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Case Report

Algorithm for Total Face and Multiorgan Procurement From a Brain-Dead Donor

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Procurement of a facial vascularized composite allograft (VCA) should allow concurrent procurement of all solid organs and ensure their integrity. Because full facial procurement is time–intensive, "simultaneous–start" procurement could entail VCA ischemia over 12 h. We procured a total face osteomyocutaneous VCA from a brain–dead donor. Bedside tracheostomy and facial mask impression were performed preoperative day 1. Solid organ recovery included heart, lungs, liver, kidneys, and pancreas. Facial dissection time was 12 h over 15 h to diminish ischemia while awaiting recipient preparation. Solid organ recovery began at 13.5 h, during midfacial osteotomies, and concluded immediately after facial explantation. Facial thoracic and abdominal teams worked concurrently. Estimated blood loss was 1300 mL, requiring five units of pRBC and two units FFP. Urine output, MAP, pH and PaO_2 remained normal. All organs had good postoperative function. We propose an algorithm that allows "face first, concurrent completion" recovery of a complex facial VCA by planning multiple pathways to expedient recovery of vital organs in the event of clinical instability. Beginning the recipient operation earlier may reduce waiting time due to extensive recipient scarring causing difficult dissection.

Key words: Composite tissue transplantation, face transplantation, multiorgan donor, organ and tissue procurement, organ protection and preservation, organ sharing

Abbreviations: OR, operating room; VCA, vascularized composite allograft.

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Introduction

Recovery of a facial vascularized composite allograft (VCA) from a brain–dead donor presents a unique set of challenges compared to solid organ and extremity allografts. The facial segment is highly variable and depends on the recipient defect. Isolation of multiple vessels, nerves, muscles, and osseous structures *in situ* (1) may require well over 12 h versus 2–3 h for solid organ procurement (2,3). The consistency of hand allografts results in procurement times as low as 25 min and does not require simultaneous integration into the procurement process (4). Face transplantation also demands consideration of the recipient operation, which may run overtime due to dissection through scarred tissue (5).

Beginning the procurement "face first" preserves facial perfusion but potentially jeopardizes donor physiology through prolonged anesthesia or blood loss. Because they are potentially life–saving, solid organs must be given priority. The ideal approach would begin with face procurement and allow each procurement to conclude immediately following donor heparinization: a "face–first, concurrent completion" approach. It would also allow rapid procurement of solid organs if their integrity is threatened.

Although it is impossible to prescribe a standard technique, recent literature recognizes the need for a coordinating algorithm for each team's function in context of the donor's physiological status (6). Drawing from the experience of a research procurement (7), we present our experience and algorithm.

Materials and Methods

Donor preparation

All work was approved by the Institutional Review Board (HP-40219) and registered with clinicaltrials.gov (NCT01140087). The donor was a previously healthy 21–year–old brain–dead male. The Living Legacy Foundation obtained informed consent for all procedures. Preoperative computed tomographic angiography allowed computerized surgical planning using Synthes ProPlan CMF (West Chester, PA) and 3D printing using Materialise (Leuven, Belgium). Open tracheostomy and silicone facial impression were performed on preoperative day 1 in the intensive care unit.

Operative technique

The donor operation was performed in a 570 square foot operating room (OR) at the R Adams Cowley Shock Trauma Center (Figure 1). The operative

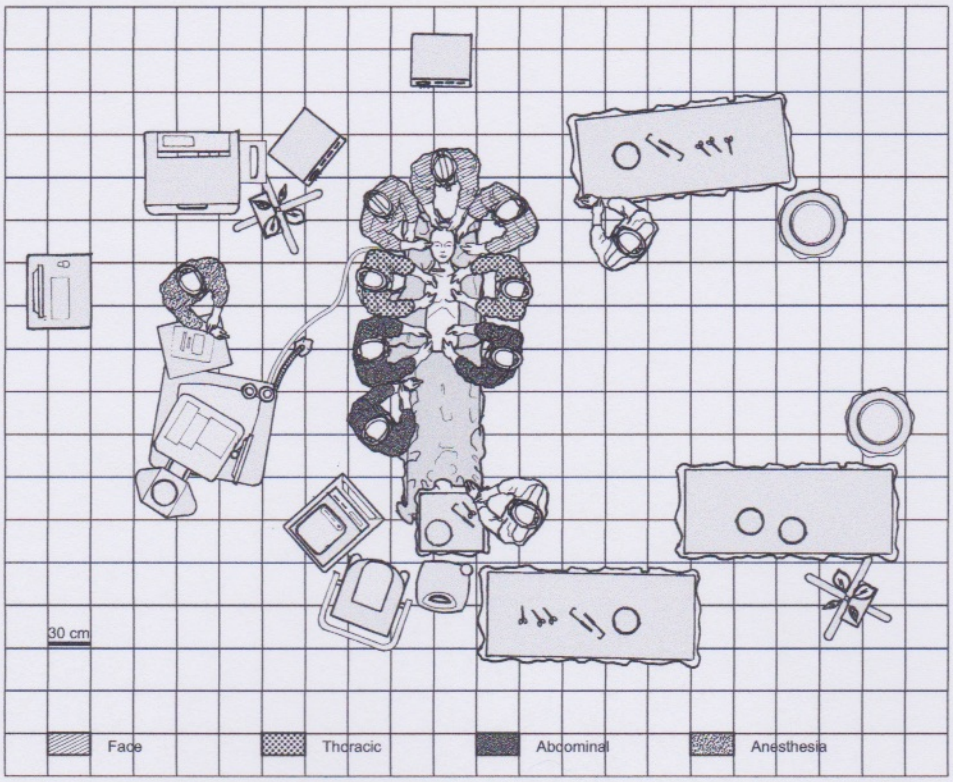

Figure 1: Donor operating room. The arrangement allows face, thoracic and abdominal teams to work concurrently with the sole exception of sternotomy. In addition to standard anesthesia and monitoring equipment, there were two OR lights, two monopolar and one bipolar electrocauteries, three suction assemblies and two head lamp light sources. The operating table was complemented by one back table at each end for face and solid organ teams, respectively, and a back bench for organ preparation.

areas were prepped with povidone–iodine (face, neck) and alcohol/chlorhexidine (chest, abdomen) and draped in one continuous sterile field.

The facial VCA procurement technique has been previously detailed (7). The VCA included all facial skin; the midfacial skeleton and mandible via Le Fort III osteotomies and bilateral sagittal split osteotomies; mimetic muscles below the orbital border of the zygoma; multiple sensory and motor nerve branches; and anterior tongue. Perfusion via bilateral external carotid arteries and internal/external jugular veins was verified using fluorescence angiography (LifeCell SPY Elite Imaging System, Bonita Springs, FL).

Lungs, heart, liver, pancreas and kidneys were procured in standard fashion (2,3).

Results

Donor physiology

The donor remained hemodynamically stable without pressor requirements. Estimated blood loss was 1300 mL, requiring five units packed red blood cells and two units fresh frozen plasma. Hemoglobin ranged from 9.3 to 8.1 mg/dL and INR from 1.3 to 1.6. Urine output was 6.4 mL/kg/h, and 18 L of crystalloid were infused. Mean arterial pressure averaged 84 ± 9 mmHg, pH 7.40 ± 0.03 and PaO_2 206 ± 28 mmHg.

Facial segment

Facial segment dissection time was approximately 12 h, spaced over 15 h to avoid cold ischemia while the recipient was being prepared (Figure 2). Good hemostasis was achieved and adequate perfusion confirmed. Following isolation of the facial segment on its vascular pedicles, the midfacial skeleton was tailored and pre-plated to a 3D printed model of the recipient skull. This allowed work to progress while awaiting recipient site preparation.

The vascular pedicles were ligated and divided at 18 h, following heparinization. The recipient site required additional preparation time; however, explantation proceeded

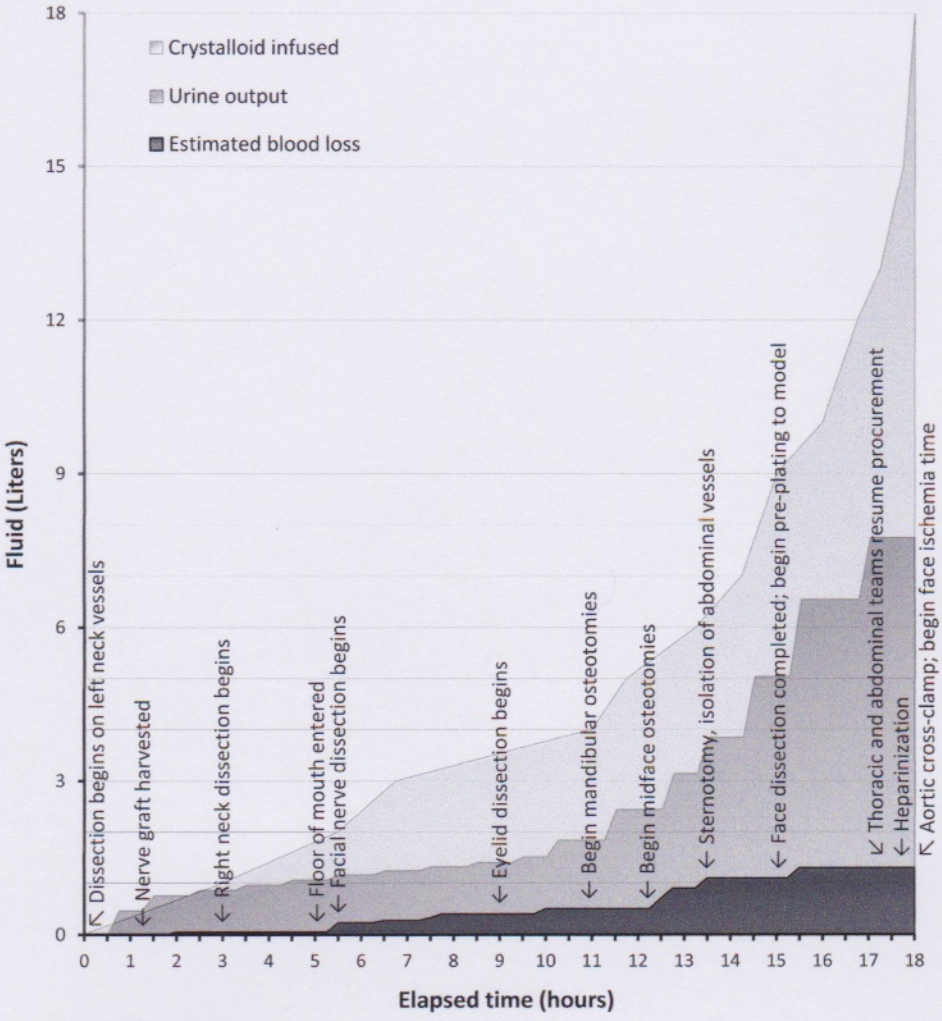

Figure 2: Intraoperative blood loss, urine output and crystalloid infused over time with major operative timepoints. Increase in crystalloid infusion rate was paralleled by an increase in urine output rate.

due to concern for the solid organs and the heart recipient. The facial VCA was removed to the back table, where it was flushed with cold UW solution via both carotid arteries before storage in UW. Total ischemia time was 4 h 26 min, of which 2 h 55 min was in cold storage.

Solid organs

Facial thoracic and abdominal teams were able to work concurrently (Figure 1; Table 1). Solid organ recovery began at approximately 13 h 30 min, during the midfacial bony dissection as total blood loss approached 1000 mL (Figure 2). The estimated time remaining for facial allograft preparation was 2 h. The abdominal and thoracic vessels were isolated, and the pancreas was partially dissected with stapling of the duodenum in the expectation of imminent donor operation completion. However, extended recipient dissection required a pause to decrease VCA ischemia time. Sterile prep of the heart recipient also began concurrently with solid organ recovery, and over 3 h elapsed from recipient sternotomy until the heart was available. During this time, the heart recipient remained stable and did not require transfusion.

The solid organ teams resumed procurement at approximately 17 h 30 min, 1 h before estimated face recipient preparation. The stapled and distended duodenum was drained through a small incision. Immediately following heparinization and facial vascular pedicle ligation, the aorta was cross–clamped and procurement proceeded per protocol.

Table 1: Composition of surgical teams at any given time with additional personnel totals

Face	One to two plastic surgeons and one to two plastic surgery residents
Thoracic organs	One cardiac surgeon or fellow and one cardiothoracic resident
Abdominal organs	One transplant surgeon, one transplant fellow and one general surgery resident
Scrub assistants	One at head of bed with face team; one at foot of bed with solid organ teams
Additional personnel	Three anesthesiologists, three CRNAs, two scrub nurses, three scrub technicians, seven circulators and five organ procurement organization representatives

No solid organ abnormalities were identified. One lung, heart, liver and one kidney were transplanted at our institution during the following day. One lung was used for research and the simultaneous pancreas/kidney was transplanted at an outside institution. All organs had excellent postoperative function.

Discussion

Key steps

Bedside preparation on preoperative day 1 decreased general anesthesia time, alleviated time burden to the operative teams and spared OR resources. Unlike smaller facial segments, full face VCA procurement including oromandibular segment is challenging without a tracheostomy. Tracheostomy did not interfere with lung procurement despite published concerns (8), and can be performed at the bedside along with facial mask impression (6,9,10).

Intraoperatively, isolation of the facial VCA vascular pedicle initially increases safety in case of donor instability. Vessels can then be rapidly cannulated for cold perfusion without resorting to time–consuming and potentially compromising emergency thoracic vascular access (8).

Risk–benefit balance

Early concerns surfaced regarding concurrent procurement (11,12), with newer protocols describing procurement after cardiac death (13) and simultaneous procurement with approximately half the dissection under cold perfusion after cardiac death (8). These approaches would produce unacceptable cold ischemia times for complex full face allografts. Most facial VCA recoveries have been performed "face–first" (11).

The ischemia time tolerated by facial allografts is unknown, with concerns over muscular components (14) and relationship of ischemic times with rejection (15). Extrapolating from free tissue transfer and hand transplantation, ischemia times under 4 h should be well–tolerated (1,16,17). Our approach minimizes facial VCA ischemic time while prioritizing the integrity of life–saving visceral organs.

Temporal coordination

The temporal–logistical imperatives of organ procurement are largely new to plastic surgery. While solid organ teams are accustomed to tightly choreographed recovery procedures, the typical plastic surgery scenario of free flap harvest usually occurs in relative isolation in a stable patient and does not demand extensive coordination with other teams.

In Figure 3, we propose an algorithm that coordinates the recipient room, facial procurement, and solid organ procurement teams. The solid organ teams remain on standby in–house and ideally scrubbed during any phase with elevated risk of blood loss.

Hemodynamic deterioration can occur rapidly in a donor. It may therefore be helpful to establish access to thoracic and abdominal structures against the contingency of recipient instability requiring immediate aortic cross–clamping and procurement. Here, we discuss three possible approaches to timing thoracoabdominal incision.

First, dissection may begin prophylactically before high–risk facial dissection. While it saves minutes in the event of emergency, this approach may increase donor hypothermia, blood loss, and inflammatory mediators (18). It may be best in predictably high–risk cases such as extensive midfacial osteotomies or donors with renal, cardiac or hemostatic dysfunction.

Second, dissection may be triggered by a physiological indicators previously agreed on by surgical and anesthesia teams. This provision preempts serious donor deterioration without early thoracoabdominal incision.

The third option delays thoracic and abdominal incision until 60 min before anticipated facial segment explantation. This approach may be preferred in a lower–risk facial dissection comprising mostly soft tissue, or by solid organ teams that do not require extensive lead time or donor preparation.

Thoracic and abdominal teams may face different time requirements and may prefer to set their own thresholds for beginning their dissection. Cardiac surgeons may feel that saving minutes in preliminary dissection does not justify an open chest, given that thoracic recovery demands less time than abdominal organs. Meanwhile, abdominal surgeons may be able to isolate key abdominal vessels with minimal morbidity and significant time savings. Naturally, all three approaches describe preemptive dissection and would be superseded in the event of acute hemodynamic instability.

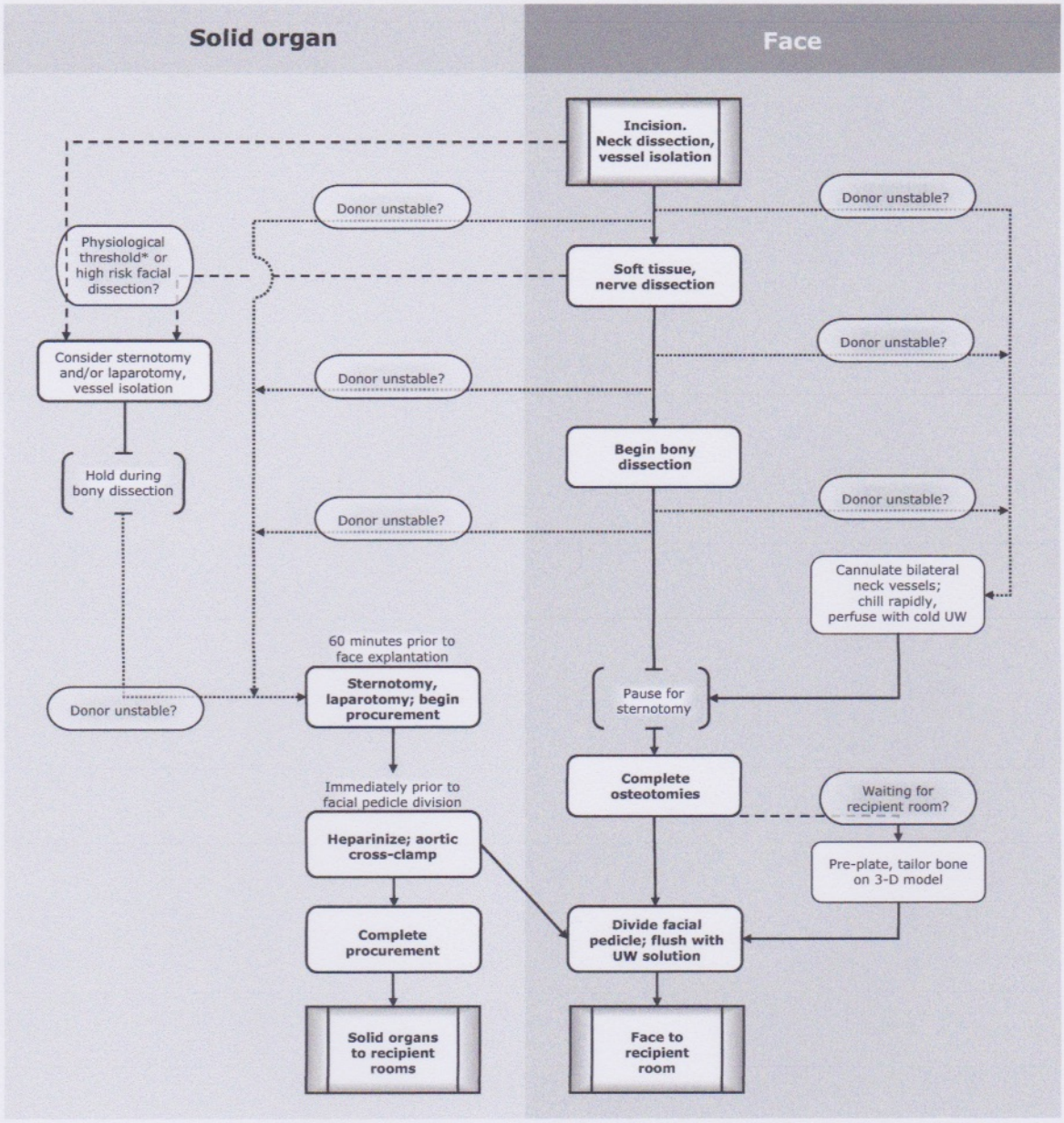

Figure 3: Proposed algorithm for "face first, concurrent completion" total face and solid organ procurement. **Physiological threshold may be any set of prearranged parameters, including blood loss, coagulopathy, urine output, pressor requirements, blood product requirements, acidemia, etc.*

In our case, preemptive abdominal and thoracic dissection was begun empirically based on the potential for bleeding during midfacial osteotomies. This team decision reflected heightened caution toward an unfamiliar and high–profile procedure. Early preparation of solid organ recipients due to optimistic donor operation times estimates resulted in brief ischemic time and uneventful procurement, although more accurate timing could have decreased delays and the accompanying risk. The most prudent approach may be to delay thoracoabdominal dissection either until 60 min

before facial vessel division or until a physiological threshold is met. Solid organ recipients do not require preparation before procurement of their respective organs.

Finally, the concurrent donor and recipient start forced donor surgeons to wait to avoid prolonged cold ischemia. The resulting donor room standby increased potential for complications. Beginning the recipient operation several hours before the donor (but not proceeding beyond a "point of no return" such as neurotomy, pedicle ligation, or complete hard/soft tissue removal) may avoid unnecessary prolongation of the donor operation. This also reduces unnecessary facial ischemia time if expedited explantation becomes necessary.

Limitations

Our algorithm does not address simultaneous extremity transplant, outside institution procurement teams or outside institution donors. Although we do not have experience in extremity procurement, we suggest that it is compatible with our algorithm, especially if completed before face procurement begins. The algorithm also does not exclude outside institution solid organ teams, although they face the inconvenience of remaining available outside their institution for prolonged periods. Procurement at outside institutions remains challenging. Although published protocols allow for outside institution procurement (1), we currently consider the logistical demands too complex for a "face–first, concurrent completion" approach. To our knowledge, no full–facial osteomyocutaneous VCAs have been procured at outside institutions simultaneously with solid organs.

Conclusions

Facial VCA procurement introduces unique temporal–logistical challenges. We propose an algorithm that coordinates facial and solid organ procurement based on donor status reassessment, allowing "face–first, concurrent completion" isolation of a complex facial VCA. Multiple pathways allow expedited recovery in the event of donor instability. Preoperative bedside tracheostomy and facial mask impression reduce operative time. Beginning the recipient operation first reduces waiting for recipient site preparation prolonged by extensive scarring. Partial thoracic and abdominal dissection can initiate before high–risk facial dissection or impending hemodynamic compromise. Barring acute intraoperative events, all organs may be explanted simultaneously following systemic heparinization. Communication between recipient and donor facial teams, thoracic and abdominal recovery teams, and anesthesia is critical to success.

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Disclosure

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

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