an indicator of adequate peripheral circulation has not proved reliable in our hands. It requires massive crystalloid infusion and leads to interstitial oedema which may result in poor tissue oxygenation.

The use of regional block has proved to be beneficial to the microcirculation. This not only improves circulation to the limb due to the complete block of the sympathetic system, but reduces dependence on the anaesthetic as well as providing excellent postoperative relief of pain. The inhibition of the sympathetic system locally as well as systemically with a low output of endogenous catecholamines contributes substantially to optimal microcirculation.[7] The use of regional anaesthesia is an advantage in cases where early surgical revision is necessary. A regional anaesthetic technique such as an epidural or axillary block can effectively do away with the need for a second general anaesthetic. As an example — 1 patient required early surgical revision and was exposed to general anaesthesia for almost 24 hours in a 2-day period. He developed adult respiratory distress syndrome and the flap failed. In this case a regional technique was unfortunately not feasible for the second procedure.

Blood loss

Bleeding can be substantial especially during dissection in scar tissue where prolonged generalized capillary ooze is caused by an abnormal vascular bed. The venous oozing can be reduced purely by elevation of the part of the body involved. Significant blood loss can also occur during the raising of the flap, especially when bone is mobilized, for example from the iliac crest. Temporary hypotension as well as a meticulous surgical technique is advised during this phase. It must be emphasized, however, that the hypotensive techniques must have been reversed by the time the micro-anastomoses are performed. Long-acting hypotensive agents should therefore be avoided. In this series the estimated mean blood loss was 1 136 ml (SD ± 508 ml). The blood transfusion was aimed at restoring the haematocrit value to 30% or slightly higher.

Metabolic problems

Metabolic problems encountered included electrolyte imbalance, a fall in haemoglobin oxygen saturation, and metabolic acidosis. These were caused respectively by forced diuresis and haemodilution, overtransfusion and prolonged anaesthesia. Careful monitoring allowed prompt correction without any adverse influences on the patient's condition.[8] An early warning sign of overtransfusion with crystalloids was peri-orbital and conjunctival oedema.

Temperature control

The normal mechanisms of thermoregulation are abolished under general anaesthesia. Thus hypothermia during a prolonged procedure is a real threat both to peripheral perfusion and to metabolic stability. We aim to maintain the core temperature at a minimum of 36°C. Care is taken to avoid unnecessary exposure of the body surface. The control of air temperature in the theatre further assists maintenance of the patient's body temperature. Any signs of peripheral vasoconstriction are primarily interpreted as being due to a fall in limb temperature.[9] In future we plan to monitor peripheral temperature as well.

We consider that the strict control of body temperature is a basic factor in providing adequate peripheral circulation.

Medication

We do not rely routinely on any specific preparatory medication. Alpha-sympathetic blockade is considered to be contraindicated since it can diminish blood flow through a fall in perfusion pressure. The flow is directly related to perfusion pressure in the denervated graft.

Some of our patients received lysine acetylsalicylic acid (LAS) (Aspegic) intra-operatively to block prostaglandin release and thus reduce postoperative pain. LAS is a mild analgesic and requires supplementation. The effect on platelet aggregation seems to be promising and further investigation of this property is planned.

Three of our patients were heparinized during the final stages of vascular anastomosis because of repeated thrombosis at the anastomosis. One of them bled excessively from the flap during the postoperative period, and early surgical intervention and coagulation of the bleeding points was necessary. Meticulous attention to all bleeding points is essential when heparin is used.

Complications

Much has been learned (from a surgical as well as an anaesthetic point of view) from the 3 total graft failures mentioned above. All 3 failures were considered to be related to problems of surgical technique, although in 1 case there was a decline in haemoglobin oxygen saturation from 97,8% to 91,0% intra-operatively with a subsequent rise to 95,1% in the immediate postoperative period. There were no other complications related to the anaesthetic techniques suggested, and no allergic reactions to dextran 40 were reported.

Surgical aspects of this series, including complications, will be discussed in a separate article.

Conclusion

The anaesthetic plays a crucial role in the final outcome of microsurgical operations. Optimal microcirculation and control over the vital functions is of basic importance. The majority of our patients required a normal or slightly hypervolaemic or hyperdynamic circulation rather than pharmacological vasodilatation. We achieved these goals by liberal infusions of both crystalloids and colloids, very strict control of body temperature and carefully induced, balanced, analgesic-dominated anaesthesia. Dextran 40 proved to be a valuable adjunct to improve microcirculation. It is our belief that once the patient's sympathetic system has been stimulated it is impossible or at best extremely difficult to reverse or control it pharmacologically. Our aim therefore is to prevent this by meticulous attention to factors such as pain, temperature and circulatory dynamics.

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Comparison and ranking of cancer mortality rates in the various populations of the RSA in 1970

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Summary

Age-adjusted mortality rates (MRs) in all four population groups in the RSA (age range 25 - 74 years) for different types of cancer were compared and ranked. Lung and stomach cancer had the highest MRs in white, Indian and coloured males. In white males lung cancer ranked 1st (MR more than twice as high as that for stomach cancer), while in Indian and coloured males stomach cancer ranked 1st and lung cancer 2nd. The MR for lung cancer in coloured males was a little higher than that in white males. In black males oesophageal cancer ranked 1st and liver cancer 2nd.

In white females breast cancer ranked 1st and lung cancer 2nd. In coloured females cancer of the cervix ranked 1st followed by cancer of the breast and of the stomach. In black females cancer of the oesophagus and of the liver ranked 2nd and 3rd after cancer of the cervix, and in Indian females the rank order was stomach cancer 1st, breast cancer 2nd, and cervical cancer 3rd.

Cancers of the rectum and bladder were low in the rank order in both males and females of all four population groups.

The main feature of age-specific MRs for the more common cancers was the fact that MRs for stomach cancer in both coloured males and females were relatively high in the younger age groups. Also, the MRs for cancer of the cervix in coloured and black females were not only higher at all ages (except in the highest age group in blacks) but were particularly high in the younger age groups compared with figures for the other populations.

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Bradshaw and Harington published two articles in the *South African Medical Journal* on the trends in mortality rates (MRs) for some of the more common types of cancer in the four population groups of the RSA, and compared these MRs with those in populations in other countries.[1,2] However, there is a shortcoming in their calculations of MRs for cancers in that they were calculated according to the numbers of members of the various population groups at all ages. With few exceptions (such as some leukaemias), death from cancer is rare below the age of 25 years, and there are vast differences between the various populations of the RSA as regards the proportions of the populations in the younger age groups. At the 1970 census