Anesthetic Considerations in Facial Transplantation: Experience at NYU Langone Health and Systematic Review

Allyson R. Alfonso, BS, BA*
Elie P. Ramly, MD*
Rami S. Kantar, MD, MPH*
William J. Rifkin, MD*
J. Rodrigo Diaz-Siso, MD*
Bruce E. Gelb, MD†
Joseph S. Yeh, MD‡
Mark F. Espina, MD‡
Sudheer K. Jain, MD‡
Greta L. Piper, MD§
Eduardo D. Rodriguez, MD, DDS*

Background: Anesthetic considerations are integral to the success of facial transplantation (FT), yet limited evidence exists to guide quality improvement. This study presents an institutional anesthesia protocol, defines reported anesthetic considerations, and provides a comprehensive update to inform future directions of the field.

Methods: An institutional “FT Anesthesia Protocol” was developed and applied to 2 face transplants. A systematic review of 3 databases captured FTs in the peer-reviewed literature up to February 2020. Two reviewers independently screened titles and abstracts to include all clinical articles with FT recipient and/or donor-specific preoperative, intraoperative, and relevant postoperative anesthetic variables. Data charting guided a narrative synthesis, and quantitative synthesis reported variables as median (range).

Results: Our institutional experience emphasizes the importance of on-site rehearsals, anticipation of patient-specific anesthetic and resuscitative requirements, and long-term pain management. Systematic search identified 1092 unique records, and 129 met inclusion criteria. Reports of 37 FTs in the literature informed the following anesthetic axes: donor pre- and intraoperative management during facial allograft procurement, recipient perioperative care, immunotherapy, antimicrobial prophylaxis, and pain management. Quantitative synthesis of 30 articles showed a median operative time of 18 hours (range, 9–28) and fluid replacement with 13 L (5–18) of crystalloids, 13 units (0–66) of packed red blood cells, 10 units (0–63) of fresh frozen plasma, and 1 unit (0–9) of platelets.

Conclusions: Anesthetic considerations in FT span the continuum of care. Future efforts should guide standard reporting to establish evidence-based strategies that promote quality improvement and patient safety. (Plast Reconstr Surg Glob Open 2020;8:e2955; doi: 10.1097/GOX.0000000000002955; Published online 17 August 2020.)

INTRODUCTION

The success of facial transplantation (FT) depends on a multidisciplinary approach highlighted by cadaveric

From the *Hansjörg Wyss Department of Plastic Surgery, NYU Langone Health, New York, N.Y.; †Transplant Institute, NYU Langone Health, New York, N.Y.; ‡Department of Anesthesiology, Perioperative Care, and Pain Medicine, NYU Langone Health, New York, N.Y.; and §Surgical and Cardiovascular Intensive Care Unit, Department of Surgery, NYU Langone Health, New York, N.Y.

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rehearsals, research procurements, and extensive clinical preparation.1,2 The anesthesia team plays an integral role in the perioperative and intraoperative management of allograft donors and recipients, comprising up to 12% of total FT costs.3,4 The influence of anesthetic considerations on morbidity and mortality in vascularized composite allograft transplantation (VCA) has been highlighted through evaluation of upper extremity transplant anesthetic protocols that reduced perioperative bleeding and shortened hospital stay, as well as lessons learned from challenges of quadruple limb transplantation and combined face and hand transplantation.2,5

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Limited evidence exists to guide patient safety and quality improvement efforts. Edrich et al\textsuperscript{11} surveyed lead anesthetists on anesthesia duration, intraoperative management, and acute complications. Discussion of anesthetic considerations is otherwise scarce in the literature despite the field’s evolution with over 40 FTs performed worldwide.\textsuperscript{1,12–20} The goal of this study was to present an institutional anesthesia protocol and variables for 2 facial allograft donors and recipients, define reported anesthetic considerations in FT, and provide a comprehensive update to inform future directions of the field.

**METHODS**

**Institutional Experience**

Institutional Review Board approval (s14-00550; clinicaltrials.gov, NCT02158793) was obtained, and informed consent was given by FT recipients and their donors’ families. An institutional “FT Anesthesia Protocol,” including a donor transfer algorithm, was developed.\textsuperscript{21} Cadaveric simulations and a research procurement were performed to educate team members and plan procedures.\textsuperscript{3,4}

**Search Methods**

Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PubMed/Medline, Embase (Ovid), and CINAHL (EBSCOhost) databases were searched from inception to February 3, 2020 (Table 1).\textsuperscript{22,23}

**Selection Criteria**

Two reviewers independently screened titles and abstracts to include all clinical articles with FT recipient and/or donor-specific preoperative, intraoperative, and relevant postoperative variables, including intensive care and pain management. Reference lists of relevant articles were reviewed to identify any additional articles. Non–English-language articles or those involving non-human subjects were excluded.

**Data Collection**

Full-text articles were reviewed. A tool for data collection organized by FT recipient was prospectively developed and used to record anesthetic variables, including donor status, anesthesia team composition, fluid management and resuscitation, blood loss, use of vasopressors, ventilation, operative time, anticoagulation regimen, anesthetic induction and maintenance agents, perioperative laboratory studies, induction and maintenance immunosuppression, antimicrobial prophylaxis, intensive care management and length of stay, and pain assessment and management. At the completion of data charting, a qualitative synthesis was performed by organizing available evidence into representative categories: donor and recipient preoperative and intraoperative management, as well as recipient postoperative intensive care, immunotherapy and antimicrobial prophylaxis, pain management, and long-term anesthetic considerations. A narrative synthesis was constructed based on all reported cases and corresponding anesthetic variables.

**Statistical Analysis**

Quantitative anesthesia–related variables reported for most FT recipients were synthesized as median and range (minimum–maximum). The data were also stratified by allograft type (partial or full FT) and most common surgical indications (ballistic trauma, burn, neurofibromatosis, and animal attack) because these were predicted to potentially influence fluid resuscitation, operative duration, and ICU duration. Further statistical or meta-analyses were not performed due to the significant risk of bias of missing data and heterogeneity of participant characteristics and surgical procedure.

| Table 1. Systematic Search Strategy |
|-------------------------------------|
| **Search Terms Used in Databases**  |
| PubMed/Medline                     |
| “Facial transplantation” [MeSH:no exp] | “Facial transplantation” .mp. or “facial transplantation/” |
| “Face transplant” [tw]             | “Facial transplant”.mp. |
| “Facial transplant” [tw]           | “Facial transplant”.mp. |
| “Face transplantation” [tw]        | “Face transplantation”.mp. |
| “Facial transplantation” [tw]      | “Face allotransplantation” .mp. |
| “Facial allotransplantation” [tw]  | “Facial allotransplantation”.mp. |
| “Facial vascularized composite allotransplantation” [tw] | “Facial vascularized composite allotransplantation”.mp. |
| “Face vascularized composite allotransplantation” [tw] | “Face vascularized composite allotransplantation”.mp. |
| “Face vascularized composite allograft” [tw] | “Face vascularized composite allograft”.mp. |
| “Face vascularized composite allograft” [tw] | “Face vascularized composite allograft”.mp. |
| “Face allograft” [tw]              | “Face allotransplantation”.mp. |
| “Facial allograft” [tw]            | “Facial allotransplantation”.mp. |
| “Facial composite tissue allotransplantation” [tw] | “Facial composite tissue allotransplantation”.mp. |
| “Face composite tissue allotransplantation” [tw] | “Face composite tissue allotransplantation”.mp. |
| “Face composite tissue allograft” [tw] | “Face composite tissue allograft”.mp. |
| “Facial composite tissue allograft” [tw] | “Facial composite tissue allograft”.mp. |

MH, MeSH Headings; TW, text words.
RESULTS

Case Description
Anesthesia team composition included up to 4 anesthetists and 2 residents per operating room. Supine positioning and forced-air warming blankets were used. Vascular access included radial and femoral arterial lines and femoral central venous catheters.

Facial Allograft Donors
Figure 1 depicts operating room setup and team positioning. Table 2 outlines donor characteristics and preoperative status.

Donors A and B, corresponding to recipients A and B, respectively, were 26 and 23-year-old men transferred from outside institutions following brain death. Their families granted permission for facial and solid organ procurement. Upon arrival, they were assigned American Society of Anesthesiologists class 6. The head of bed was angled at 30°, and body temperature was maintained at 36°C–37.5°C, with mean arterial pressure (MAP) ≥60 mm Hg, urine output (UOP) ≥0.5 mL/kg/h over 4 hours, and central venous pressure 4–10 mm Hg. Lung-protective ventilation was maintained. Vasopressin was titrated to UOP and MAP. Levothyroxine infusion, methylprednisolone, and antimicrobial prophylaxis were administered. Preoperative imaging included computed tomography (CT) cerebral angiography, formal angiography, noncontrast CT chest/abdomen/pelvis, and echocardiography. For donor B, diagnostic bronchoscopy was performed based on previous experience. Facial impression was taken for silicone mask fabrication for donor A, whereas 3-dimensional printing technology was used for donor B.

General anesthesia was administered with isoflurane, paralysis with neuromuscular blockers, and analgesia with fentanyl. An 8.0-cuffed tracheostomy was placed preoperatively. At the start of organ procurement, intravenous indocyanine green was given for visualization of facial perfusion. The technical details of the surgical procedure have been previously described. The patients’ UOPs and MAPs were maintained at goal (Fig. 2) with vasopressin 0.02–0.04 units/min and phenylephrine boluses as appropriate. Levothyroxine and antimicrobial prophylaxis were continued inoperatively with the addition of insulin infusion (1–4 units/h) for donor B. Indocyanine green was again administered before procurement of the facial allograft, and 30,000 units of intravenous heparin were given before division of facial allograft pedicles. The procedure summary is documented in Table 3.

Facial Allograft Recipients
Recipient A, a 41-year-old man, sustained extensive burns without smoke inhalation injury in 2001. He had an uncuffed tracheostomy on presentation and had undergone 70 reconstructive procedures. Preoperative pain assessment revealed 4–6/10 pain (9/10 without medication) with intermittent tension in a “mask-like” facial distribution, controlled with oxycodone and muscle relaxants. An opioid contract was made before FT, and one provider addressed pain management for continuity of care.

Recipient B, a 25-year-old man, sustained a self-inflicted gunshot wound in 2016. He underwent several reconstructive procedures and presented with severe functional deficits and exposed facial hardware. He suffered from the chronic pain syndrome, with bitemporal headaches radiating behind his eyes without related neurologic deficits, and presented with a pain regimen of oxycodone solution, acetaminophen, and gabapentin. Pain score was 2–5/10.

Preoperative Preparation and Intraoperative Management
Tracheostomy, gastrostomy, head/neck CT, formal angiography, and medical work-up were completed in preparation of FT. Recipient B underwent additional surgical care for facial fractures and hardware removal before FT.

A wire-reinforced endotracheal tube was placed through tracheostomy, and volume-controlled ventilation was used. Anesthesia was induced with propofol, fentanyl, midazolam, and a neuromuscular-blocking agent. Recipient A had an extensive surgical history and chronic pain, and reported having had 2 prior incidents of
awareness under anesthesia. He was maintained with isoflurane (0.4%–0.8% expired concentration), midazolam 2 mg/h, fentanyl 0.5–2.5 μg/kg/h, and vecuronium 30–40 μg/kg/h. End-tidal carbon dioxide (Etco₂) and positive end-expiratory pressure were 31–42 mm Hg and 3–8 cm H₂O, respectively. Multiple boluses of phenylephrine and 1 infusion at 15 μg/min were required. Insulin infusion kept glucose <180 mg/dL. Although the use of throat packs and frequent suctioning were employed, one brief episode of intraoperative desaturation occurred, and clotted blood was suctioned from the tracheostomy. Perioperative antibiotic prophylaxis consisted of cefazolin and clindamycin.

Recipient B’s anesthesia was maintained with sevoflurane (1.1%–2.8% expired concentration), ketamine 1–2 μg/kg/min, and fentanyl 1–2 μg/kg/h. Etco₂ was 28–45 mm Hg, and positive end-expiratory pressure was 2–7 cm H₂O. Surgeons requested controlled hypotension during initial neck dissection (MAP, <65 mm Hg; central venous pressure, <5 mm Hg). After vessel anastomosis, MAP was ≥60 mm Hg. Perioperative antimicrobial prophylaxis was cefazolin, metronidazole, clindamycin, and micafungin.

Both patients received induction and maintenance immunosuppression therapy as previously described. Recipient characteristics and pre- and postoperative laboratory values are outlined in Table 4. Intraoperative MAPs and UOPs are shown in Figure 3, and the procedure summary and fluid requirements in Table 5.

### Postoperative Intensive Care Management

Patients arrived ventilated and sedated. The allograft was monitored closely. Goals were MAP >60 mm Hg, hematocrit >25%, and platelets >75,000. Antimicrobial prophylaxis was tailored to postoperative cultures. An insulin sliding scale was used for hyperglycemia, pantoprazole for gastrointestinal prophylaxis, and subcutaneous heparin and sequential compression devices for deep vein thrombosis (DVT) prophylaxis. Due to a history of hypertension, recipient A had a goal systolic blood pressure <140–160 mm Hg controlled with amiodpine. The

### Table 2. Donor Characteristics and Preoperative Status

|                     | Donor A | Donor B |
|---------------------|---------|---------|
| Age (y)             | 26      | 23      |
| Sex                 | Male    | Male    |
| Blood type          | O+      | O+      |
| Serologies          | CMV+ EBV+ | CMV− EBV− |
| BMI                 | 24.9    | 34.9    |
| Weight (kg)         | 86      | 120     |
| Medical history     | Traumatic brain injury s/p 2 craniotomies for hematoma evacuation; brain death; secondary hypothyroidism | Substance use; psychiatric illness; hepatitis/hepatosteatosis; brain death |
| ASA classification  | 6       | 6       |
| Hematology          | Hgb 6.8 | Hgb 8.2 |
| Coagulation         | PT 16.0 | PT 14.1 |
| Metabolic           | Na 148 | Na 149 |
|                      | K 3.6  | K 3.7  |
|                      | Cl 112 | Cl 117 |
|                      | Ca 9.6 | Ca 7.7  |
|                     | BUN 21 | BUN 32 |
|                      | Cr 0.5 | Cr 1.1 |
| Hepatic             | Gluc 177 | Gluc 117 |
| pH/lactate (mmol/L) | 7.39/1.2 | ALT 94 |
| MAP at procedure start | 100 mm Hg | AST 24 |
| CVP at procedure start | 9 mm Hg | Alb 131 |
| Temperature (°C)    | 36.3    | 36.9    |

Alb, albumin; Alk Phos, alkaline phosphatase; ALT, alanine aminotransferase; ASA, American Society of Anesthesiologists; AST, aspartate aminotransferase; BMI, body mass index; BUN, blood urea nitrogen; Ca, calcium; Cl, chloride; CMV, cytomegalovirus; Cr, creatinine; Gluc, glucose; CVP, central venous pressure; EBV, Epstein-Barr Virus; Hct, hematocrit; Hgb, hemoglobin; INR, international normalized ratio; K, potassium; Na, sodium; PT, prothrombin time; s/p, status post; Toxo, toxoplasma.
pain management team maintained recipient A on hydromorphone patient-controlled analgesia (PCA) with standing enteral basal rate in addition to acetaminophen and a muscle relaxant per his home regimen. He continued to have a high opioid requirement, and alternatives were limited by medication interactions. ETCO2 levels were monitored closely. He was later transitioned to oxycodone 30 mg every 4 hours, although 3 revision procedures required intermittent reintroduction of PCA.

Recipient B’s acute postoperative pain was managed with fentanyl PCA. On the first postoperative day, he underwent hematoma evacuation. Early complications also included palate and floor of mouth dehiscence requiring revision, with subsequent appropriate recovery.28

Long-term Pain Management

Recipient A continued to experience an intractable pain. He was admitted for regimen optimization. In collaboration with psychiatry colleagues, oxycodone was tapered by uptitrating clonidine and trialing ketamine infusions. He was successfully transitioned to buprenorphine–naloxone 8–2 mg 3 times daily with subsequent tapering.

Recipient B’s facial pain improved from 7/10 postoperatively to 2/10 by 11 months posttransplant. Oxycodone–acetaminophen was subsequently tapered.

### Systematic Review

A total of 1092 articles were screened, and 129 met inclusion criteria, describing 37 FT cases (Fig. 4). Qualitative analysis delineated the following essential axes to develop a narrative synthesis: donor preparation and facial allograft procurement, donor and recipient preoperative and intraoperative management, immunotherapy and antimicrobial prophylaxis, as well as recipient postoperative intensive care and pain management. Reported trends of operative time, fluid resuscitation, and length of stay are documented in Table 6 and stratified by allograft type and indication for surgery (Table 7).1,16–18,20,29–43 The evidence synthesized was obtained from prospective case series, representing the best available clinical evidence in the FT literature. Table 8 summarizes the anesthetic considerations in FT based on our institutional experience and supported by representative references from the literature review.24,25,27,16–29,130,131,221,24–27,30,31,32,33,35,36,37 These are elaborated on in the narrative synthesis summarized in the Discussion section of this article.

## DISCUSSION

### Donor Preparation and Facial Allograft Procurement

Facial allograft procurement requires an understanding of anesthetic considerations in solid organ recovery. The majority of facial allograft donors have suffered from brain death with procurement in a heart-beating donor, although less commonly, procurement has also occurred after cardiac cessation.69,30,32,27,25 The feasibility and safety of beginning

### Table 3. Donor Procedure Summary of Procedure Times, Total Urine Output, and Fluid Replacement

|                | Donor A | Donor B |
|----------------|---------|---------|
| Facial allograft procurement time (h) | 12      | 10      |
| Total procurement time (h)           | 17.5    | 16      |
| Total urine output (L)               | 4.5     | 2.0     |
| Crystalloid infusion (L)             | 8.95    | 7.6     |
| Albumin (g)                          | 25      | —       |
| pRBC                                   | 9       | 7       |
| FFP                                      | 2       | 3       |
| Platelets                                | —       | 1       |

FFP, fresh frozen plasma.

### Table 4. Recipient Characteristics and Pre- and Postoperative Laboratory Values

|                | Recipient A | Recipient B |
|----------------|-------------|-------------|
| Age (y)        | 41          | 25          |
| Sex            | Male        | Male        |
| Blood type     | O+          | O+          |
| Serologies     | CMV+ | EBV+ | CMV− | EBV− |
| BMI            | 30.0        | 29.8        |
| Weight (kg)    | 94.9        | 71.5        |
| Medical history| Thermal burn, hyperlipidemia, hypertension, chronic pain | Ballistic trauma, former smoker, depression, chronic pain |
| Extent of defect| Scalp, forehead, eyelids, nose, cheeks, lower face, ears, lips, neck | Midface, nose, maxilla, mandible, lips |
| Allograft type  | Full        | Partial     |
| Allergies      | None        | Amoxicillin |
| ASA            | 3           | 3           |
| Preoperative   | Hgb 14.1 | Hct 41.3 | Hgb 12.0 | Hct 35.3 |
| Postoperative  | Hgb 7.0 | Hct 19.3 | Hgb 15.5 | Hct 1.1 |
| Coagulation    | PT 13.2 | INR 1.1 | PT 15.4 | INR 1.3 |
| Metabolic      | Na 134 | K 4.0 | Cl 100 | Ca 9.2 |
| Hepatic        | ALT 34 | AST 29 | ALT 27 | AST 20 |
| pH/lactate     | 7.36 | 1.3 | 7.41 | 1.4 |
| CVP (start/end) | 68 mm Hg | 85 mm Hg  | 65 mm Hg | 19 mm Hg |
| Temperature (°C) | 36.6 | 39.5 | 36.5 | 37.6 |

*PPV instead of CVP documented.

Alb, albumin; Alk Phos, alkaline phosphatase; ALT, alanine aminotransferase; ASA, American Society of Anesthesiologists; AST, aspartate aminotransferase; BMI, body mass index; BUN, blood urea nitrogen; Ca, calcium; Cl, chloride; CMV, cytomegalovirus; Ctr, creatinine; CVP, central venous pressure; EBV, Epstein-Barr virus; Gluc, glucose; Hct, hematocrit; Hgb, hemoglobin; INR, international normalized ratio; K, potassium; MAP, mean arterial pressure; Na, sodium; PPV, pulse pressure variation; PT, prothrombin time; Toxo, toxoplasma.
Donor Preoperative Management

The physiologic response to brain death is complex, but improved understanding has optimized the number of viable organs procured per donor. Table 9 highlights donor management goals and recommended interventions recommended by the organ system based on published consensus statements and reviews.93–97 Institutional protocols continue to evolve with the worldwide experience. Examples include the addition of antipseudomonal agents to antimicrobial prophylaxis, and a routine preoperative bronchoscopy to rule out undiagnosed respiratory tract infection.24,74

Donor preparation has been shown to decrease general anesthesia time.44 Preoperative tracheostomy can be performed at a preliminary stage in anticipation of FT, or as the first step of the procurement procedure.4,52,53 Due to previous concerns of tracheostomy potentially interfering with lung procurement, facial allograft procurement with endotracheal intubation has also been described.46,50,51 Preoperative CT cerebral angiography, formal angiography, mask production, and placement of radial artery and femoral venous catheters are other essential preparatory steps.44,46,63,64 Donor selection and preparation must occur within a certain distance from the FT center to control for ischemia time; this highlights the importance of sufficiently stabilizing the donor for travel and controlling for transit-associated risks.21,47,50 To date, facial allograft donors have all been sex matched, and ages have ranged from 18 to 65 years.51,65

Donor Intraoperative Management

Anesthetists are positioned within communication distance from all procurement teams (Fig. 1). This improved from earlier arrangements that limited access to the lower body, preventing simultaneous VCA and solid organ procurement.2 Teams practice the flow of the donor operation to recreate this setup before FT.4,52,53 Graft procurement experiences have been described and even practiced before FT.2,4,44–46,50,52,53 One allograft procurement approach is “face-first, concurrent completion,” where the procedure begins with facial procurement and allows each additional organ procurement to conclude shortly after donor heparinization.44 Other strategies have included various cannulation and in situ cooling techniques to recover the facial allograft after solid organs.1,46,50,83

Facial allograft procurement time (range, 4.3–13.3 hours for partial, 4–12 hours for full facial allografts) depends on the recipient defect and efforts to decrease ischemia.1,16,25,33,34,44,45,54,65,67,75 Maintenance of hemodynamic stability and euvolemia in solid organ and facial allograft procurement is particularly challenging. Despite efforts to ensure meticulous hemostasis, donor coagulopathy is not uncommon.29 Blood loss can be most prominent during scalp dissection and skeletal osteotomies, and after initiation of abdominal organ recovery.4,53 Despite these challenges, meticulous planning has resulted in successful recovery of up to 11 organs and tissues from a single donor.68 Donor facial integrity is restored with a silicone-based or, more recently, a 3-dimensionally printed mask, eliminating the need for an invasive impression procedure.69–71

Facial Allograft Recipients

Anesthetists consent patients for general anesthesia, including the risk of death and the high likelihood of

Table 5. Recipient Procedure Summary of Duration of Surgery, Fluid Resuscitation, and Length of Stay

|                        | Recipient A | Recipient B |
|------------------------|-------------|-------------|
| Duration of surgery (h)| 26          | 25          |
| Estimated blood loss (L)| 6           | 4           |
| Total urine output (L) | 3.9         | 4.6         |
| Crystalloid infusion (L)| 18          | 15.5        |
| Albumin (g)             | 137.5       | 152.5       |
| pRBC                   | 13          | 17          |
| FFP                    | 11          | 6           |
| Platelets              | 2           | 2           |
| ICU length of stay (d)  | 51          | 23          |
| Total hospital length of stay (d) | 62 | 37 |
| Tracheostomy duration (d) | 241 | 150 |

FFP, fresh frozen plasma.
blood product transfusion. Reported operative times show a significant variation (range, 9–28 hours), exposing recipients to further complications under prolonged anesthesia.1,16,17,20,29–41

Recipient Preoperative Management

FT indications have included ballistic trauma, burn, animal attacks, trauma resulting from machinery, blunt trauma followed by necrotizing inflammation, neurofibromatosis, vascular tumor, cancer/radiation therapy, or recently, chronic rejection of a primary facial allograft.12,99 Recipient age has ranged from 19 to 64 years at the time of transplantation.28,57 Significant medical comorbidities have included hepatitis C infection (stable viral loads after alpha-interferon and ribavirin), HIV infection (on highly active antiretroviral therapy, CD4 >400/mL, negative viral load), hypertension, non–insulin-dependent diabetes mellitus, granulomatosis with polyangiitis associated with pyoderma gangrenosum, generalized epilepsy, surgically clipped cerebral aneurysm, glaucoma, cardiac septal hypokinesia on echocardiography, and lower extremity phlebitis.17,32,76,83,100 Other comorbidities have included a history of alcohol and substance use disorders, smoking history, posttraumatic stress disorder, major depressive disorder, and bipolar disorder.32,61,77,101 Pretransplant reconstructive surgical histories are typically extensive with the exception of one case of immediate FT.79 Many patients have histories of difficult airways. Mouth opening can be limited by burn scar contractures or trauma-related trismus, and obstruction can occur from soft-tissue ptosis.55–59

Recipient Intraoperative Management

Meticulous care is taken to preserve hemodynamic stability and hemostasis, prevent pressure injury by
offloading, and avert airway occlusion. Median operative time in the literature is 18 hours (range, 9–28) with fluid replacement, including a median crystalloid infusion of 13 L (range, 5–18 L), 13 units of packed red blood cells (pRBCs) (range, 0–66 units), 10 units of fresh frozen plasma (range, 0–63 units), and 1 unit of platelets (range, 0–9 units) (Table 6). Few reports describe the use of fibrinogen for hemostasis or colloids such as albumin for volume repletion. A survey study of lead anesthesiologists involved in the first fourteen FT cases...
Recipient Postoperative Intensive Care Management

Intensive care focuses on maintaining hemodynamic stability and adequate ventilation, and monitoring for allograft viability and/or potential rejection, in addition to other postoperative complications, including postoperative delirium and infection.17,19,101 Decannulation has been reported to occur between 1 week and 1 month post-transplant, with almost all tracheostomies closed by the first year posttransplant.36,37,49,54,58,60,85 Enteral feeding is typically initiated after bowel sounds have resumed with subsequent oral diet advancement as tolerated, and cessation of enteral access by 12 months in most reported cases.17,49,56,58,60

Recipient ICU length of stay has ranged from 1 to 51 days in the literature, excluding a patient with face and bilateral hand transplant who expired after a 65-day–long complicated course.1,16,17,20,32,55,57,70,42,48,84 Team experience is associated with reduction in the length of stay,17 and early rehabilitation promotes recovery.85–87

Immunotherapy and Antimicrobial Prophylaxis

Although exact timing is not universal, anesthetists have administered at least a portion of induction immunosuppression intraoperatively. For example, corticosteroids alone or with antithymocyte globulin have been given before reperfusion of the facial allograft.1,32,34,56,78 The complete induction regimen has also been administered at incision time.32 Antimicrobial prophylaxis covering bacterial, viral, and fungal infections is particularly important in the early postoperative period when the highest incidence of infection occurs.1,17,35,37,74,75,79,81,82

Table 9. Donor Physiologic Responses after Neurologic Determination of Death, Management Goals, and Recommended Intervention by Organ System93–97

| System      | Physiologic Responses                                      | Management Goals                                                                 | Recommended Intervention                                                                 |
|-------------|------------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Cardiovascular | • Initial hypertensive crisis followed by hypotension  
• Arrhythmia secondary to metabolic derangements | • MAP ≥60 mm Hg  
• CVP 4–10 mm Hg  
• HR 60–120 beats/min  
• Left ventricular ejection fraction ≥45%  
• ≤1 vasopressor and low dose (eg, dopamine ≤10 µg/kg/min) | • Nitroprusside or esmolol for initial hypertension  
• Vasoactive agents to maintain hemodynamic goal and organ perfusion: dopamine, vasopressin (refractory shock), norepinephrine, phenylephrine, dobutamine, epinephrine (severe shock) |
| Respiratory | • Pulmonary edema                                          | • Pao₂/Fio₂ ratio >300 mm Hg  
• pH value from arterial blood gas 7.3–7.45 | • Use lung-protective ventilation (eg, small TV 6–8 mL/kg, low Fio₂, high PEEP 8–10 cm H₂O)  
• Begin with lung recruitment maneuvers  
• Elevate head of bed to reduce risk of aspiration  
• Consider diuretics if marked fluid overload |
| Renal       | • Vascular constriction resulting in AKI  
• Hyperglycemia  
• Vasopressin deficiency  
• Corticosteroid deficiency  
• Hypothyroidism | • Urine output over 4 h ≥1 mL/kg/h  
• Glucose level <150 mg/dL * | • Goal is euvolemia using CVP, PAOP, or PPV and SVV with preferably crystalloid  
• Insulin infusion to goal glucose  
• Consider vasopressin replacement  
• High-dose corticosteroids bolus then continuous infusion† |
| Endocrine   | • Coagulopathy                                             | • Hemoglobin level >7 g/dL                                                       | • Consider thyroid replacement therapy with T3 and T4 bolus then continuous infusion  
• Monitor with coagulation laboratory values and TEG  
• Transfuse for hemoglobin <7 g/dL  
• Correct coagulopathy with clotting factors (ie, FFP) or platelets if ongoing bleeding |
| Hematologic | • Coagulopathy                                             | • Temperature >35°C  
• Serum sodium level <155 mmol/L  
• Movements mediated by spinal reflexes | • Active warming to maintain temperature  
• Cautious correction of hypernatremia can be possible with slow, hypotonic infusion of 0.45% NaCl  
• Intraoperative skeletal muscle paralysis to reduce somatic response to surgical stimulus |
| Neurologic  | • Hyperthermia  
• Central diabetes insipidus and hypernatremia  
• Movements mediated by spinal reflexes | • ≤1 vasopressor and low dose (eg, dopamine ≤10 µg/kg/min)  
• CVP 4–10 mm Hg  
• MAP ≥60 mm Hg  
• Norepinephrine  
• Intraoperative skeletal muscle paralysis to reduce somatic response to surgical stimulus |

*Hyperglycemia should be controlled based on institutional intensive care unit guidelines.
†High-dose corticosteroids should only be administered after blood has been collected for tissue typing.

Recipient monitoring has most frequently been performed with at least a femoral venous catheter in addition to radial and femoral arterial lines.11,17 Preference for femoral over subclavian or internal jugular venous access is explained by concerns for thrombosis affecting venous outflow from the face and risk of pneumothorax in a long case with mechanical ventilation.11,17

Concerns for intraoperative blood loss are typically heightened following reperfusion of allografts procured in donors after cardiac death.90,94,59 or surgical excision of plexiform neurofibromas shown to require the most units of pRBCs among surgical indications (Table 7),72,105 and has led to the use of a Mobile Laboratory Unit to monitor hemostasis.73 Intraoperative cell salvage has been used to replace blood loss, in addition to transfusion of pRBCs.8 Subcutaneous heparin is most commonly used for DVT prophylaxis.17,32,57,66 However, a case with historical concern for heparin-induced thrombocytopenia and thrombosis led to avoidance of chemical DVT prophylaxis in the recipient and donor anticoagulation with bivalirudin.104

If not present before the procedure, a gastrostomy tube is placed to address postoperative nutrition.17,92

Reported data on intraoperative catecholamine use.11 Recipient hemodynamic instability and adequate ventilation, and monitoring for allograft viability and/or potential rejection, in addition to other postoperative complications, including postoperative delirium and infection.17,19,101 Decannulation has been reported to occur between 1 week and 1 month post-transplant, with almost all tracheostomies closed by the first year posttransplant.36,37,49,54,58,60,85 Enteral feeding is typically initiated after bowel sounds have resumed with subsequent oral diet advancement as tolerated, and cessation of enteral access by 12 months in most reported cases.17,49,56,58,60

Recipient ICU length of stay has ranged from 1 to 51 days in the literature, excluding a patient with face and bilateral hand transplant who expired after a 65-day–long complicated course.1,16,17,20,32,55,57,70,42,48,84 Team experience is associated with reduction in the length of stay,17 and early rehabilitation promotes recovery.85–87
Recipient Pain Management

Preoperative counseling can reduce postoperative use of prescription pain medications. Preoperative management of chronic pain is warranted in FT, considering the incidence of alcohol or other substance use disorders, or long-term opioid use seen in this patient population. The pain thermometer and visual analog scale are assessment tools with reported use in FT. Quality of life surveys such as the 36-Short Form Health Survey and EuroQol-5D (EQ-5D) also incorporate pain assessments. Postoperative facial nerve pain control has included oxycodone and gabapentin, or the combination of oxycodone with methadone in a patient with a history of intravenous drug use. The extent of recovery and long hospital stay have contributed to postoperative opioid dependence and reduced quality of life. Oser et al described worsened depression in association with opioid dependence, and Lennmens et al described hyponatremia attributed to pain regimen interactions. Deprescribing or tapering pain medications should be prioritized early to ensure adequate pain relief while preventing adverse events. In our experience, this requires a multidisciplinary collaboration.

Recipient Long-term Considerations

Recipients will inevitably return for secondary revisions. Although they may present with improved mouth opening and airway volume, their extensive histories before FT will continue to require vigilance and proactive pain management strategies, as learned from recipient A’s clinical course. Local anesthetics can be used for revision procedures when possible, and importantly, their use reflects sensory recovery. Unfortunately, secondary procedures have also included allograft explantation, providing further insight into strategies for handling adverse outcomes.

Anesthetic Challenges and Future Implications

As the field continues to evolve and attempts at more extensive procedures are undertaken, multidisciplinary collaboration remains crucial to ensuring patient safety. Anesthesia teams are challenged to find innovative solutions to manage complex scenarios such as combined VCA. Reduction of ischemia time, prophylactic hemodilution, and extracorporeal allograft perfusion are hypothesized solutions to improve medical management. Other necessary advances include developing better tools to assess and manage pain, and preventing and treating substance dependence. Although these concerns are not exclusive to FT, they are particularly relevant to the field.

Limitations

Although we present a comprehensive review, evidence is limited to reports in the peer-reviewed literature captured by our systematic search strategy. The report of our institutional experience serves to exemplify the thorough presentation of anesthetic considerations in FT, which is infrequently disclosed. Missing quantitative data on fluid resuscitation, operative duration, and ICU duration, in addition to a limited number of cases performed in a relatively heterogeneous cohort of patients and surgical approaches, did not allow for further statistical analyses. However, to our knowledge, this study represents the most comprehensive assessment of anesthetic considerations in FT and provides a platform for future efforts to establish evidence-based strategies that promote quality improvement and patient safety.

CONCLUSIONS

Implementing a “Face Transplant Anesthesia Protocol” requires extensive preparation and vigilance throughout the continuum of care to address the challenges of prolonged operative time, difficult airway, high risk of blood loss, and tailored anesthetic management in patients with complex surgical and medical histories. These responsibilities continue postoperatively with intensive care and pain management. Optimizing anesthetic care in FT can advance reconstructive transplantation.

Eduardo D. Rodrigues, MD, DDS
Hansjörg Wyss Department of Plastic Surgery
Helen L. Kimmel Professor of Reconstructive Plastic Surgery
NYU Langone Health
222 East 41st Street
6th Floor
New York, NY 10017
E-mail: eduardo.rodriguez@nyulangone.org

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