Complex Head and Neck Microvascular Surgery

Comprehensive Management and Perioperative Care

Anastasiya Quimby
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To my son, who was with me through this entire journey. Thank you for lighting up my world first with your kicks and then with your smile. You made this journey memorable and fun in more ways than I could have ever imagined. We did it, Kai!!! Love you so much, Mom.

Preface

Modern surgical capabilities continue to develop and improve at an accelerating rate. Whereas less than 50 years ago a diagnosis of head and neck cancer or a devastating injury destined patients to lifelong disfigurement and severe functional deficits, in the recent decades, with the advent of microvascular free tissue transfer, the prognosis for these patients is no longer that grim. Even more fascinating, recent developments in the field of personalized surgery with computer-aided surgical planning and custom-made hardware allow us to perform devastating surgery with exceptional esthetic and functional outcomes due to outstanding reconstructive capabilities. We are fortunate to enjoy success rates well above 90% for microvascular tissue transfer. However, every single head and neck microvascular surgeon is keenly aware of the disastrous implications affecting patients' life expectancy and quality of life if reconstruction failure occurs. The remarkably technically challenging surgery carried out successfully is just half the battle, however. Consideration of various perioperative aspects is essential to ensuring overall satisfactory patient outcomes.

As the field of microvascular surgery is still relatively new, there are countless opportunities to continue to develop our understanding on how to improve patient care and surgical outcomes.

A single source that addresses all aspects of perioperative management of head and neck patients who underwent microvascular reconstruction does not exist. There is a generalized effort to improve overall quality of surgical care with initiatives such as the National Surgical Quality Improvement Program (NSQIP) and surgical patient recovery with efforts of Enhanced Recovery After Surgery (ERAS). These initiatives have shown significant reduction in complications and costs associated with the management of surgical patients in other specialties. Most recently, in 2017, ERAS published guidelines on the management of head and neck patients and highlighted paucity of data regarding optimal perioperative care. Perioperative management varies widely between hospitals and individual surgeons, and no standard guidelines aimed at optimization of patient outcomes currently exist. It has been shown in other specialties that standardization of perioperative management results in reduced complication rates, hospital stays, and cost.

In the following chapters, some of the world's most experienced head and neck microvascular surgeons share their knowledge, experience, and latest available scientific evidence on how to avoid pitfalls in the preparation for surgery, manage challenging intraoperative situations, and provide the most

effective postoperative care to our patients so that they can enjoy timely hospital discharge and return to their life.

Deepest gratitude goes out to my colleagues across the United States and the globe for their initiative and valuable contributions.

Sincerely

West Palm Beach, FL, USA Anastasiya Quimby

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Introduction

The advent of microvascular free tissue transfer has allowed many patients with complex head and neck defects to regain form and function in ways that previously may not have been possible. With a greater than 90% success rate, and some highly experienced surgeons even citing a greater than 99% success rate, free tissue transfer has become a powerful reconstructive option for most patients with head and neck oncologic ablative defects, benign tumor ablative defects, traumatic defects, or secondary complications of prior treatments such as osteoradionecrosis [1, 2].

An optimized patient is essential to prevent fistula and life-threatening wounds, to maximize postoperative function and aesthetics. Due to the risk factors that may lead to the need for head and neck free flap surgery, these patients commonly have a high burden of comorbidities that can affect their wound-healing abilities and recovery. The surgeon must undertake careful consideration of each patient including a full medical, surgical, and social history to determine the patient's candidacy.

There are few definitive contraindications to a surgical approach. Ultimately, those that would contraindicate any major surgery are strict contraindications for head and neck microvascular reconstruction (HNMVR) such as MELD >12, severe aortic stenosis, severe cardiac or pulmonary disease, and unresectable disease. Relative contraindications include surgery that will irreparably destroy basic essential functions, surgery that would render them unable to ever leave the hospital, and an inability to consent to surgery.

The surgeon's doorway exam or "eyeball test" should be strongly considered; however, this must be reinforced with objective data. An analysis of medical, surgical, nutritional, and psychosocial factors preoperatively is critical. Fortunately, with advanced planning, many conditions can be managed to minimize perioperative risk. While the literature is scant regarding medical considerations specifically for HNMVR, one can generally extrapolate the data from studies focused on any major surgical intervention. The patient's own medical history is also important to consider, and tightly intertwined with this

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is their current substance use, nutritional status, and mental health. The surgeon is encouraged to enlist available multidisciplinary consultants such as primary care physicians, cardiologists, pulmonologists, endocrinologists, social workers, nutritionists, speech language pathologists, dentists, and anesthesiologists to exercise their expertise and help optimize complex patients prior to these major surgeries. The head and neck microvascular surgeon plays a key role in coordinating care among these team members, and open and early conversation with anesthesia colleagues is critical.

In this chapter, we review important modifiable and nonmodifiable considerations when evaluating a patient for surgical readiness for HNMVR.

Medical Comorbidities and Their Preoperative Management

A thorough medical, surgical, and social history is essential when assessing a patient prior to surgery. Preoperative checklists and guidelines can be helpful to ensure that specific conditions have been assessed [3, 4]. An example of a preoperative checklist for a head and neck free flap patient that addresses many of their common issues is depicted in Table 1.1. In addition to careful questioning of the patient and caregivers, a review of referring records and primary care notes may provide essential information. Diagnoses, prior hospitalizations, medications, and prior surgeries all play an important role when determining surgical candidacy and reconstructive options. Preoperative blood work including comprehensive blood count (CBC), basic metabolic panel (BMP), international normalized radio (INR), prothrombin time (PT), and partial thromboplastin (PTT) should be obtained preoperatively routinely. Other laboratory studies may be relevant depending on the clinical scenario and past medical history including liver function tests (LFTs), thyroid-stimulating hormone (TSH), prealbumin, and others. Important considerations for the physician exam are listed in Table 1.2.

Table 1.1 An example of a preoperative checklist for a head and neck free flap patient to assess common and important considerations

Category	Considerations
Diagnosis/pathology	Pathology-confirmed diagnosis if applicable
Available imaging	Imaging and dates
Donor-site evaluation/selection	Examine and specify donor site
Preoperative labs	CBC, CMP, PT, PTT, INR, type, and screen
History of hypothyroidism or radiation	TSH level
Current feeding access	Oral/gastrostomy tube
Nutrition assessment	Dietician appointment, prealbumin, ferritin
Social work consultation	Perioperative support, discharge needs
Tobacco, alcohol, and substance use screening	Smoking cessation, preparation for withdrawal
Swallow assessment	Preoperative speech language pathology consult
Dental assessment	Dentition/occlusion
Current anticoagulation	Instructions for preoperative discontinuation
History of DVT/VTE	Use of mechanical compressive devices and chemical prophylaxis
History of urinary issues or prostate hypertrophy	Foley placement
Preoperative consultations/risk assessments	Anesthesia, cardiology, pulmonology
Perioperative pain management	Current pain medications, plan inpatient

As with any complex and prolonged operation, comorbidity burden affects medical outcomes after HNMVR [5–9]. Comorbidity burden is strongly associated with postoperative emergency department visits, unplanned readmission, and cardiac complications [10–13]. Patients with a heavy comorbidity profile that do not have any specific contraindications to surgery may benefit from the involvement of the primary care physician and anesthesia colleagues to ensure that the patient is optimized.

Risk calculation tools and scales are useful to estimate the perioperative risk of complications and functional decline. These tools may help in determining if the estimated risks for a particular

Table 1.2 Important aspects of the physical exam prior to HNMVR

Factor/site	Considerations
General exam	Ambulatory assist devices Nutritional status Evidence of substance use/abuse
Neurologic/ psychiatric	Comprehension Ability to consent Ability to participate in care and rehabilitation
Primary site assessment	Ability to restore reasonable function Resectability
Dental assessment	Number and quality of teeth Occlusion
Neck assessment	Evidence of prior treatment or surgery Adequate skin for closure Presence of recipient vessels
Upper extremity donor sites	Evidence of prior surgery Allen's test and reverse Allen's test Evidence of prior axillary dissection
Lower extremity donor sites	Evidence of lymphedema Evidence of PVD (smooth skin, hair loss, pulses) Evidence of prior surgery such as vein graft harvest

patient are unacceptably high, contraindicating surgery, and at minimum to counsel patients about what to expect after surgery. The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) is a highly practical and free online tool that can provide patient-specific information using 20 patient predictors and the procedure code to calculate various outcomes including cardiopulmonary complications. Other tools include the Charlson Comorbidity Index (CCI) and the American Society of Anesthesiology (ASA) score.

Older age is not a specific contraindication to surgery. Older adults must be individually assessed for surgical fitness. A number of evaluation tools exist to estimate perioperative risk in this population, such as sarcopenia measurements [14, 15], comprehensive geriatric assessment, modified frailty index [16], and Fried's frailty score [17], among others [18, 19].

Though not a contraindication to surgery, prior treatment including radiation, particularly over 60 Gy, and chemotherapy may impact outcomes postoperatively. Prior treatment has been associated with fistula formation, worse functional outcomes, flap viability, and infection—likely related to treatment-induced tissue fibrosis, inflammation, and a prothrombotic state [7, 20–24]. While a priori knowledge of prior treatment does not necessarily affect surgical candidacy, the additional risks should be discussed with the patient. Detailed perioperative considerations for patients who have been previously treated with radiation and chemotherapy will be discussed in a subsequent chapter.

Cardiac Comorbidities

Cardiac risk assessment preoperatively can identify modifiable and nonmodifiable factors that are critical to prepare for HNMVR. Symptomatic severe aortic stenosis, poorly controlled symptomatic tachyarrhythmia or bradyarrhythmias, acute ischemic heart disease, and decompensated congestive heart failure may contraindicate major surgery [25]. Coronary artery disease in itself is not associated specifically with free flap failures [26].

There are several tools available to determine a patient's specific risk. Basic initial assessment with functional capacity such as inability to climb more than two flights of stairs (metabolic equivalent tasks) may indicate that further assessment is warranted. If the patient cannot perform four metabolic equivalent tasks (METs) or greater, their risk for perioperative cardiovascular complication is doubled [25]. The Lee Cardiac Risk Index (LCRI) is a short assessment that is predictive of cardiovascular complications [27]. Other scores previously discussed that can be implemented include the ASA score and Adult Comorbidity Evaluation (ACE-27) score.

In conjunction with anesthesia, primary care, and/or cardiology, some interventions may reduce perioperative risk. Perioperative beta-blockers and

statins may be protective. Routine use of aspirin preoperatively for low-risk patients undergoing noncardiac surgery is not associated with reduced risk of perioperative events but may be associated with bleeding events [28]. Anticoagulation medications for atrial fibrillation are discontinued from 2 to 5 days preoperatively depending on the agent pharmacokinetics [25]. A study assessed the risk of perioperative arterial thromboembolism (ATE) in atrial fibrillation randomizing patients to bridging with low-molecular-weight heparin or placebo. ATE was not lower with bridging for atrial fibrillation patients, but bleeding rates were higher (3.2% vs. 1.3%, $p = 0.005$) [29]. Patients on warfarin for mechanical mitral or aortic valves may require bridging. Patients with cardiac stent placement within the past 1 year are at increased risk of perioperative events [25]. Non-emergent surgery should be delayed at least 30 days after bare metal stent placement and at least 3–6 months after drug-eluting stent placement [25].

The surgeon should involve a patient's cardiologist and the anesthesiologist to determine which tests and interventions may be warranted to minimize perioperative cardiac risks. Routine testing is not indicated for low-risk patients with good functional status.

Coagulation Disorders

Both hypercoagulable conditions and anticoagulated states must be carefully considered and actively managed when preparing for surgery. Patients with a malignant diagnosis are fundamentally in a hypercoagulable state. Other conditions that the surgeon may encounter include prior venothromboembolism (VTE), factor V Leiden, antiphospholipid syndrome, and other diagnoses associated with a hypercoagulable state. Occasionally, these can be contraindications to free flap surgery.

A recent study of 1061 patients undergoing HNMVR demonstrated that a history of VTE was independently associated with free flap pedicle thrombosis (OR 95% CI = 3.65 (1.12–11.90), $P = 0.032$). Prior pulmonary embolism specifically was associated with greater than seven times higher risk of flap failure [30].

Anticoagulation medications typically must be interrupted prior to surgery to prevent major bleeding risks. Tools are available to estimate the risk of thrombosis with cessation of therapeutic anticoagulation relative to the risk of perioperative bleeding with the medications. Any procedure longer than 45 min is considered a high-bleeding-risk procedure [31]. If the risk of interrupting these medications is unacceptably high, this may be a contradiction for HNMVR. Patients with a very recent VTE who require surgery may benefit from placement of an inferior vena cava filter in order to safely interrupt anticoagulation. Other patients with a congestive heart failure, hypertension, older age, diabetes, and previous stroke/transient ischemic attack (CHADS2) score of 5 or greater may require bridging anticoagulation.

Rarely, the surgeon may encounter a patient with a bleeding disorder such as von Willebrand disease or hemophilia. While there is no specific data in head and neck free flap surgery about these issues, one can extrapolate management from other high-bleeding-risk procedures. A hematologist consultation is essential to determine the exact timing and agent administered to minimize perioperative bleeding risk.

Involvement of the primary care physician or hematologist may be helpful to determine the optimal perioperative management of these patients to minimize microvascular thrombosis, other thromboembolic complications, and bleeding complications.

Peripheral Vascular Disease

While PVD may not be a direct contraindication to HNMVR, this diagnosis is heavily considered when choosing a donor site especially from the lower extremity. Arterial changes associated with this disease may make microvascular anastomoses more technically challenging to perform. Donor site considerations will be discussed in detail in subsequent chapters.

PVD is associated with several other serious medical conditions such as coronary artery disease, which may affect anesthesia tolerance. While peripheral vascular disease may be associ-

ated with anesthesia complications, the association with free flap loss is unclear [26, 32, 33]. Patients with PVD warrant subsequent cardiac risk assessment prior to surgery, but PVD in itself is not necessarily a contraindication for HNMVR.

Pulmonary Dysfunction

Many patients with head and neck cancer have a history of heavy smoking and potentially associated lung disease. Major pulmonary comorbidities, especially those that are actively symptomatic and require home oxygen therapy, may result in significant medical complications intraoperatively and perioperatively with prolonged surgeries. Unexplained dyspnea or symptoms of untreated pulmonary dysfunction should be elicited in the patient history. Other patients who may be at risk of pulmonary complications perioperatively include those with obesity, poor overall health, and asthma [34]. Limited exercise capacity may also be indicative of pulmonary dysfunction and perioperative risk [35]. A diagnosis of chronic obstructive pulmonary disease (COPD) (Fig. 1.1) portends a relative risk of 2.7–4.7 for postoperative pulmonary complications [34, 36, 37]. Patients with this diagnosis should be optimized with inhaled medications, incentive spirometry, or oral corticosteroids [34].

Selective assessment with preoperative pulmonary risk stratification may be warranted, but this test is potentially of limited value for decision-making in non-pulmonary surgeries. Patients with poor outcomes on PFTs may still undergo surgery with acceptable risk [34, 36–39].

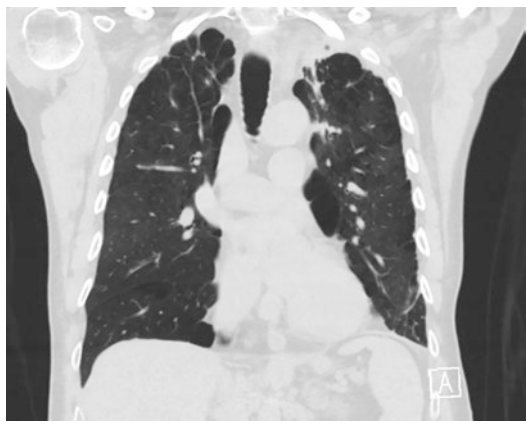

Fig. 1.1 Computed tomography demonstrating radiographic findings of chronic obstructive pulmonary disease

Diabetes

Though not a definitive contraindication to surgery, poorly controlled diabetes contributes to worse outcomes, and this condition should be optimized prior to surgery to reduce risk. Diabetes is associated with a higher rate of perioperative complications, up to five times more likely for patients undergoing free flap surgery [40–43]. An analysis of the NSQIP database reported that patients with diabetes were significantly more likely to have complications including postoperative ventilator dependence, reintubation, cardiac complications, and surgical complications [44]. A systematic review and meta-analysis including 7890 patients reported that diabetic patients have a 1.76 times increased risk of complications with free flap surgery [45]. Similar findings have been reported in other studies [11, 40, 41].

Preoperative optimization for diabetic patients can mitigate risks related to major operations [46–48]. Preoperative diabetes optimization programs that utilize multiple practitioners such as endocrinologists and nutritionists may be helpful to comprehensively manage these patients [49]. Fortunately, guides are available to aid in the preoperative assessment and management of these patients [50]. Hemoglobin A1c levels over 8% may escalate the situation, and severe hyperglycemia with a glucose >250 mg/dL contraindicates elective surgery [50]. Involvement of the patient's primary physician or endocrinologist is essential for patients with poor glycemic control.

Hypothyroidism

While routine screening for thyroid dysfunction prior to major surgery is not indicated, patients with symptoms and risk factors may benefit from assessment prior to surgery. Prior radiation treat-

ment to the head and neck is a risk factor for hypothyroidism and has been reported in up to 32% of patients within the first year after therapy [51]. Because the consequences of poorly controlled hypothyroidism are significant in HNMVR cases, preoperative testing of TSH is advisable for patients with prior head and neck treatment with radiation, prior diagnosis of hypothyroidism, or history and physical exam evidence of hypothyroidism.

The multisystem effects of hypothyroidism can result in reduced cardiac output, decreased clearance of medications, gastric outlet slowing and postoperative ileus, increased susceptibility to anesthetics and narcotics, and electrolyte abnormalities. Relevant to free flap surgery, hypothyroid patients have an increased risk of intraoperative hypotension when compared to euthyroid patients [52]. Poorly controlled hypothyroidism is associated with major wound-healing complications postoperatively [53–55]. It is also associated with a significantly increased risk of fistula formation [54, 56], postoperative sepsis [57], and increased readmission rates [53].

Ideally, a patient is euthyroid or mildly hypothyroid prior to proceeding with surgery. Checking a thyroid-stimulating hormone (TSH) level and free T4 level when first evaluating the patient for surgery may allow some time to initiate treatment preoperatively with thyroid hormone. Oral levothyroxine can be prescribed at a typical initial dose of 1.6 mcg/kg/day, with a recheck of TSH in approximately 6 weeks. If surgery is urgent or emergent, intravenous levothyroxine is given at a loading dose of 200–500 micrograms followed by a daily IV dose of approximately 50% of the weight-based oral dosage. Oral or intravenous liothyronine can also be added in severe, nonresponsive cases. Involvement of an endocrinologist in these cases is encouraged. The physician should proceed with caution prescribing these medications in patients with cardiac ischemic disease.

Renal Disease

Renal diseases such as chronic kidney disease and end-stage renal disease should be carefully considered prior to surgery but are not strict contraindications to proceeding. Chronic kidney disease has been associated with an increased perioperative risk of bleeding [58]. End-stage renal disease (ESRD) is especially challenging as it is associated with a number of issues such as cardiovascular function, coagulation, electrolyte abnormalities, fluid management challenges, and pharmacokinetic/pharmacodynamic alterations. The risk of 30-day mortality is four times higher in those with ESRD undergoing elective vascular procedures [59]. Active involvement of the nephrologist with dialysis the day before surgery and clear communication with anesthesiologist are required to minimize complication risk such as electrolyte abnormalities and cardiopulmonary complications of fluid overload.

Hyponatremia

Hyponatremia, a prevalent issue in cancer patients, is a common finding in head and neck cancer patients. This electrolyte abnormality may be caused by decreased oral intake, pain, alcohol abuse, syndrome of inappropriate antidiuretic hormone, hypothyroidism, and systemic chemotherapies. In a review of over 800,000 patients, preoperative hyponatremia (<135 mEq/L) was associated with a higher risk of 30-day mortality (5.2% vs. 1.3%), greater risk of perioperative major coronary events, wound infections, and pneumonia [60]. In head and neck surgery patients specifically, preoperative hyponatremia was associated with a 60% overall risk of complications including cardiac, renal, and respiratory complications and increased length of stay [61]. It has also been associated with increased rates of 30-day readmission [62]. Involvement of a nephrologist may be appropriate to investigate causes and administer appropriate treatment. Overly rapid correction of hyponatremia can rarely result in cerebral edema and mortality from rapid osmotic shifts. If the patient's hyponatremia is subacute/acute, hyponatremia <125 mEq/L is a contraindication to surgery, and correction is required prior to a prolonged anesthetic and any elective major head and neck operation.

Soft Tissue, Connective Tissue, and Dermatologic Diseases

Rarely, the surgeon may encounter patients with severe soft tissue and connective diseases or extensive dermatologic conditions such as scleroderma or severe psoriasis that may be challenging for cutaneous tissue harvesting and successful wound healing. Though there is limited evidence in this particular area, severe disease with high risk of poor wound healing or contracture may be a contraindication to surgery as this would result in unacceptable outcomes. These patients may also be on immunosuppressant medications, which may increase the risk of postoperative wound infection and breakdown. Patients with these diagnoses should be carefully considered on an individual basis based on severity and in conjunction with the patient's primary treating physician.

Preoperative Considerations for Substance Use

Smoking and tobacco use are major risk factors for the development of head and neck cancer, and as a result, many surgical patients would have previously smoked heavily or are active smokers. It is well known that smoking perioperatively has risks specifically related to head and neck surgical sites and medical complications. Complication rates in current and former smokers have been reported to be as high as six times higher than nonsmokers undergoing head and neck surgery (Hatcher 2016) such as wound breakdown and reoperation [63]. The literature is mixed if cessation truly improves surgical complication rates [64–66]. Medical complication rates after surgery are improved with cessation including mortality, pulmonary complication, and intensive care unit stays [67]. Four weeks may be the optimal minimum time frame to observe some improvement in outcomes [68, 69]. Though smoking is not a contraindication to surgery, some surgeons may delay elective HNMVR such as repair for osteonecrosis until the patient has quit smoking in order to minimize the risk of additional wound complications. Fortunately, there are many publicly available, and sometimes free, resources to aid patients in cessation such as nicotine replacement therapy.

Heavy alcohol use is not a contraindication to surgery, with few exceptions. Active intoxication without the ability to consent to surgery is a contraindication to surgery. In addition, heavy alcohol use may result in decompensated medical issues such as hyponatremia and liver failure, which may be a contraindication to a general anesthetic. Patients with chronic heavy alcohol use are at elevated risk for postoperative complications including flap failure [70–72] and should be counselled accordingly. Patients should be encouraged to wean slowly prior to surgery.

Active cocaine and/or methamphetamine may be a contraindication to anesthetics and HNMVR. Patient metabolism of anesthetic drugs may be altered, and patients may be unable to consent for surgery. However, existing literature supports that recent cocaine use may not be associated with certain anesthetic or medical complications postoperatively [73]. These substances do cause vasoconstriction, which may affect flap microcirculation.

Nutritional Assessment and Intervention

A careful assessment of the patient's medical history and a general physical examination, as noted above, importantly help prepare the patient for their reconstructive surgery. However, this patient population also often faces significant nutritional challenges preoperatively. These challenges may range from undernutrition and malnutrition to sarcopenia, cachexia, and overall frailty. Identifying these conditions and possible intervention and preventive measures will be outlined throughout this section.

Nutritional management may not seem like a relevant skill for the microvascular free flap surgeon; however, free flap outcomes are greatly intertwined with the patient's nutritional status [74]. Thus, screening for malnutrition is a vital part of these patients' preoperative management.

The surgeon may benefit from pairing with a registered dietician or nutritionist to help augment this aspect of the patient's care, or they may choose to screen the patient themselves prior to deciding on a referral.

Defining Malnutrition

To begin, it is important for the surgeon to consider the patient's risk factors for malnutrition. For example, a patient with a malignant tumor may have marked pain precluding their ability to take in enough food by mouth, or their tumor may have grown to such an extent that they have lost appropriate function to swallow. Difficulties with oral intake are very frequently reported in our head and neck cancer patients, and while these symptoms may worsen after surgery, chemotherapy, and/or radiation therapy, the patients often experience these symptoms even before beginning their treatment [75, 76]. These symptoms are collectively termed nutritional impact symptoms (NISs). However, aside from the usual symptoms experienced by most cancer patients (pain, anxiety/depression, nausea/vomiting), head and neck cancer patients' tumors directly can result in additional NIS such as dental pain, trismus, and restricted tongue mobility, to name a few [76, 77]. Even those without a head and neck cancer may experience significant NIS due to the location of their injury or surgical defect. For example, a patient who has suffered a trauma or a fracture from necrosis of the mandible may require an altered diet due to their severe discomfort. These NISs typically result in significant weight loss in our patients and are an important part of the patient's history to make note of during the presurgical assessment.

In general, weight loss is due to either increased energy expenditure or decreased caloric intake, and both are very multifactorial in our cancer patients. As little as an involuntary 5% loss of body weight in a 6-month period is associated with increased complications and longer hospital stays [78]. However, when assessing weight alone, the most reliable definition of malnutrition is a greater than 10% unintended weight loss [79]. This assessment of change in weight can be expeditiously done at the patient's preoperative appointment or at a dedicated nutritional consultation. Furthermore, at a minimum, the patient's vital signs, including their body mass index (BMI), are likely recorded and calculated at each office visit. BMI is often used as a defining feature of malnutrition, with some studies citing BMI <20 or BMI <18.5. However, BMI alone is not a reliable marker of malnutrition, as even those with high BMI are at risk for malnutrition [79]. To clarify, those who originally had a higher BMI may still be malnourished if they have lost a significant amount of weight and muscle mass in a short time frame. This loss of muscle mass is termed "sarcopenia" and will be reviewed later in this section.

Cachexia

Cachexia is a multifactorial syndrome that includes weight loss and increased energy expenditure, and in the setting of cancer, this increased expenditure is due to the metabolic demands the tumor exerts on the patient. Thus, when related to cancer, this is termed cancer cachexia syndrome. Numerous proinflammatory cytokines are upregulated in these patients, with interleukin (IL)-1, IL-6, and tumor necrosis factor (TNF)-alpha playing key roles [80]. Treating cancer cachexia is thus complicated and multifactorial and should ideally focus on improving nutritional intake/caloric intake, improving muscle mass through physical therapy and strength training, and possibly including pharmacologic intervention to decrease inflammation, for example.

Sarcopenia

Sarcopenia is a progressive loss of muscle mass and is highly prevalent in our head and neck cancer patients. This is again due to the location and nature of the patients' tumors, but it is also due to the proinflammatory state underlying their cancer. Where BMI is lacking in its ability to identify body compositional differences, assessing sarcopenia prevails. Assessing for sarcopenia in the presurgical setting is arguably

extremely important, as numerous studies have identified an association between sarcopenia and decreased survival in cancer patients [14, 81]. In head and neck cancer patients specifically, sarcopenia is reportedly present in anywhere from 30% to 60% of patients and is a poor prognosticator [82, 83]. In one study of 260 patients undergoing major head and neck surgery, sarcopenia was a significant negative predictor of both 2-year and 5-year overall survival on multivariate analysis [14]. Specific to patients undergoing complex head and neck reconstruction, sarcopenia was associated with an increased rate of intraoperative blood transfusions and postoperative complications, including wound disruption, fistula, prolonged ventilation, and flap-specific complications [15]. Thus, identifying and attempting to mitigate sarcopenia and malnutrition preoperatively are extremely important.

Sarcopenia can be identified by assessing the patient's muscle mass, muscle strength, and physical performance. Low muscle mass alone reveals a probable chance of sarcopenia being present, with low muscle mass plus decreased muscle strength being a defining feature [84]. The gold standard for assessing muscle mass and sarcopenia is by assessing skeletal muscle index (SMI) via imaging. While whole-body skeletal muscle volumes would be ideal, this would be extremely time consuming and not practical in a clinical practice. Thus, cross-sectional measurements of skeletal muscle index (SMI) at the L3 vertebral level are most commonly performed and correlate with whole-body SMI. At this level, sarcopenia is often defined as SMI $\leq$41.6 cm^2/m^2 in men and $\leq$32.0 cm^2/m^2 in women [15]. However, in head and neck cancer patients, it is far more common to have imaging at the cervical spinal level rather than of the abdomen. Studies evaluating images at the C3 vertebral level have revealed promising results, with SMI at C3 correlating to L3 SMI [85, 86]. Head and neck reconstructive surgeons thus commonly have these images available to assess for sarcopenia in their patients and should strive to identify these patients for presurgical intervention whenever possible.

Medical optimization for sarcopenic patients is often focused on exercise interventions, with an improvement in muscle strength often more readily achieved than an increase in muscle mass [87]. However, the issue in our head and neck patients is that many do not have the luxury of time to implement a presurgical exercise program prior to their surgery, especially if they are pending surgery for cancer. It is thus clear that while assessing for sarcopenia is beneficial to our surgical patients and is associated with important clinical outcomes, it is often not an easy feat to identify or to mitigate.

Additional Nutritional Screening Methods

As preoperative imaging assessment of SMI is time consuming and requires specialized training, it is admittedly not the most accessible way for the microvascular surgeon to assess for malnutrition in the preoperative setting. The Patient-Generated Subjective Global Assessment (PG-SGA) is a valid screening tool used to assess malnutrition in cancer patients and is particularly attractive as it realistically assesses the patient's nutritional status as a dynamic and changing process throughout their cancer treatment [88]. Head and neck cancer patients have found the PG-SGA to be beneficial in increasing their own self-awareness regarding their nutritional status [89]. The PG-SGA specifically assesses the patient's weight history, food intake, symptoms, and activities/function and combines these four patient-reported categories with additional variables input by the provider, which include metabolic demand (presence of fever, use of corticosteroids) and physical examination (muscle and fat status). The patient then receives both a numeric and letter score, with the numeric score acting as a continuous variable that assists the clinician with categorizing the patient into specific triage categories (Table 1.3).

Laboratory markers have additionally been historically used to assess for malnutrition, specifically albumin and prealbumin. However, both are acute-phase reactants that have altered synthesis in times of inflammation and thus have limited use in the setting of active cancer and acute surgery. Thus, more useful is combining

Table 1.3 Nutritional triage recommendations based on PG-SGA scores

0–1	No intervention currently required. Reassess on routine basis during treatment
2–3	Patient and family education by dietician, nurse, or others
4–8	Requires intervention by dietician
≥9	Critical need for improved symptom management or intervention

these laboratory markers into aggregate scores, which may predict nutritional status and outcomes, such as the prognostic nutritional index (PNI) and geriatric nutritional risk index (GNRI).

The PNI is calculated using the serum albumin level and total lymphocyte count, and a score less than or equal to 40 has reportedly been associated with a high complication rate and poor prognosis. Furthermore, when used in patients undergoing head and neck surgery with free tissue transfer reconstruction, PNI less than or equal to 40 was a significant risk factor for adverse surgical outcomes, postoperative complications, and prolonged hospitalization (Imai 2020). The geriatric nutritional risk index (GNRI), which has somewhat of a misnomer as it is beneficial in more than just a geriatric population, similarly has been shown to be a promising prognostic tool in patients with advanced head and neck cancer [90]. The GNRI is calculated with the serum albumin, patient's current body weight, and their ideal body weight. Ideal body weight is a standard calculation measured differently for men and women based on their height. These tools and calculations are summarized in Table 1.4.

Table 1.4 Tools for calculating nutritional indices

Prognostic nutritional index	[10 × serum albumin (g/dL)] + [0.005 × total lymphocyte count]
Geriatric nutritional risk index	[1.489 × serum albumin (g/L)] + [41.7 × (body weight/ideal body weight)]
Ideal body weight	Men: 50 + (0.91 × [height in cm—152.4] Women: 45.5 + (0.91 × [height in cm—152.4]

Nutritional Intervention

Ensuring adequate enteral nutrition in any form is of utmost importance. Thus, carefully identifying which patients may require a preoperative percutaneous endoscopic gastrostomy (PEG) tube may be key in ensuring that the patient receives adequate nutrition.

Newer, immune-enhancing formulas, termed immunonutrition, are gaining traction in the cancer world and as an important supplement in the perioperative setting. Immunonutrition contains arginine, omega-3 fatty acids, and dietary nucleotides and promotes an attractive anti-inflammatory and immune environment [91]. Use of these formulas for as little as 5 days preoperatively, and ideally continuing their use through the patient's hospitalization and initial postoperative period, is associated with improved wound healing, decreased complications, and shortened hospital stay [92, 93].

Aside from specifically using immunonutrition, oxandrolone is an interesting pharmacologic agent thought to improve cachexia. Oxandrolone is an anabolic-androgenic steroid approved by the Food and Drug Administration (FDA) for weight gain following disease-related weight loss and has been shown to improve weight in cancer patients [94]. In 18 head and neck cancer patients treated perioperatively twice daily, oxandrolone resulted in an improvement in prealbumin levels and in subjective wound healing [95]. However, additional larger scale studies with more rigid end points are needed to define which patient more clearly would benefit from its use preoperatively.

Mental Health Assessment

Just as a thorough examination of the patient's physical and nutritional well-being is extremely important preoperatively, the head and neck patient's mental health and psychological well-being should also be assessed. These patients are facing a surgery which will potentially be physically disfiguring and functionally result in difficulties in speech and swallowing, all of which are essential for social interaction and maintaining

relationships. Thus, it is not surprising that approximately 40% of head and neck patients report depression, and patients with oral cavity, pharynx, and larynx cancer are among the greatest at risk for suicide [96, 97].

There are numerous tools available for screening for depression in the outpatient setting. Some may be concerned that there is insufficient time in an already busy consultation or presurgical visit to also screen for depression; however, the very simple question "Do you often feel sad or depressed?" is surprisingly effective at screening for depression [98]. To take this one step further, the patient health questionnaire (PHQ) 2 question screen is highly efficient at identifying those at risk for depression and when coupled with the 9-question version (PHQ-9) its specificity for identifying depression increases to 94%, with a sensitivity of 97% [99].

For those looking for and able to perform a more detailed screen, the Quick Inventory of Depressive Symptoms is available for use both by the clinician and for self-reporting from the patient (QIDS-C versus QIDS-SR, respectively). The self-report method is particularly appealing to some of our head and neck patients who have difficulty with verbal communication, and those who score greater than 4 are at a higher risk of developing moderate-to-severe depression during their treatment [100].

With these tools and the known risk of depression in our patients, it is thus extremely important to consider screening each preoperative patient. Especially in patients with cancer who are undergoing head and neck reconstruction, screening for and diagnosing depression can hopefully improve compliance with treatment and survival [101].

Conclusion

Surgical readiness for HNMVR, a major operation, reflects an interplay of external modifiable factors and inherent, non-modifiable factors. To avoid catastrophic outcomes and complications, mitigation of modifiable factors and management of non-modifiable factors may be undertaken in a multidisciplinary fashion.

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Surgical Assessment

2

Omar Breik and Sat Parmar

Radiological and surgical assessment of head and neck microsurgical patients is crucial to accurate diagnosis, treatment planning, and determination of the ideal management for each individual patient. With the advent of patient-specific diagnosis, and treatment considerations, it is vital that the appropriate investigations are selected in evaluating individual patients. Careful attention to the medical history, comorbidities, and specific patient questions may help avoid adverse outcomes and potentially catastrophic results.

In this chapter, we evaluate the role of clinical and radiological assessment in guiding surgical management, focusing on important factors to consider in specific patient circumstances such as the previously operated patient, previously irradiated patient, and age-based considerations. For every reconstructive patient, the following factors need to be considered:

- Tracheostomy—Is it required or not?
- Resection—planned resection—structures to be sacrificed, structures to be preserved, and potential challenges.
- Access—Is an access procedure required to perform an adequate resection.
- Vessels—vessels available for potential microvascular anastomosis.
- Reconstruction—What are the reconstructive options to replace with like plan A, plan B, and plan C?
- Rehabilitation—Plans for rehabilitation.

This chapter touches on all of these factors but focuses on and mainly discusses the indications for tracheostomy in head and neck reconstructive patients, approach to patients with virgin or previously treated necks including options for managing the vessel-depleted neck, and factors to consider during decision-making when selecting the ideal flap for reconstruction. Overall, each individual patient requires careful assessment, and although protocols are valuable in guiding the management of these patients, clinical acumen and experience are ultimately essential to making the correct choices for the individual patient.

Tracheostomy Indications

Temporary elective tracheostomy should be seriously considered by the majority of surgeons performing microvascular reconstruction of the head and neck [1, 2]. The value of a tracheostomy in these patients is obvious, such as reducing the

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risk of catastrophic upper airway obstruction post-operatively, difficulties of emergency intubation in case of return to theatre, and reduction of aspiration [3]. However, a tracheostomy still carries the significant risks of obstruction, tube displacement, chest infection, haemorrhage, a longer hospital stay, and potentially tracheal stenosis [4, 5].

In addition, there is a significant psychological impact for the patient recovering from microvascular reconstruction, with the majority of patients expressing that they felt significant distress and fear from having a tracheostomy with detrimental effects on their ability to sleep, sensation of choking, and discomfort from a temporary tracheostomy [1]. Hence, it is prudent that we consider these potential impacts and that we are more selective when deciding which patients require a tracheostomy.

Several units have moved away from temporary tracheostomy, and depending on the patient would consider either immediate extubation or delayed extubation 24-48 h after surgery [4–7]. However, often these options require management in a high-dependency unit or intensive care for observation, while often a tracheostomy patient can be admitted to an experienced ward instead.

So then, how do we decide which patient requires a tracheostomy and which patient does not? There are no validated algorithms to help the surgeon choose the ideal patient to have a tracheostomy. Several scoring systems have been proposed, and each has its own limitations. Cameron et al. published the first scoring system that used retrospective data from 1999 to 2001. Although this scoring system yielded acceptable results, the scoring system only focused on the site of resection and type of reconstruction used [8]. In turn, they did not include burden of disease, or comorbidities to the algorithm. Kruse-Losler et al. (2005) also published a scoring system based on retrospective data [9]. However, similarly, their data is based on data from almost 30 years ago, and although it included significant comorbidities and personal factors such as smoking and alcohol intake, it was based on patients who had soft tissue reconstructions, and all patients with T3 or T4 tumours underwent a tracheostomy. Gupta et al. (2016) published the CASST criteria for deciding on the need for elective tracheostomy [10]. Although they reported good specificity and sensitivity, the 10-point scoring system is difficult to apply and cumbersome. Additionally, their data is based on a large proportion of patients who had small resections and no reconstruction with flaps. Singh et al. (2016) performed a retrospective review of 78 patients who had microvascular reconstruction of the head and neck and compared the outcomes of those who had a tracheostomy and those who had delayed extubation. The authors proposed an algorithm to determine the ideal patients to receive a tracheostomy. In summary, the algorithm suggested that any oral resection with bilateral neck dissection or an oropharyngeal resection with an access procedure is at higher risk of upper airway obstruction and should hence receive an elective tracheostomy [4]. Patients undergoing oral resection and reconstruction with only a unilateral neck dissection should be considered for delayed extubation within 24-48 h rather than a tracheostomy unless they have obstructive sleep apnoea, obesity, poor lung function, or difficult intubation. Although this algorithm provides a good framework, it does not include other important factors such as comorbidities that increase the risk of bleeding and swelling, and specific location of the resection and reconstruction which should also be considered.

In 2018, Mohamedbhai et al. proposed the TRACHY score, which characterized T staging, type of reconstruction, anatomical location of tumour, coexisting conditions (measured as ASA score), history (of head and neck surgery or radiotherapy), and laterality (or need for bilateral neck dissection) [11]. This score was based on a large retrospective series of 149 patients and identified that the most important factors associated with the need for tracheostomy included previous radiotherapy, bilateral neck dissection, and two or more flaps [11]. This study reported that a score of 4 gave a sensitivity of

91.4%, a positive predictive value of 90.9%, a specificity of 90.8%, and a negative predictive value of 88.2%. However, it has not been validated in larger prospective or randomized trials. Although it is the most 'user-friendly' score available, this study has some important limitations. In the retrospective series data, there was a surprising number of patients who required late tracheostomy due to clinical features of airway obstruction and did not report on rate of returns to theatre in the cohort, or details of length of post-operative intubation, or reasons for late tracheostomy, or other relevant details that may be relevant to a preoperative decision on whether a tracheostomy is needed. The most glaring limitation however is that it compares those who should have tracheostomy or undergo delayed extubation. Overall, we consider delayed extubation at 24-48 h somewhat counterintuitive as the majority of post-operative oedema is expected between 48 and 72 h post-operatively, so delayed extubation at 24–48 h may miss the time when risk of upper airway oedema is likely to be the greatest. It also requires intensive care support compared to a tracheostomy, which can be easily managed on the ward by an experienced nursing team. Also, when deciding on the appropriateness of post-operative extubation, flexible nasoendoscopy while intubated to assess for a clear upper airway is difficult due to secretions, multiple tubes, and soft tissue collapse while sedated. However, teams experienced with delayed extubation report good predictable results [7]. In our experience, if the head and neck surgeon is worried enough about upper airway obstruction for the first 24–48 h to keep the patient intubated, then a tracheostomy is probably warranted.

Although these scoring systems are yet to be validated through large prospective trials, they all emphasize the importance of considering individual factors on a case-by-case basis. In our experience, a tracheostomy is always performed in cases requiring oropharyngeal resection, bilateral neck dissection at the same time as reconstruction, and difficult intubation; in previously irradiated patients; and in those with comorbidities that increase the risk of complications such as thrombotic, bleeding, or airway complications. A tracheostomy is rarely performed for maxillary reconstructions where the soft palate is minimally involved, benign disease where minimal soft tissue is resected and only neck vessel access is required, and those with mainly facial soft tissue resection and reconstruction. The remaining patients are considered on a case-by-case basis.

In a favourable neck where landmarks are easy to palpate, the authors prefer percutaneous tracheostomies over open tracheostomies. Percutaneous tracheostomies are quicker, have fewer complications such as communication of the tracheostomy with the neck wound, and heal much faster once the patient is decannulated.

The 'Virgin' Untreated and the Previously Treated Neck in the Head and Neck Microsurgical Patient

The ideal situation in microsurgical reconstruction of the head and neck is a patient with a virgin unoperated, untreated neck. However, with the improving survival of head and neck cancer patients, and increasing rehabilitative demands of patients, we are presented with increasingly complex reconstructive scenarios. Decisions regarding the need for tracheostomy, planned incisions, and available vasculature for microvascular reconstruction become more complex in those with previous treatment in the head and neck region, and it makes accurate and thorough history taking, clinical assessment, and radiographic evaluation more critical.

History Taking

During the initial consultation, it is vital to determine if any head and neck operations or interventions have been made. Specifically asking about previous procedures and interventions in the neck is required to not miss anything that may affect the anatomy of the neck. Previous treatments that may not immediately be remembered by patients

during history taking include previous dental infections, pharyngeal procedures for obstructive sleep apnoea, treatment for thyroid disease, treatments for head and neck skin cancers, procedures on the cervical vertebrae, and open or endoluminal procedures for carotid artery stenosis. These interventions can all alter the anatomy of the head and neck and potentially limit the available vasculature for microvascular reconstruction.

Clinical Examination

Clinical assessment of the head and neck commences with visual inspection looking for any obvious deformity, scars, or skin defects or changes that may suggest previous treatment. Oral and pharyngeal examination can also demonstrate ease of access for resection and reconstruction, and whether access procedures may be required to safely remove a tumour or to reconstruct the anticipated defect. Palpation of the neck will demonstrate mobility and suppleness of the overlying tissues and presence of an external jugular vein (EJV) and identify any neck disease that may require more than just a standard selective neck dissection. In previously irradiated patients, determining the field of previous radiation is crucial when considering which incisions to make for neck access, and the nature of the overlying tissues gives the surgeon a clue to the potential difficulties they will encounter when accessing this neck. The long-term inflammatory effects of radiation on vessels make them more prone to intimal thickening, cardiovascular disease [12], and hence potentially vascular complications and microvascular free flap failure [13, 14]. In necks that have been previously dissected and irradiated, vessel access will likely be extremely challenging, and surgeons should seriously consider the contralateral neck for anastomosis, and this in turn has serious implications when it comes to flap selection as the pedicle length is likely to be a major issue. This is particularly challenging in mandibular osteoradionecrosis cases as often the neck has been heavily irradiated, the neck skin is affected by chronic scarring from orocutaneous fistulas, and often the neck has also been dissected. In these cases, accessing the contralateral neck should always be included in the consent, and appropriate choice of flap made to ensure that the pedicle can reach the contralateral neck vessels.

Other important factors that may affect difficulty of the procedure is neck movement, especially in elderly patients and previously treated patients. Limited neck extension and lateral movement warrant an elective tracheostomy as intubation is likely to be challenging, and microvascular anastomosis is likely to be more challenging.

Previous operation notes should be assessed for the type of neck dissection and if any vessels had been sacrificed. Dose of previous radiation would also indicate the degree of scarring that is anticipated.

Preoperative Imaging

Radiographic evaluation is crucial in determining the planned resection, available vasculature for reconstruction, and anticipating challenges. Contrast-enhanced computerized tomography (CT) of the head and neck should be the baseline minimal imaging performed. In cases where previous radiotherapy or surgery has been performed, a dual-phase CT angiogram of the neck and chest should be performed [15]. In addition to highlighting the arterial anatomy of the neck, the dual-phase CTA obtains a delayed set of images which highlights the available venous vasculature. In these patients, ideally, the dual-phase CTA should include the neck and chest, which includes imaging from the skull base to the diaphragm to confirm patency of the internal mammary vessels and the cephalic veins.

Communication Between Teams

If different teams are involved in the patient's care, and one team is performing the ablation while another is performing the reconstruction, then clear preoperative communication is required. All details should be discussed in a

preoperative meeting including planned incisions, anticipated extent of resection, extent of neck dissection required, and anticipated challenges including risk of vascular sacrifice. The reconstructive surgeon should highlight their planned reconstruction and the need for specific vessels that should be preserved where possible. Good preparation and communication may avoid any unexpected surprises on the day of surgery.

Intraoperative Considerations

During neck access or neck dissection, every attempt should be made where oncologically safe to preserve as many vessels as possible for potential microvascular anastomosis. Our goal is to minimize ligation of any venous branches of the internal jugular vein for potential use. The most easily preserved branches which are very useful for anastomosis include the deep/lingual branch of the common facial vein, which travels deep to the posterior belly of digastric. Preserving this vessel and dissecting lateral to it are safe oncologically and protect the hypoglossal nerve. Also, this vein is often of good calibre and can be a get-out-of-jail vessel in the neck if the pedicle is too short to reach the internal jugular vein for tension-free anastomosis. The external jugular vein (EJV) is also easily preserved in a neck dissection. Keeping the EJV in continuity as it extends superiorly into the parotid gland as the retromandibular vein will maintain it as a great additional venous option. The facial artery, although often ligated during level 1B dissection, can be followed to its origin at the external carotid artery (ECA) by dividing the posterior belly of digastric. This often provides an extra 1–2 cm of vessel length for potential anastomosis. Additionally, the superior thyroid artery can almost always be preserved in a selective neck dissection, and every attempt should be made to avoid injuring this vessel as it is an easily accessible arterial option for anastomosis. Being mindful to preserve as many options as possible for microvascular anastomosis is crucial for any reconstructive surgeon.

Management of the Previously Treated and the Vessel-Depleted Neck

The vessel-depleted neck is defined as a situation where the recipient vessels most frequently used for microvascular anastomosis are compromised by either prior surgery, prior radiation, or both (Fig. 2.1). These cases are extremely challenging and require more creative options to ensure that there is a recipient artery and vein for reconstruction. Where possible, if the contralateral neck is not vessel depleted, that would be the ideal solution; however, appropriate flap selection is crucial here to ensure an adequate length pedicle to reach the contralateral neck. Additionally, some patients may seem to have virgin necks, but are in fact 'vessel compromised', and these cases are important to recognize. For example, patients who have had embolization of an arteriovenous

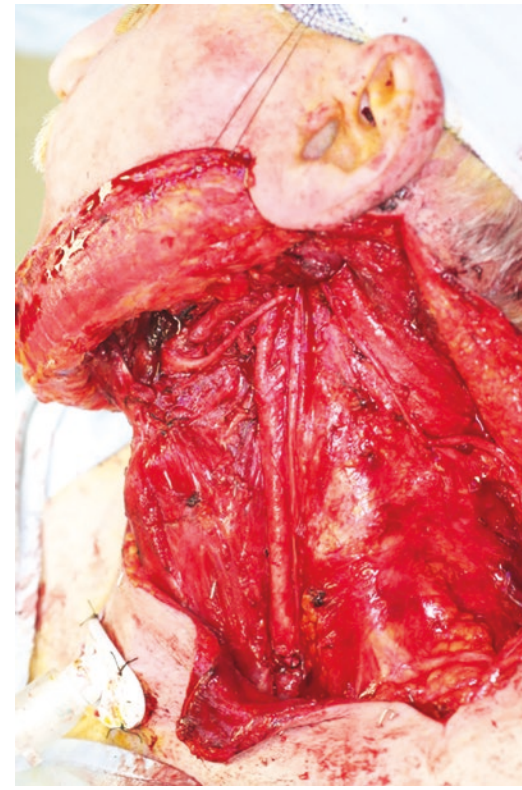

Fig. 2.1 Vessel-depleted neck demonstrating only the common carotid and the internal carotid and no internal or external jugular vein

malformation prior to resection have likely had endovascular catheters passed through most of the branches of the external carotid artery for embolization within 24–48 h of surgery. These vessels have often been injured endoluminally by the catheters and are at higher risk of vascular compromise during and after surgery. Knowing which vessels were accessed is crucial to the operating surgeon, so they can avoid any potentially compromised vessels.

In general, although external carotid artery (ECA) branches are the most commonly used recipient arteries for head and neck reconstruction, alternative options can be used if the ECA is no longer available.

Arterial Options in the Vessel-Depleted Neck

The transverse cervical artery (TCA) is a consistent vessel often encountered during a neck dissection at the base of level IV. It has a variable origin, originating occasionally from the thyrocervical trunk in 77% of cases, from the subclavian artery in 22% of cases, or from the internal mammary artery in 2% [16]. It has a good calibre closest to its origin, with a diameter of approximately 2.2 mm at 2 cm from its origin where it is usually encountered (Fig. 2.2) [17]. The pedicle length can be increased by following the vessel posteriorly, but this comes at a cost of a narrower vessel diameter.

The internal mammary artery (IMA) and vein can also be considered and is the most commonly used vessel in the vessel-depleted neck in the systematic review of cases by Frohwitter et al. [18]. The IMA is located on the undersurface of the upper six ribs, just lateral to the lateral border of the sternum (approximately 1–2.3 cm lateral to the sternum) [19]. The IMA originates from the subclavian artery, and its associated vein drains into the brachiocephalic vein. Given its location beneath the sternum, dissection can be challenging. Several factors have been described by Urken et al. to aid in identifying the vessels and harvesting them at their most ideal calibre including preferencing the right-side vessels as they are bigger and harvesting the vein within the third intercostal space (caudal to that, it narrows greatly) [19].

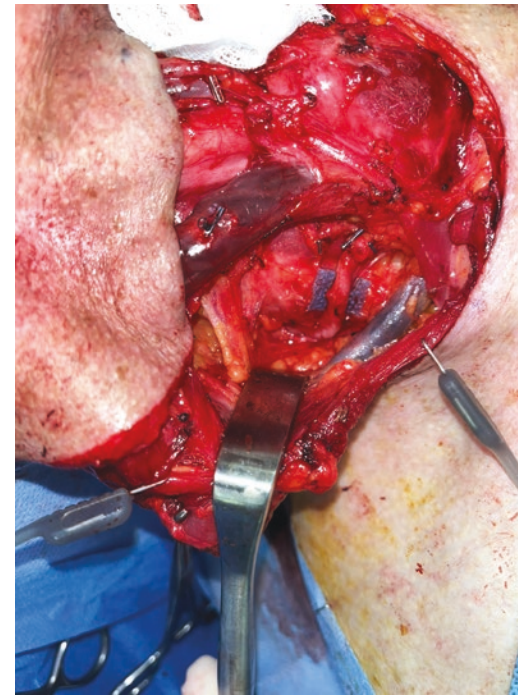

Fig. 2.2 Photograph of the root of the neck of a patient who was planned for pharyngeal reconstruction after a previous laryngectomy, radiotherapy, and an endoluminal stent in the common carotid artery. The transverse cervical artery was the only available artery in the neck for arterial anastomosis

The common carotid artery (CCA) can also be used for microvascular anastomosis where other options are unavailable [20]. Although an end-to-side anastomosis to the CCA seems fraught with danger, where there is a patent ECA to maintain ICA perfusion, it is safe, and in reported cases, there were no incidences of neurological deficit post-reconstruction [21, 22]. We use a punch biopsy tool to create the puncture in the CCA vessel wall, and this creates a clean puncture for end-to-side anastomosis (Fig. 2.3). Where the ECA has been previously sacrificed, or compromised by using it for a previous flap, a shunt can be used to maintain perfusion of the ICA throughout the period of end-to-side anastomosis [23].

Several other arterial sources have been reported in these complex cases. The

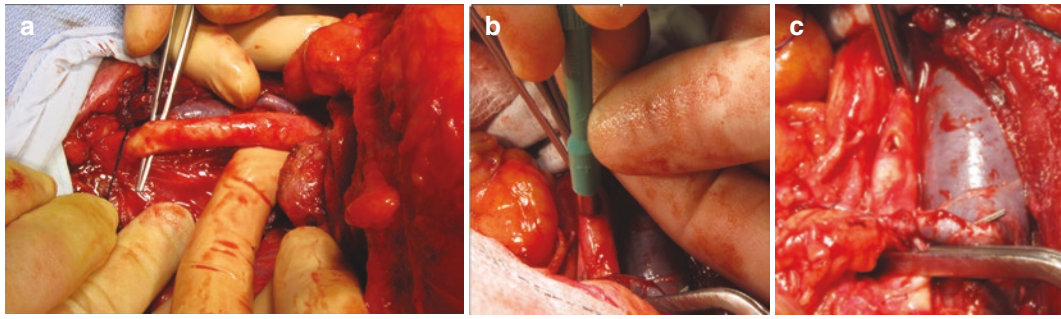

Fig. 2.3 (**a**) Common carotid artery isolated for anastomosis. (**b**) Use of a punch biopsy tool to create the puncture. (**c**) The puncture in the CCA ready for end-to-side anastomosis

thoracoacromial artery is a branch of the axillary artery and has been described successfully when other vessels are unavailable. The vessels are very caudal, and so a flap with a long pedicle length is often needed, and the vein is often very caudal, frequently requiring a vein graft [24]. Also, harvesting the thoracoacromial artery will compromise any potential for utilizing a pectoralis major myocutaneous pedicled flap as a salvage option. Contralateral neck arteries can also be used as mentioned earlier. However, as anticipated, a longer pedicle length is needed to reach the contralateral neck vessels. Additionally, vein grafts, or a Corlett loop, can be used to reach the contralateral neck vessels where needed [25]. The Corlett loop will be discussed further in the next section.

Venous Options in the Vessel-Depleted Neck

Venous drainage is often the rate-limiting step in the vessel-depleted neck and may require creative solutions by the reconstructive surgeon to achieve adequate venous drainage. The internal jugular vein and the external jugular vein are the main venous systems used for venous anastomosis. However, these options are often unavailable in the vessel-depleted neck and so alternative options are usually needed. In the above section, we discussed the accompanying veins of the superficial temporal system, the transverse cervical system, and the internal mammary vessels. Vein grafts can be utilized where needed to lengthen the available venous or arterial options. However, vein grafts require two anastomoses for each vessel, and hence have a higher rate of failure in several studies [26]. The cephalic vein can be harvested and rotated into the neck defect for venous anastomosis. Often, this vein has not been affected by prior surgery or radiation. The cephalic vein drains directly into the axillary vein and can be harvested relatively easily. The cephalic vein travels from the axillary vein through the coracoclavicular fascia proximally. It then travels between the pectoralis major and the deltoid muscles before travelling in the groove of the lateral border of the biceps brachii. It then crosses superficial to the musculocutaneous nerve and then courses between the brachioradialis and the brachii muscles distal to the elbow. A curved incision can be extended from the neck incision along the deltopectoral groove to locate the vein and follow it distally [26]. Once adequate length is acquired, it can then be rotated and transposed into the neck (Fig. 2.4). Care needs to be taken to avoid the cephalic vein from kinking at the coracoclavicular fascia.

When a suitable local artery and vein are not available, the technique of a Corlett loop can be used. This technique utilizes the long length of the cephalic vein to achieve both arterial and venous vessels for microvascular anastomosis. In this technique, the cephalic vein is harvested as described above, and it is first anastomosed to the contralateral neck branches of the external carotid artery forming a temporary arteriovenous fistula. The vessel is then divided, and the proximal end is attached to the vein of the flap, and the distal

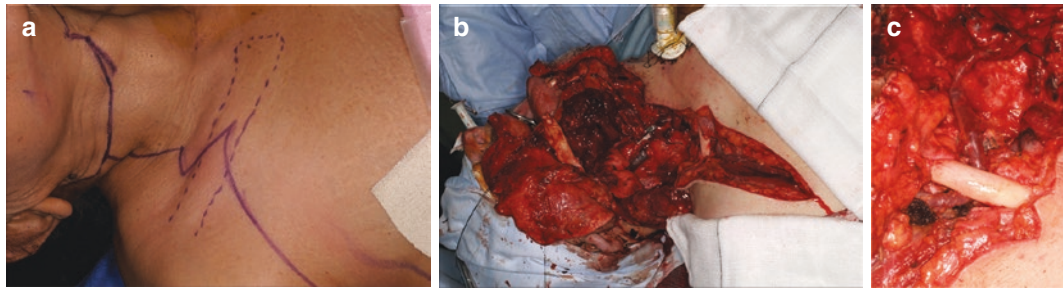

Fig. 2.4 (**a**) Incision markings for cephalic vein transposition for a known vessel-depleted neck. (**b**)Exposed cephalic vein along the deltopectoral groove. The flap pedicle vessels are clamped here to approximate the length needed for the cephalic vein transposition. (**c**) Cephalic vein transposed and tunnelled under the clavicle to reduce the risk of compression from external neck pressure and swelling. An adequate space is obviously needed under the clavicle to allow the vein to safely distend under the clavicle

end (which was anastomosed to the contralateral neck artery) is attached to the artery of the flap [25]. This can be performed as a single-stage or a two-stage delayed procedure [27]. The technique of forming an arteriovenous fistula has been well described in limb reconstruction, but it is rarely used in head and neck reconstruction [27]. The study by Lin et al. demonstrated a higher rate of failure with two-stage arteriovenous fistulas [27]. All reported cases in the head and neck have been single-stage procedures [25, 28].

Extreme Circumstances

When suitable locoregional alternative vessels are not available, surgeons can consider the pedicle of previous flaps used for reconstruction. The options in this scenario include (1) using a side branch of the proximal pedicle; (2) assuming that the former flap has developed alternative vascularization, sacrificing the current pedicle vessel using the pedicle as recipient vessels; and (3) using the distal end of the previous flap pedicle for 'flow-through' anastomosis[20]. Where no possible vessels are available, Wolff et al. have described the use of extracorporeal perfusion devices to maintain vascularity to a flap while it develops independent blood supply. The protocol aims to accelerate neovascularization and autonomization of the flap within 2 weeks of reconstruction [29].

Flap Selection

Selecting a flap is a combination of art and science—there are many different flaps to choose from, and while some may be suggested by particular scenarios, there is rarely a single possible choice. The clinician should consider the pathology, the patient as a whole (including their opinions and priorities), what previous treatment has been performed, and the availability of necessary equipment and/or expertise.

Pedicle length in particular is important in the reconstruction of maxillary defects as there are few suitable donor vessels in close proximity.

In soft tissue reconstruction, the choice of flap depends on the type of skin, the thickness of skin, and the colour of skin required. For partial glossectomy defects, often a radial forearm free flap reconstruction provides thin, pliable skin that can seal the oral cavity from the neck and provide enough pliability of skin to allow tongue extension and movement from the residual tongue. When the base of tongue/oropharynx is likely to be involved, or greater than a hemiglossectomy is planned, then more skin and soft tissue bulk may be required, and hence an anterolateral thigh flap is the workhorse flap for these reconstructions. Alternatives for soft tissue flaps include medial sural artery perforator (MSAP) flaps, Superficial circumflex iliac artery perforator flap (SCIP) lateral arm flap, TDAP, scapula (soft tissue only), and freestyle free flaps based on unnamed perforators.

Bony reconstruction however has more specific options. These include the fibula free flap, deep circumflex iliac artery (DCIA), flaps based on the subscapular artery system, composite radial free flap, and medial femoral condyle free flap. Once a bony flap has been selected, it is now considered best practice to undergo preoperative virtual planning. This can be done with traditional dental models, 3D software, rapid prototyping, or a combination of techniques. CAD/CAM techniques have revolutionized bony reconstruction. Cutting guides can now be made to perform the resection, and the use of cutting templates allows accurate 3-dimensional reconstruction. Plates used to stabilize the bone can also be custom-made. These techniques have improved reconstructive results and also save intraoperative time.

In this section of the chapter, we will briefly discuss the advantages and disadvantages of the most common free flaps, and key preoperative planning needed for these flaps.

Radial Forearm Free Flap

The radial forearm free flap is the most commonly used free flap for intra-oral soft tissue reconstruction. The reliability of the anatomy, presence of thin pliable skin, and quick harvest make it an ideal option to consider. Due to its pliability, it is ideal for defects involving moving structures like the soft palate, lips, and tongue. It is our preferred flap for partial glossectomy defects, floor of mouth defects, buccal mucosal defects, oropharyngeal defects, and posterior maxillary defects.

Advantages

- High-quality thin skin produced.
- Long, large-calibre, reliable pedicle.
- Very reliable anatomy.
- Choice of venae comitantes or cephalic vein or both for venous drainage.
- Allows two-team operating.

Disadvantages

- Donor site must be skin grafted.
- Poor aesthetics of donor site.

Preoperative Planning

Clinical examination of the forearm is necessary to ensure no previous scars or evidence of interventions where the radial artery has been harvested. Allen's test should be performed to ensure adequate collateral supply. If Allen's test is inconclusive, then a duplex US should be considered to ensure normal vascular anatomy.

Anterolateral Thigh Flap

The anterolateral thigh free flap has become increasingly popular since its first description in 1984. This flap is based on various perforators from the descending branch of the lateral circumflex femoral artery and its associated venae comitantes. It is a versatile flap, which can be harvested as a subcutaneous, fasciocutaneous, musculocutaneous, or adipofascial flap, making it an option for a variety of applications in the head and neck. It can also be harvested as a chimeric flap. Additionally, the donor site can often be closed primarily and heals with acceptable donor-site morbidity. The pedicle is also long, potentially 7–16 cm.

Advantages

- The pedicle is long and possesses large-calibre vessels.
- Up to 25 cm diameter, skin paddle can be harvested with only one perforator.
- It can be harvested as a chimeric flap.
- Primary closure of the donor site is often possible.
- It allows a two-team approach.

Disadvantages

- It is technically more demanding.
- It has high variability in the position of perforators.
- In very rare cases, there may not be a perforator.

Preoperative Planning

Clinical examination of the leg will identify any previous scars, surgical interventions, or injuries. Pinch test will give a clue to the thickness of the skin. Especially in oral cavity reconstruction, bulkiness of the flap may render the ALT inappropriate. Doppler within a 3 cm radius circle around the centre of the line from the superolateral aspect of the patella to the ASIS may demonstrate likely position or availability of perforators (Fig. 2.5). However, this is not generally accurate, and the only way to check for perforators is to make an incision and check.

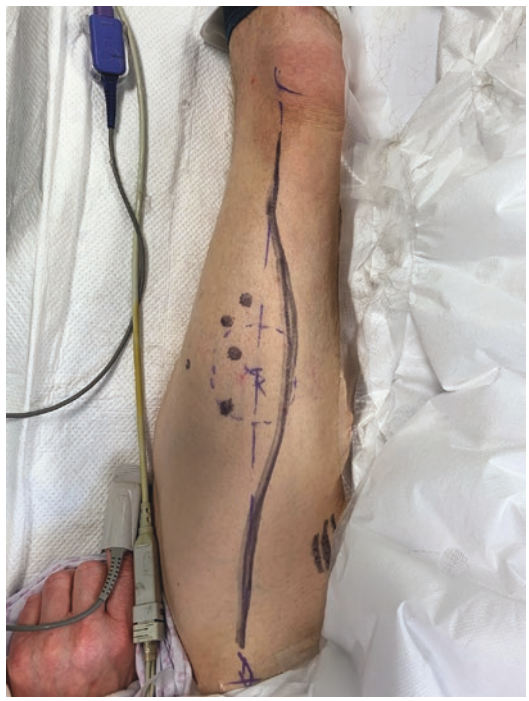

Fig. 2.5 Markings on the anterolateral thigh with the dotted line extending from the ASIS to the superolateral aspect of the patella. The dotted circle demonstrates 3 cm radius from the centre of the line, and the black dots correspond with the perforators identified on Doppler

Fibula Free Flap

The fibula is the 'workhorse' flap for the reconstruction of bony defects in the head and neck. It provides a great length of high-quality bone, which is suitable for osseointegrated implants, and has a long, large-calibre, reliable pedicle. It can also be harvested with skin, although the skin paddle is less reliable than the bony component. The skin defect can also be slow to heal, even when grafted, and so where appropriate, we sometimes use muscle and subcutaneous fat alone to line intra-oral defects, which we find generally mucosalizes well and reduces intra-oral bulk. It is the ideal flap for long-segment mandibular defects, mandibular defects involving the temporomandibular joint, and low-level maxillectomies [30–32]. It is also the ideal flap for immediate implant surgery and virtual planning. It's exact shape and the pedicle orientation allows for application of accurate surgical guides, and it has a good bicortical structure that allows for good primary stability of the implants at the time of insertion.

Advantages

- Large length of high-quality bone (25 cm).
- Long pedicle (15 cm).
- Can provide skin for reconstruction of intra- or extra-oral defects.
- Bone is suitable for placement of osseointegrated implants.
- Allows two-team approach.

Disadvantages

- Not possible in all patients—Patient may not have adequate three-vessel flow to the foot; hence, a fibula flap may jeopardize the vascularity of the foot.
- Skin paddle is not as reliable as the bony component.
- Defect closure requires grafting if skin is taken.
- Healing of donor site can be slow, requiring lengthy specialist wound care.

- Unaesthetic donor-site scar.
- Can cause foot drop if peroneal nerve damaged.

Preoperative Planning

Clinical examination of the lower leg will identify any previous scars, surgical interventions, or injuries. Palpate the pulses of the foot, and look for evidence of venous stasis and vascular insufficiency in the form of venous skin changes, varicosities, or peripheral oedema. All of these features are contraindications for fibula free flap reconstruction.

Imaging

Preoperative angiogram—either a CT angiogram or an MR angiogram is necessary when planning for a fibula free flap reconstruction. This is vital to ensure normal trifurcation of the popliteal artery into anterior tibial, posterior tibial, and sural arteries and to ensure no significant atherosclerotic narrowing of the vessels due to peripheral vascular disease. This is necessary because in 0.2–8% of the population, the dominant blood supply to the foot is the peroneal magna artery. As mentioned above, in these cases, fibula free flap harvest is an absolute contraindication, as it risks vascular compromise to the foot.

Deep Circumflex Iliac Artery Flap

The DCIA flap provides a good quantity and quality of bone, which has contours that can be adapted to the mandible or maxilla. It can also provide vascularized muscle for soft tissue coverage, but the traditional skin paddle was not flexible. More recently, perforator-based skin paddles have overcome this disadvantage.

There are also questions over its reliability: a meta-analysis of nearly 10,000 composite free flaps suggested that DCIA flaps were less reliable overall than other composite flaps for mandibular reconstruction (6.2% flap failure rate vs. 3.4% for all other flaps combined) [33]. Furthermore, closure of the DCIA flap is not trivial, and inadequate closure can lead to troublesome incisional hernias.

However, it is ideal for reconstruction of the dentate mandible and high-level Brown class 3 and 4 maxillary defects.

Advantages

- Good quality and quantity of bone (up to 14 cm) with curves suitable for mandibular or maxillary reconstruction (important for the dentate mandible and class 3 and 4 Brown defects).
- Can provide muscle and skin for reconstruction of intra- or extra-oral defects.
- Bone is in excellent quality for placement of osseointegrated implants.
- The donor-site scar can be concealed by clothing.
- Allows two-team operating.

Disadvantages

- Short pedicle (6 cm), but this can be improved by raising the flap posterior to the anterior superior iliac spine.
- Post-operative mobilization is slow and painful.
- Less reliable than other composite flaps.
- Risk of donor-site hernia.
- Defect closure is laborious.
- Associated soft tissue is bulky and inflexible.

Preoperative Planning

Clinically, examine the pelvis, palpating for the iliac crest. Look for scars from previous abdominal surgery. Obese patients make raising the DCIA more difficult.

No specific imaging is required for the DCIA free flap preoperatively.

Subscapular Artery System Flaps

The scapular/parascapular flap and scapular tip flaps are versatile flaps that are notable for providing excellent skin coverage, the possibility of a chimeric flap, a good amount of high-quality bone, and an aesthetic, low-morbidity donor site. Furthermore, the flaps are characterized by great flexibility, with the osseous and cutaneous components able to be positioned independently. The downsides are that it is most commonly harvested in lateral decubitus position to harvest the flap, which makes two-team simultaneous operating all but impossible, greatly increasing the overall operative time.

The true scapular flap is taken with the horizontal branch of the circumflex scapular artery. The parascapular flap is based on the descending branch: choosing between them is largely down to the preference and experience of the surgeon. A chimeric, dual-paddled flap can also be taken with one paddle arising from each branch. The edge and/or tip of scapula can be taken as the osseous component, providing good-quality bone and a flap with great 3-dimensional flexibility. The scapular flap is ideally suited to elderly patients for mandibular reconstruction, patients where the fibula is unsuitable for any reason.

The scapula tip can be harvested independently based on the angular branch of the thoracodorsal artery. This flap provides thinner bone than the true scapular flap but has a much longer pedicle (up to 17 cm) and can be harvested with the thoracodorsal artery perforator and part of latissimus dorsi. The scapula tip is particularly suited to maxillary reconstruction considering its shape and long pedicle.

Advantages

- Large amount of good-quality skin.
- Skin paddles have considerable flexibility (independent of each other and the bone)—allows simultaneous reconstruction of skin, bone, and mucosal defects with a single flap.
- Skin has good colour match with facial skin.
- Good-quality bone, up to 14 cm.
- Very reliable anatomy.
- Reliable pedicle of good diameter.
- Good-quality bone.
- Low donor-site morbidity.
- Long pedicle for scapular tip free flaps (up to 17 cm).

Disadvantages

- Short pedicle (3–4 cm) for lateral border scapula free flaps.
- Need to move the patient into decubitus position.
- Two-team operating is difficult.
- The skin paddles can be too bulky for intraoral reconstruction, especially in obese patients.

Preoperative Planning

Clinically examine the back for scars, and palpate for any scapula abnormalities.

Generally, vessels in this area of the body are rarely affected by peripheral vascular disease, and so no angiography is needed to investigate these vessels.

Virtual planning can be performed by capturing the scapula bone from the CT chest performed for staging purposes.

Composite Radial Forearm Free Flap

The radial forearm flap is the most commonly used and most reliable soft tissue flap for intraoral reconstruction. In addition to the pliable, thin skin, if a composite flap is required, a moderate amount of unicortical bone can also be harvested without major modification to the technique. This bone is often inadequate for implant rehabilitation. It is ideally suited to reconstructing edentulous mandibles and smaller orbitomaxillary defects.

Advantages

- High-quality thin skin produced.
- Long, large-calibre, reliable pedicle.
- Choice of venae comitantes or cephalic vein or both for venous drainage.
- Straight, unicortical bone (up to 10 cm) (Fig. 2.6).
- Allows two-team operation.

Disadvantages

- Risk of post-operative fracture of radius—risk minimized by using a cutting guide and plating of the radius (Fig. 2.7).
- Bone is often not suitable for osseointegrated implants.
- Donor site must be skin grafted.
- Poor aesthetics of donor site.

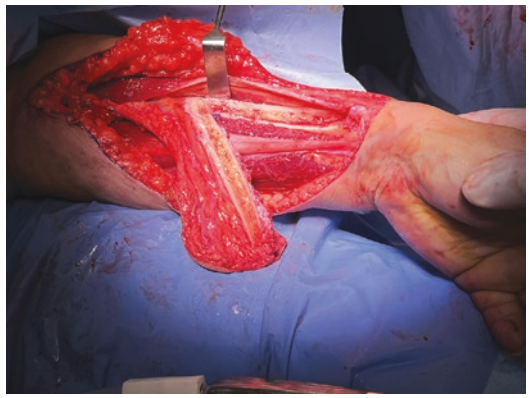

Fig. 2.6 A composite radial harvested with 10 cm of bone for mandibular reconstruction

Preoperative Planning

Clinical examination of the forearm is necessary to ensure no previous scars or evidence of interventions where the radial artery has been harvested. Allen's test should be performed to ensure adequate collateral supply. If Allen's test is inconclusive, then a duplex US should be considered to ensure normal vascular anatomy.

CT forearm is ideal for virtually planning the amount of bone being harvested to minimize the risk of radius fracture post-operatively. CT scans can be used to design a cutting guide to take the right amount of bone and to prebend a distal radius plate reducing the risk of post-operative fracture.

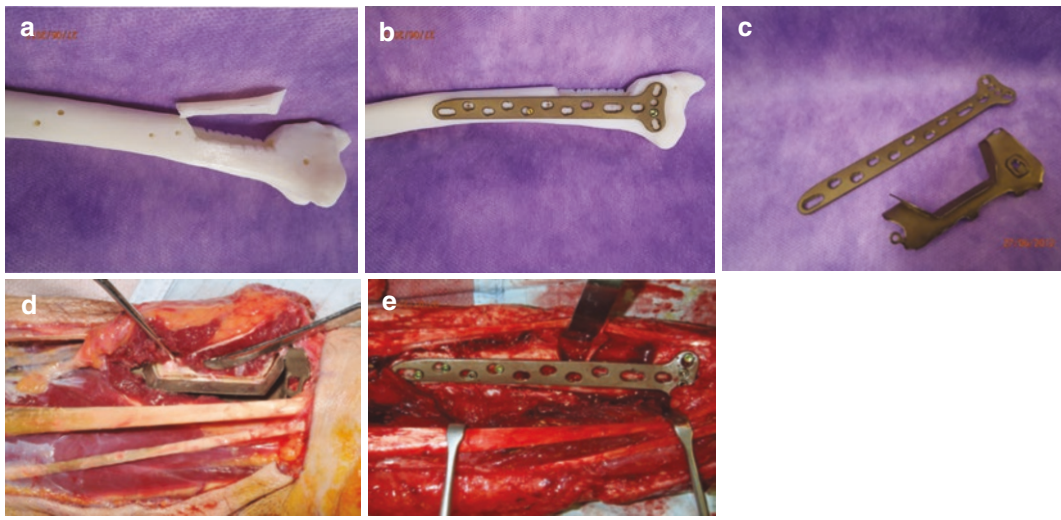

Fig. 2.7 Virtual plan for a small composite radial free flap. (**a**) 3D printed radius bone with the planned bone harvest. (**b**) Planned distal radius plate adapted to the 3D printed radius bone. (**c**) Distal radius plate and titanium cutting guide for intraoperative adaptation to the radius. (**d**) Radius cutting guide in situ. (**e**) Pre-adapted distal radius plate in situ

Flap Selection in the Vessel-Depleted Neck

Reconstructive surgeons tackling these cases need to have a wide spectrum of free microvascular flaps within their armamentarium. In a recent systematic review of microvascular reconstructions in the vessel-depleted neck, 329 reconstructions from 26 included studies were performed with a vast diversity of 18 different flaps used [18]. The most commonly used were the anterolateral thigh flap (ALT) and the radial forearm free flap (RFFF). When choosing the ideal flap, several factors need to be considered. Firstly, which options are available as some flaps may have already been utilized in previous surgeries. Secondly, adequate pedicle length is particularly important in these patients as they are already compromised in terms of vessels available for anastomosis. Commonly used soft tissue flaps for head and neck reconstruction with the longest pedicle lengths are radial forearm flaps, anterolateral thigh flaps, latissimus dorsi flaps, and rectus abdominis flaps, respectively. Composite flaps with the longest pedicle lengths are fibula and scapula-tip flaps (utilizing the angular branch of the thoracodorsal artery as the pedicle).

Where possible, the surgeon can also plan to modify a particular well-known flap to increase pedicle length through a variety of ways. The deep circumflex iliac artery (DCIA) flap pedicle length can be increased by harvesting the bone more posterior to the anterior superior iliac spine than usual. The scapula free flap pedicle can be lengthened by harvesting the thoracodorsal artery and anastomosing to the distal end of the thoracodorsal artery. Blood will travel in a reverse flow into the circumflex scapular artery supplying the flap. During planning for these cases, the reconstructive surgeon should consider their plan A but always have a plan B and plan C for the patient depending on which vessels are identified on neck exploration. Pedicled reconstructive options need to be considered in cases when no good recipient vessels are identified. Most commonly used include pectoralis major myocutaneous flaps, pedicled latissimus dorsi flaps, deltopectoral flaps, and supraclavicular artery flaps [18, 34].

Rehabilitation and Virtual Planning

Planning for rehabilitation should not be an afterthought but should be considered at the time of initial surgical planning. What are the patient's long-term goals from treatment? What factors are important for each individual patient's quality of life? Considering these factors will help guide the chosen reconstruction and the chosen approach. Sometimes, a microvascular free flap is not the ideal option, and small defects can often be managed with skin grafts and prostheses to help the skin graft to take (Fig. 2.8). In the majority of cases however, microvascular free flaps are required, and rehabilitation can be made much more accurate with the availability of virtual surgical planning, and advances in virtual surgical planning have allowed for immediate jaw reconstruction at the same time as surgery

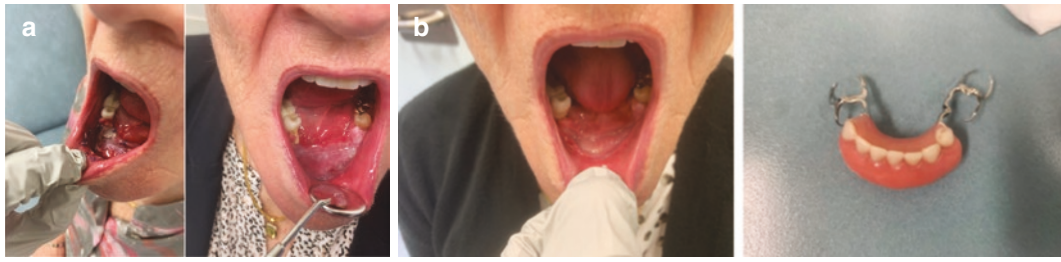

Fig. 2.8 86-Year-old female patient who had a small anterior mandibular alveolar SCC. She underwent a marginal mandibulectomy and split-thickness skin graft for reconstruction. The skin graft was inset and supported by a denture dressed with coe-pak dressing for 2 weeks. (**a**) Appearance of the defect at 2 weeks and 6 weeks postoperatively. (**b**) Skin graft at 3 months demonstrating good sulcus depth and a partial denture for rehabilitation

[31]. However, the majority of patients will have delayed rehabilitation, and the way for rehabilitation can be prepared by accurate custom patient-centred reconstructions. There is a wide variety of ways in which 3D computer-aided design (CAD) and computer-aided manufacturing (CAM) can be used to aid the surgeon in their reconstructive goals ranging from just printing biomodels to allow a reconstruction plate to be bent on the model (Fig. 2.9) to fully guided 3D printed cutting guides, titanium plates, and stents (Figs. 2.10, 2.11, 2.12). Preoperatively planning the soft tissue for future implant rehabilitation is as important as the bony reconstruction. Predicting the future soft tissue issues with implant rehabilitation will also guide the approach. Often, skin paddles are not ideal for the future implant interface. Considering fat fascia paddles with fibula free flaps instead of skin paddles, or lining the oral cavity with muscle instead of skin, allows for better mucosalization, making implant rehabilitation easier (Fig. 2.13).

As the technology continues to advance, most of these options will be available in-house and will not depend on proprietary providers. This will allow for more rapid turnover of designs and will render this technology available to all patients being considered for bony reconstructions [32].

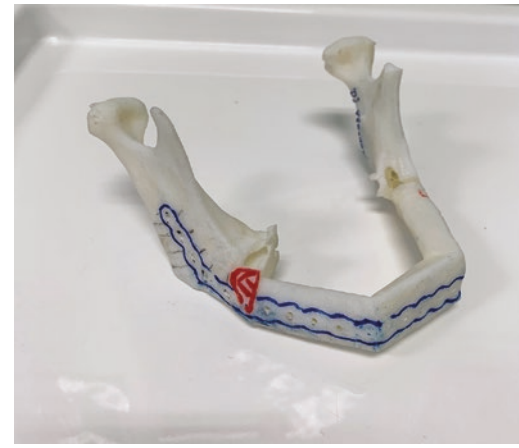

Fig. 2.9 3D printed biomodel of a planned mandibulectomy and reconstruction with a fibula. The plate was bent and adapted on the biomodel

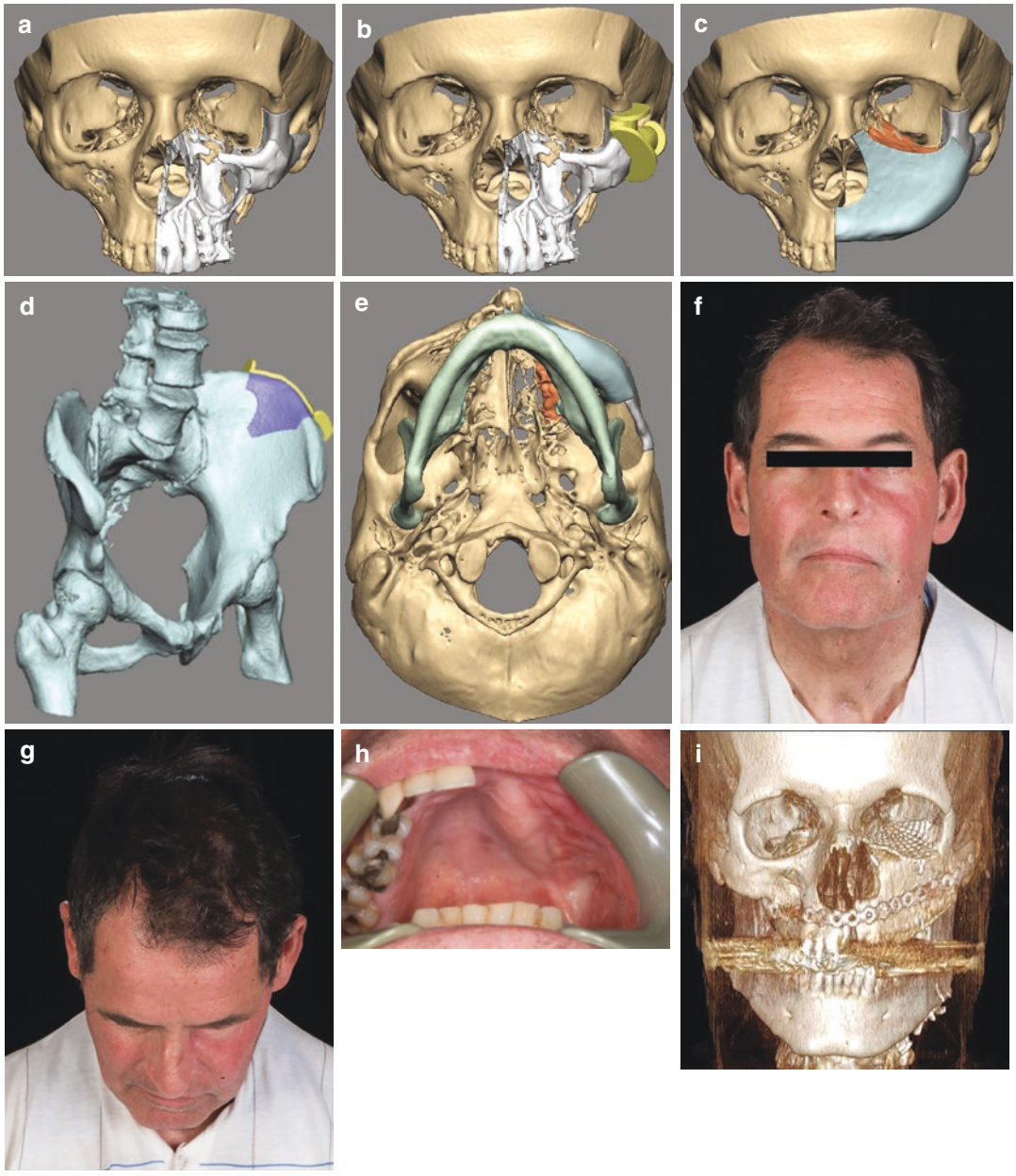

Fig. 2.10 Case demonstrating the 3D computer-assisted planning of a class III defect with a DCIA free flap with prefabricated orbital floor reconstruction. (**a**, **b**) Showing the area of resection and planned lateral cutting guide. (**c**) DCIA planned and shaped to reconstruct the left maxilla. (d) Cutting guide designed to harvest the iliac crest bone. (**e**) A worm's-eye view of a 3D computer-guided reformat demonstrating the symmetry achieved by the DCIA reconstruction. (**f–i**) Showing the clinical result of DCIA reconstruction of the left side of the face after radiotherapy showing good facial symmetry and good mucosalization

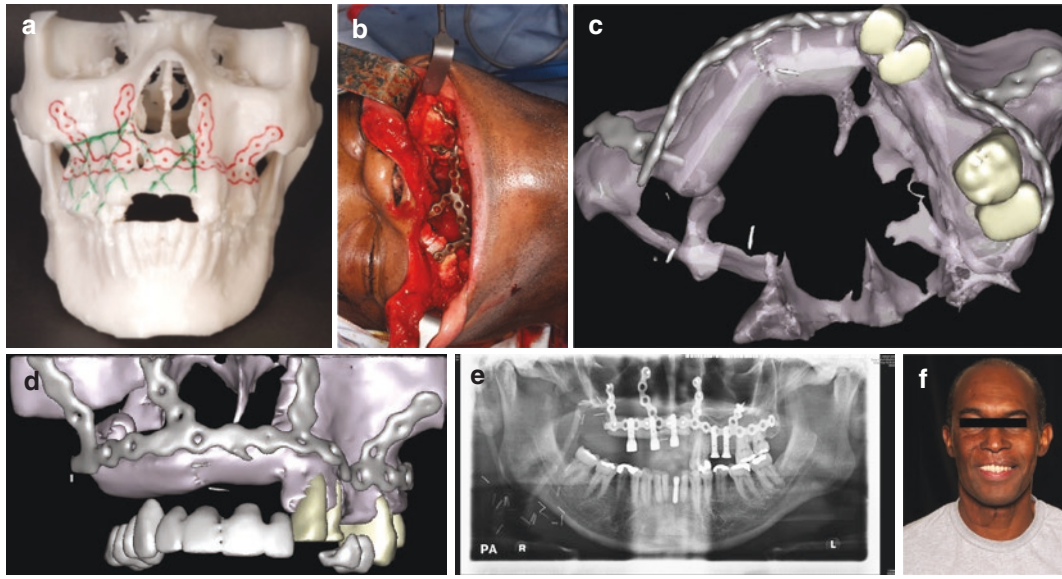

Fig. 2.11 Case demonstrating the use of a fibula free flap for a class II low-level defect. This case demonstrates the use of the fibula free flap to recreate the alveolar arch. This case utilizes computer-aided planning to print a stereolithographic model (**a**), followed by pre-bending a reconstruction plate. (**b**) Intraoperative image of the defect and reconstruction plate. (**c**, **d**) 3D computer-aided planning is used to guide implant placement and rehabilitation, with planned prosthetic position of restoration. (**e**) Final orthopantomogram (OPG) showing fibula position and implant positions. (**f**) Final facial photograph after reconstruction and rehabilitation

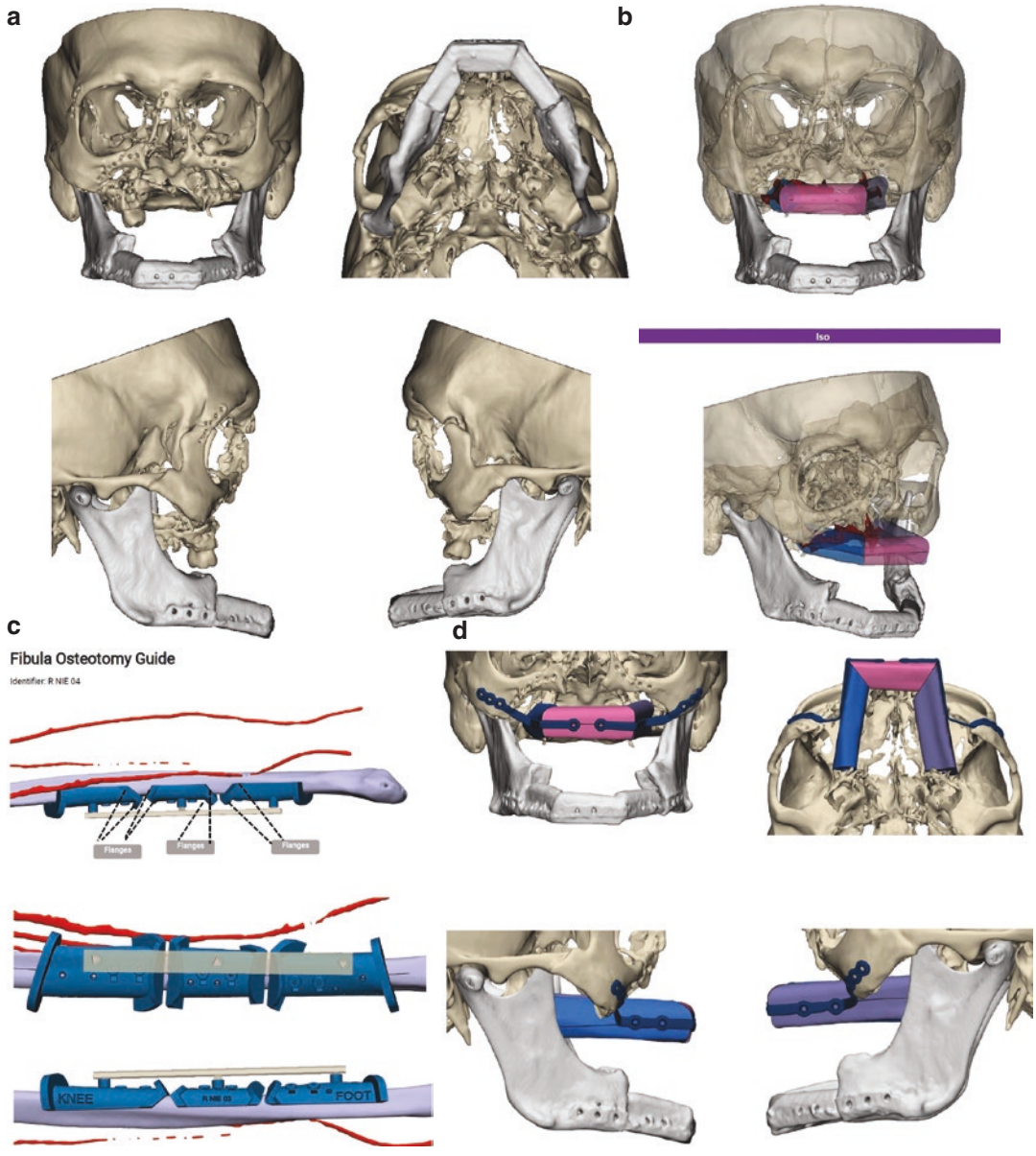

Fig. 2.12 3D planning images with plans for reconstruction of the midface after a self-inflicted rifle injury to the face. This patient has recently had mandibular reconstruction with a fibula. (**a**) The midface defect after mandibular reconstruction. (**b**) Planned fibula reconstruction of the midface. (**c**) Custom cutting guide for the fibula for the planned reconstruction. (**d**) Design of 3D printed titanium plates for inset of the maxillary reconstruction

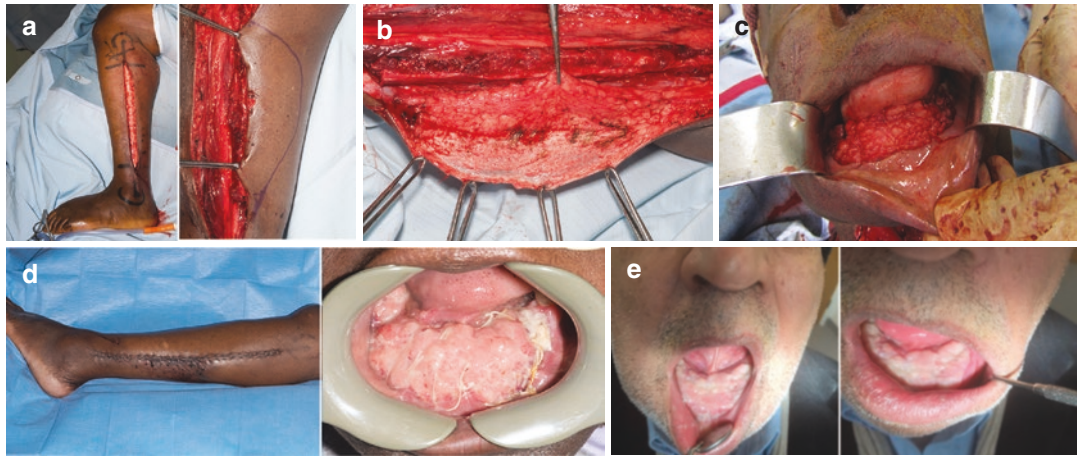

Fig. 2.13 Fat-fascia harvest for a fibula free flap. (**a**) Demonstrates the incision made for fibula reconstruction and the marked skin paddle size. The notch excised from the skin is the site of the perforator. (**b**) Harvesting the fat-fascia paddle. The fascia is raised subcutaneously. (**c**) Inset of the fat-fascia skin paddle. (**d**) Appearance of the donor site and the intra-oral appearance at 6 weeks post-operatively. (**e**) Appearance of the fat-fascia paddle at 3 months post-operatively demonstrating a good labial sulcus and early signs of mucosalization

Conclusion

A structured approach to assessing the head and neck reconstruction patient is crucial to achieve the ideal surgical and long term functional result. When assessing these patients pre-operatively, the clinician should consider the need for a tracheostomy, the planned resection, access needed for resection and reconstruction, vessels available, reconstructive options available and the long term rehabilitation of the patient. In this chapter, we focused on the considerations for tracheostomy, dealing with the previously treated and vessel depleted neck, and appropriate investigations when considering the most commonly used flaps for head and neck reconstruction.

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3 Preoperative Visit Counseling and Patient Education

Sam R. Caruso and Anastasiya Quimby

Introduction

The preoperative patient visit helps set the stage for patients' expectations regarding their cancer treatment journey. Patients with a recent diagnosis of head and neck cancer can experience high degrees of distress and anxiety, which may serve as barriers to learning about their condition and comprehending the management strategies. Cancer management is always multidisciplinary and therefore involves multiple providers, different physical office locations for patient visits, and a battery of diagnostic tests that must be completed. These factors contribute to the challenges in carrying out timely and effective care. Coordination of a cancer patient care initially falls heavily on the surgeon involved in the diagnosis and workup of the patient. Implementation of perioperative checklists has demonstrated definitive improvements in surgical patient morbidity and mortality outcomes [1]. A recent study by Kain et al. concluded that implementation of a pre-op and post-op checklist into their EMR for patients undergoing microvascular reconstruction in the head and neck led to reduced major medical complications, post-op antibiotic administration, hospital length of stay, and improved discharge outcomes [2]. Therefore, head and neck surgeons are encouraged to adopt published or create institution-specific checklists and implement them into routine practice. These measures create safeguard mechanisms to ensure that all the appropriate tests and diagnostic workups are completed, as well as they allow the patients to have a sense of what to expect next. The following chapter aims to summarize key points of preoperative discussion focusing on three distinct components that include assessing a patient's level of understanding, management stages, and overview of anticipated recovery and rehabilitation.

Assessment of Patient's Understanding

During the discussion with the patient, it is important that the surgical team understands the patient's expectations and their level of understanding of their condition. Discussion of the patient's specific pathological diagnosis is very important. The patient may have been triaged to the surgeon's office via appropriate referrals but

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Table 3.1 NCCN recommendations for head and neck cancer clinical surveillance

Year	Frequency (months)
1	q1–3
2	q2–6
3–5	q4–8
>5	q12

has not had a physician discuss the specific aspect of their disease or the significance of the prognostic factors [3]. Some patients may have a minimal understanding of the treatment of head and neck malignancy. Others may be well versed by virtue of having friends or family members diagnosed with a similar condition. Understanding this may help the surgeon tailor the conversation in a way that is most specific to this particular patient, and if needed, time may be spent dispelling myths or clarifying issues from previous experiences. Ensuring that the patient has a basic understanding of their disease process will allow a physician to discuss the necessary steps of the entire management plan. Patients should be advised of preoperative workup, surgical treatment, adjuvant therapy, and surveillance. Although the surveillance frequency is usually decided by the treating physician on a case-by-case basis, the usual ranges for surveillance as recommended by the National Comprehensive Cancer Network (NCCN) are presented in Table 3.1. Majority of cases recur within the first 2 years; therefore, patients should be advised of the importance to be compliant with the recommended follow-up schedule during this time. If the patient is a smoker, an effort should be dedicated to encourage smoking cessation and they should be educated on the higher cancer recurrence rates and lower survival rates with continued smoking [4].

Management Stages

General approach to the management of the head and neck cancer should be explained as most patients will very likely hear the words "tumor board," "adjuvant therapy," etc. for the first time in their lives. The National Comprehensive Cancer Network (NCCN) guidelines for head and neck cancers are a widely accepted standard of care in the United States that also provides useful patient education tools. Patients can be advised to think of their journey in several stages.

Stage 1: Diagnostic Workup

In order to ensure that they are managed appropriately, the necessary diagnostic workup must be completed. This phase includes but is not limited to clinical exam, including in-office flexible endoscopic exam and/or direct laryngoscopy in the operating room, biopsy, imaging, primary care physician consultation, and possible subspecialty consultations with additional tests as indicated by comorbidities. Patients must be clearly informed that going to operating room under general anesthesia for direct laryngoscopy does not mean that they will be undergoing treatment. They need to understand that they are still in the diagnostic workup stage even though they had "surgery." The type and purpose of the necessary scans should be explained to the patient. It is important that they understand that a CT or MRI of the neck will help assess the location and extent of primary tumor and point to any concern for cervical metastatic disease, which in turn provides a clue to whether the patient is a candidate for surgery or if the disease is deemed unresectable. CT chest and/or PET scans are necessary on patients with advanced local disease to rule out distant metastasis. Need for any additional imaging such as CT angiography of bilateral lower extremities to facilitate reconstructive surgery planning should also be emphasized. Oftentimes, patients will also need to undergo laboratory and other evaluations with their primary care physician to ensure that they are a suitable surgical candidate. Patients with significant comorbidities not infrequently will also require evaluation by specific subspecialties such as cardiology, pulmonology, and nephrology. Last but not least, patients should be advised to see their dentist for dental clearance.

Stage 2: Multidisciplinary Head and Neck Tumor Board Discussion

Patients should be advised that once the necessary diagnostic information is available, their case will be discussed at a multidisciplinary head and neck tumor board, where a consensus treatment recommendation specific for the patient will be made. Explanation of peer-reviewed quality practices such as tumor boards is likely to ease patient's concerns about a sole decision maker given the life-changing choices that they will need to make [5]. Currently, head and neck cancer patient management relies on surgical interventions, radiation therapy, and/or chemotherapy and immunotherapy. Patients should be educated that in some instances, they may be treated with surgery alone, or radiation therapy alone, or a combination of these modalities and addition of chemotherapy. The amount of information given to the patient may be overwhelming; thus, breaking down the possible options into a finite number of solutions is likely to be helpful. Expressing to the patient that there are three treatment modalities with the most effective being surgery or radiation initially with addition of chemoradiation or chemotherapy/immunotherapy, if necessary, conveys a clear message and helps patients have set expectations. Additionally, it alerts the patient that they will be navigating their cancer journey with various providers during different phases. In those instances where surgery is the initial recommended approach, patients must be advised that need for adjuvant therapy, i.e., radiation and/or chemo, will be assessed after final pathology evaluation is available. Explaining to the patient that cancer treatment is not a sprint race but a relay marathon where different phases of treatment are headed by different providers is essential in preparing them for a lengthy and often challenging journey.

Stage 3: Surgical Management

Ablative and reconstructive procedures in the head and neck are rather complex, and conveying the information to the patient in terms that are understandable is not an easy task to achieve. It is also well known that patients in general have poor ability to recall and retain key aspects of surgical discussion, which prompted research into various visual and video aids [6, 7].

Consent for surgery is an important medicolegal component of preoperative discussion. Informed consent was defined as patient receiving sufficient information to balance the benefits against the risks before consenting to a medical procedure by Justice Bray of California Appeals Court in 1957 [7]. Although in the United States specific informed consent requirements vary by state, the common theme is that the nature of the procedure, its purpose, benefits, risks, and alternative options, including no treatment, are discussed [8]. Therefore, any visual and/or audiovisual aids in forms of drawings, information pamphlets, and educational videos should be employed, when possible, to facilitate the patient's understanding so that they can provide informed consent. If virtual surgical planning was utilized in the preparation for surgery, the proposed custom surgical plan should be explained and demonstrated to the patient. The author provides patients with the PDF of their plan so that they can review it in detail at home, and if any questions arise, they can be discussed prior to surgery. Even with the most sophisticated surgical planning, the nature of oncologic surgery is unpredictable at times; therefore, the patient should be made aware of the level of uncertainty that exists as well as other surgical options being considered. It is recommended that planned surgery is discussed at a preoperative visit in detail as well as key points are highlighted on the day of surgery and patients' final questions answered when legal documentation is signed.

In common to many head and neck patients is the need for elective temporary tracheostomy and nutritional support. The likelihood of tracheostomy must be discussed with patients, and the subsequent temporary inability to communicate verbally is important to state clearly, as many patients do not equate the presence of a tracheostomy with lack of ability to speak. They should be educated on the anticipated timeline for trach

downsizing, use of Passy-Muir speaking valve, and decannulation. When estimating the timeline, in addition to the surgery itself, the surgeon must consider the patient's overall status including any history of pulmonary issues, obstructive sleep apnea, obesity, history of smoking, and risk of developing pneumonia. Any indication for possible prolonged presence of tracheostomy should be brought to the patient's attention. Need for nasogastric (NG) or gastrostomy tube (G-tube), a brief discussion about their differences, and the anticipated length of time to be relying on this mode of nutritional supplementation should be discussed. Patients should be cautioned that in the event of delayed healing or fistula formation, they may be discharged home with tube feeds.

General surgical risks including risk of post-op infection, pulmonary complications, urinary tract infection, deep vein thrombosis, and pulmonary embolism must also be discussed.

Surgery-Specific Discussion: Ablative Defects

Head and neck surgery encompasses a broad variety of ablative procedures, the effects of which vary greatly with respect to functional and esthetic outcomes. Next, we will highlight key discussion points with respect to resection site.

Cutaneous Defect

Cutaneous resections in the face and neck primarily warrant a discussion about anticipated esthetic changes as well as potential facial nerve functional deficits. Patients should be reassured about the use of relaxed tension lines to place incisions to minimize scarring when possible. Depending on a type of reconstructive option selected, any color, texture, and hair-bearing changes should be highlighted. In case of expected post-op facial nerve deficit, discussion about future dynamic or static reanimation can be broached.

Defects involving lips may lead to decrease in overall mouth circumference, leading to limited opening, change in red lip appearance, asymmetries due to loss of muscular tone of orbicularis oris, and possible difficulties in speech. Patients should be informed of remedial steps including red tattoo to improve appearance and possible additional surgical revisions to correct microstomia, asymmetry, etc.

Defects that include nasal structures may result in nasal airway difficulties; thus, temporary nasal trumpets/stents maybe required. If the patient wears glasses, they should be cautioned about any temporary interference from planned reconstruction. They are usually reconstructed in multistep procedures and cosmetically are some of the most challenging procedures to achieve perfect results. Thus, the patient's expectations should be carefully assessed and managed to ensure postoperative patient satisfaction.

Ear resection and reconstruction are especially problematic for patients who always wear glasses or have hearing aids. In recent years, due to COVID-19 pandemic, masks with ear loops have become commonplace. Effects of surgery and planned reconstruction should be discussed and eyewear, hearing aids, and masks modified as possible to avoid compromise of the surgical site. Patients may require assistance that they will need to arrange for if they will be unable to wear their audiovisual aids.

Oral Cavity

Surgical procedures involving oral cavity have tremendous implications on patients' quality of life due to significant initial limitations in function. It is very likely that immediately post-op patients will experience difficulty with speaking, swallowing, and breathing. These patients are likely to require a tracheostomy and a feeding tube at least for the duration of their hospital stay. It is imperative that patients understand that these significant limitations will be lifted in most cases as they go through recovery process and initial swelling and pain resolve. Maxillary site involvement may pose a risk of oroantral or oronasal communication. Thus, the risks of speech hypernasality and food/drink regurgitation should be discussed. Extensive maxillary involvement may result in loss of vision or smell. Esthetic considerations include possibility of cicatricial ectro-

pion, loss of nasal support, and loss of facial volume. Involvement of oral tongue, floor of the mouth, and mandibular sites is likely to have the most pronounced immediate functional limitations. Defects of buccal mucosa are likely to be the most well tolerated by patients immediately post-op but carry the highest risk of development of trismus over time. Use of mouth-stretching and -opening exercises and devices must be emphasized to the patient to help avoid the debilitating consequence. Arrangements to order mouth-opening devices may be made preoperatively. The role of speech therapist is invaluable in facilitating timely and meaningful recovery. Patients should be reassured that they will be cared for by specialists who will help them with the recovery of these vital functions. Depending on the extent of surgery and any remaining dentition, patients may need to have a lifelong change to soft or pureed diet.

Implications for the Patient

- Alterations in speech
- Alterations in swallowing
- Trismus

Postoperative Expectations and Complications

- Need for speech and language pathology assessment
- Prolonged liquid/puree diet or feeding tube
- Mouth-opening physical therapy

Oropharyngeal and Laryngeal Defects

The initial management of oropharyngeal and laryngeal cancer in most cases is with radiation therapy. Therefore, the patients who are likely to require surgical interventions are those with a history of radiation or chemoradiation therapy. Due to radiation injury, cellular damage and excessive collagen formation become more pronounced with time and create an inhospitable environment for healing with higher complication rates further out from the initial radiation therapy [9, 10]. Effacement of surgical planes and difficulty identifying important anatomic landmarks render surgery also higher risk for iatrogenic injury during dissection [9, 10]. Increased risk of intra-op difficulties, post-op surgical site breakdown, infections, pharyngocutaneous and orocutaneous fistulas, and need for additional surgical procedures should be emphasized. Despite postoperative course likely to be fraught with local wound complications, numerous studies have demonstrated that overall free tissue transfer survival outcomes are comparable to non-radiated patients and are safe to perform [11–14]. Therefore, a realistic conversation of anticipated complicated post-op recovery is highly encouraged. Discussions about the possible need for additional surgical procedure, prolonged local wound care with various types of dressings, or negative-pressure wound VAC therapy should be made.

Oropharyngeal Defects

Base-of-tongue defects mainly affect swallowing and speech function. It should be explained to the patient that the main goal of reconstructive efforts is to provide adequate bulk as it has been correlated with better functional outcomes in the long term. This, however, implies excessive tissue bulk in the immediate post-op period that may be of great discomfort to the patient and necessitates a tracheostomy, possibly for a prolonged period of time.

Implications for the Patient

- Alterations in speech
- Alterations in swallowing
- Likelihood for tracheostomy
- Cosmesis of lip split or mandibulotomy for access

Postoperative Expectations and Complications

- Need for speech and language pathology
- Prolonged liquid/puree diet or feeding tube
- Prolonged tracheostomy

Laryngeal Defects

Preoperative discussion surrounding a laryngeal defect is centered on loss of innate speech function and significant alteration of swallowing function. Another extremely important alteration that must be imparted on the patient that can be lifesaving is that their sole route of breathing is via laryngeal stoma in the neck. Patients must be educated that they will no longer be able to breathe through their mouth or nose. This becomes critical information in the setting of unanticipated emergency room (ER) visit to a hospital that is not familiar with the patient. Application of supplemental oxygen via nasal cannula or mask ventilation will have no effect. Since laryngectomies are not extremely common, and it is plausible that an ER physician or a paramedic may not have had any prior experience with such patient, it becomes the patient's responsibility to alert the caring provider. Patients should be encouraged to have a wristband that alerts medical personnel about their laryngectomy status, as well as a wallet size info card with basic facts about postoperative alterations in neck anatomy and breathing function that they always carry with them. These items are offered by ATOS Medical or can be made for patients (Fig. 3.1). The info card should also include recommendations against the use of traditional tracheostomy tubes in the laryngeal stoma as they may result in injuries to tracheal walls given different curvatures of the devices (Fig. 3.2).

The implications of this irreversible life-altering surgery are challenging for patients to fully understand; therefore, major effort should be directed at explaining the permanent nature of the outcomes. Patients should be provided with resources and encouraged to identify groups of others who underwent similar surgeries and can share their experiences. Fortunately, with the advent of various social media platforms, identifying and linking up with groups of laryngectomy patients have become much easier, even though laryngectomies per se are not very commonly performed surgeries. Time permitting, it may be prudent and beneficial for a patient to have a preoperative consultation with speech pathologist who can discuss voice rehabilitation options with the patient. Alternatively, such discussion can be had immediately pre- or post-op during inpatient consultation with a speech therapist. In general, patients should be educated on the available speech rehabilitation options, such as use of electrolarynx, esophageal speech, and tracheoesophageal prosthesis (TEP) [15]. The detailed discussion regarding speech rehabilitation follows in Chap. 13.

I CAN ONLY BREATH THROUGH THE HOLE IN MY NECK

I AM A LARYNGECTOMY PATIENT

MY VOICEBOX WAS REMOVED

IN CASE OF EMERGENCY:

- REMOVE MY EXISTING NECK TUBE IF I HAVE ONE IN PLACE
- DELIVER OXYGEN VIA ENDOTRACHEAL TUBE INSERTED INTO THE HOLE IN MY NECK

LARYNGECTOMY DATE_____

LARYNGEAL TUBE SIZE_____

SPEAKING DEVICE _____

MAY INCLUDE AN ILLUSTRATION OF THE ALTERED ANATOMY SHOWING THE NECK STOMA

Fig. 3.1 Example of a laryngectomy wallet card

Fig. 3.2 Comparison of laryngeal tube versus Shiley tracheostomy size and curvature

Patients should be advised about postoperative reliance on laryngeal tubes, use of HME filters, and their proper care.

Postoperative swallow function is evaluated with contrast-enhanced radiographic studies, and patients should be educated on strict NPO adherence until cleared by their surgeon. As already mentioned, due to high risk of pharyngocutaneous fistula, especially in radiated patients, reliance on enteral nutrition could be prolonged [16].

Implications for the Patient

- Loss of speech
- Future use of electrolarynx, esophageal speech, or TEP
- Alterations in swallowing

Postoperative Expectations and Complications

- Need for speech and language pathology assessment
- Prolonged liquid/puree diet or feeding tube
- Tracheoesophageal fistula
- Info card/wristband to alert medical providers

Surgery-Specific Discussion: Flap Donor Sites

The selection of free flap donor site is guided primarily by the requirements of the anticipated defect, patient donor site availability, and surgeon preference. In general, a greater degree of functional limitation is expected immediately post-op due to either acute surgical pain or use of range-of-motion restrictive dressings to facilitate surgical site healing. Flap donor sites that require application of a skin graft most often will require application of a bolster dressing or a wound VAC with possible use of splints or CAM boots. Most often, these dressings are removed within 5–10 days post-op. Significant long-term postoperative functional deficits are not anticipated, as loss of important function would likely serve as a contraindication to selection of that particular donor site.

Patients should be warned about the discomfort from the split-thickness skin graft harvest site. The restrictive dressing on flap donor sites reconstructed with skin grafts is intended to ensure that there is close adaptation of the graft to the wound bed. This reduces the muscle sheering forces that may increase the chance of the skin graft loss. Negative-pressure wound VAC therapy may also be utilized to improve graft survival [17].

Use of flow couplers for anastomosis monitoring and temporary drains at the flap sites should be mentioned. Patients should be advised that most drains are removed within the first postoperative week.

Next, we will review key points of preoperative discussions depending on the donor site for the most common free flaps used in head and neck reconstruction:

Radial Forearm Free Flap

Implications for the Patient

- Nondominant hand preferred.
- Advise the patient to educate medical providers (pre-admission lab draws) on not using the arm intended for free flap harvest for IVs.
- Restricted mobility immediately post-op due to restrictive dressing/splint for 5–7 days.
- Presence of additional surgical site: split-thickness skin graft site.

Postoperative Expectations and Complications [18–20]

- Skin graft failure partial or complete, tendon exposure, may require secondary surgical procedures.
- Temporary or permanent anesthesia or paresthesia along the superficial radial nerve distribution.
- Unesthetic appearance.
- Poor grip strength.
- Hair growth at the site of reconstruction from the transferred flap.

Anterolateral Thigh

Implications for the Patient

- Primary closure, a scar extending from proximal thigh to above the knee.
- Minimal to no functional limitations.
- No need for secondary surgical sites.

Postoperative Expectations and Complications [18, 21, 22]

- Temporary or permanent thigh paresthesia.
- Incisional dehiscence/breakdown.
- Seroma, hematoma.
- Unesthetic appearance.
- Musculoskeletal dysfunction (higher likelihood if significant amount of muscle is harvested, fascia elevated, tensor fascia lata harvest, or violation of motor branch of femoral nerve to vastus lateralis, which may lead to weakness in knee extension, however not shown to have impact on long-term quality of life).
- Compartment syndrome (rare but serious possible complication).

Fibula Free Flap

Implications for the Patient

- Restricted mobility for 5–10 days post-op due to restrictive dressing (ACE bandage) or CAM boot.
- Pain often more severe than at the head and neck (may discuss local anesthesia block or local catheter placement).
- PT/OT evaluation and management while inpatient and possibly after discharge.

Postoperative Expectations and Complications [23, 24]

- Skin graft failure partial or complete, tendon exposure, may require secondary surgical procedures.
- Unesthetic appearance due to scar and possible deformity depending on the amount of muscle harvested.
- Sensory deficit.
- Claw toe deformity, weakness of the great toe, dorsiflexion of the great toe (rare).
- Ankle instability or limited range of motion (rare).
- Gait abnormality (rare).

Deep Circumflex Iliac Artery Free Flap

Implications for the Patient

- Restricted mobility.
- Abdominal binder wear.
- No heavy lifting (>10 lbs) for 6–8 weeks.

Postoperative Expectations and Complications [25, 26]

- Sensory deficit to ipsilateral anterolateral thigh, scrotum.
- Hernia, potential use of hernia mesh, and associated risk of mesh complications.
- Gait disturbance.
- Chronic pain.

Scapula System Free Flap

Implications for the Patient

- Standing cone or dog ear deformity.
- Restricted range of motion due to wear of shoulder sling.
- Need for inpatient and outpatient PT/OT to reduce long-term functional deficits.

Postoperative Expectations and Complications [24, 27]

- Axillary lymphatic drainage, seroma.
- Decreased range of motion at the shoulder.
- Scapula bone fracture (rare).

Postoperative Recovery and Rehabilitation

The immediate postoperative period revolves around working towards patient's discharge from the hospital. In the first 1–3 days after microvascular reconstructive surgery, patients may spend in the intensive care unit or a dedicated specialty unit. Patients should be advised if postoperative sedation and ventilation are planned. This period is punctuated by frequent flap checks, as timely recognition of flap perfusion issues increases chances of successful salvage. Possibility of take-back to the operating room for flap exploration and reanastomosis is important to discuss with the patient. Daily lab draws, weaning of intravenous pain medications, transition from bed rest to mobilization, initiation of tube feeds or PO intake, and removal of Foley catheter also occur within the first few days. The following days are dedicated to downgrading patient's status, establishment of adequate multimodal enteral/PO pain med regimen, monitoring for infection, increasing levels of mobilization, possible PO trials, tracheostomy downsizing and decannulation, and making discharge arrangements (Table 3.2). Patents should be advised that they will work with physical therapists, occupational therapists, nutritionists, and speech therapists during their hospitalization. If necessary, outpatient follow-up should be arranged prior to discharge with the respective ancillary services.

Anticipated length of their hospital stay should be discussed. Free flap reconstruction of extraoral defects warrants about 4–7 days of hospital stay, as tracheostomies and PO intake are usually not an issue. However, reconstruction of intraoral flaps may require at least 5 days and up to 2 weeks or more of hospitalization depending on the patient's comorbidities and post-op course. Patients should be advised that in the event that they do not meet the criteria for safe discharge home, they may be discharged to an acute rehab facility. A case manager is usually involved in assessing home discharge needs or identifying the appropriate acute rehab facility. For patients who are indicated for adjuvant radiation therapy, discharge to a rehabilitation center should be carefully timed, as radiation therapy treatments should start within 42–50 days (6–7 weeks) after surgery [29]. It is prudent to inform the patient and family members of this important timeline so that the patient's discharge from the facility is planned in the timely manner or appropriate arrangements are made for the patient to see a radiation oncologist.

Table 3.2 Microvascular flap protocol, adopted and modified from "Clinical Pathway Implementation Improves Efficiency of Care in a Maxillofacial Head and Neck Surgery Unit" Yetzer et al. [28]

	POD 0	POD 1	POD 2	POD 3	POD 4	POD 5	POD 6	POD 7	POD >7
Airway	Trach as is, cuff inflated	Vent wean, cuff deflation	Trach collar	Trach collar	Trach downsize to 6 cuffless fenestrated, cappping trials	Capping trials/decannulate if appropriate	Capping trials/decannulate if appropriate	Capping trials/decannulate if appropriate	Optimize as indicated
Pulmonary care	Duoneb q8hrs scheduled			Duoneb q8hrs + chest physio	No resp treatments if capped or decannulated				
Flap Checks	every 1 hour		every 2hrs	every 4hrs	every 6hrs	every 8hrs	every 8 hrs	every 8 hrs	
Pain Management	Multimodal + PRN IV opioid			Multimodal + PRN oral opioids, wean opioids as apropriate					
Nutrition	NPO, no TF, meds only through NG/G-tube	start PO if extra-oral flap, start TF if intraoral flap	advance TF to goal	advance TF to goal	cont TF	cont TF	consider PO trials with clears	consider advancing to full liquid diet	
IV fluids	Maintenance LR	Decrease fluids as TF increase	DC fluids						
Labs	CBC, BMP, Mg, Phos, others as indicated. Order prealbumin with Monday morning labs for each H&N patient								
DVT ppx	Lovenox, unles Cr elevated, then Heparin								
GI ppx	Pepcid or PPI (check if any home meds), stool softeners (pericolace, add Miralax if no BM at POD 5)								
DT ppx	hx of EtOH abuse? Start Librium if no liver issues or Barbuturate taper if liver disease								
Antibiotic ppx	Pre-op Unasyn	Post-op Unasyn 3 doses	no abx unless ssi noted						
Catheter	Remains in place	Eval for removal, remove if able to self-assist	DC foley, must void 6hrs after removal. If not, check bladder scan, if >500cc, straight cath, if retention continues, re-insert foley, consult Urology						
Activity	Bedrest	Bedrest/Edge of bed	Edge of bed/out of bed to chair	Out of bed to chair/ambulate					
Flap donor site	Leave dressing in place						Take down OR dressing, re-dress	Re-dress, suture removal if appropriate	
Skin graft donor site	Leave Adaptic/Tegaderm dressing in place. If accumulated serosanguinous fluid under tegaderm, aspirate with blunt needle, re-inforce with ACE wrap						Take down OR dressing, re-dress with xeroform/gauze/kerlix		
Drains	JP drian to bulb suction, monitor quality and quantity of output. Penrosss in place			Eval drains for removal after patient ambulated, remove if <30cc/24hrs				Remove drains prior to DC	
Consults		Nutritionist	PT/OT		SLP, Case Manager, DC planning	Case Manager, DC planning			

It is important to ensure that patients are discharged with the necessary contact information for the required follow-ups. Outpatient speech and physical therapy as well as lymphedema and trismus management may be needed for months following surgery and radiation. Since the surgical team has the most comprehensive knowledge of the patient's postoperative anatomy, it is in the best position to help navigate patients' needs with the numerous supporting providers.

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Part II

Intra-operative Considerations

Medical Optimization

4

Rusha Patel and Anastasiya Quimby

Hemodynamic Management

Intraoperative management of patients undergoing free tissue transfer is uniquely challenging. Surgeries can be long, and maintenance of fluid balance and hemodynamic stability can be difficult. Surgeon-specific concerns around maintaining viability of the free flap have led to caution when administering vasopressors. Intraoperative hemodynamic management of patients undergoing head and neck free tissue transfer remains controversial. Although various vasoactive agents have been studied in vivo and in vitro, no general consensus with regard to its safety in free tissue transfer or guidelines exists. The contradicting findings on intraoperative vasoconstrictor use may not be entirely surprising. Due to complex interplay of a multitude of physiologic variables, one study stated that it is impossible to predict the response to administration of vasopressors even in the setting of normal physiology [1]. In the setting of free tissue transfer, there have been conflicting reports with regard to pedicle sensitivity to alpha agonists, further casting doubt on our ability to predict a response [2, 3]. Moreover, effective tissue perfusion depends on the pressure gradient between the arterial and venous systems that encourage flow; thus, intraoperative vasoconstrictor administration could be beneficial in certain circumstances during free tissue transfer [1, 3].

Successful outcomes in free tissue transfer are dependent on the establishment of adequate perfusion to the transferred tissues across the newly established anastomoses. Although it is generally accepted that adequate intraoperative blood pressure must be maintained to ensure flap perfusion, there are no standardized guidelines for management. A study by Kass et al. on a cohort of 445 patients concluded that the odds of flap failure increase with mean arterial pressure below 60 for more than 20 episodes of q 5-min measurements [4]. Crystalloid administration was cited as the first choice for the management of intraoperative hypotension [5]. Fluid overload and hemodilution have been shown to increase the risk of flap failure [6]. Historically, over-administration of fluids during free flap surgeries led to concern over pedicle edema and disruption [7]. In the early 2000s, Haughey et al. found that administration of >7 L of fluid during a free flap case was associated with worse flap outcomes, including higher rates of fistula and wound dehiscence [8].

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Several studies have since corroborated these results and found that intraoperative fluid administration between 5 and 7 L was associated with adverse patient and reconstructive outcomes [9–11] and confirmed that excessive perioperative fluid administration leads to poor free flap outcomes in head and neck cancer patients [10, 12]. Studies continue to indicate surgeons' reluctance to use intraoperative vasoconstrictors due to concern for vasospasm and subsequent flap failure, while acknowledging that no convincing scientific evidence exists to merit this viewpoint [5, 13]. Numerous published articles have found the use of vasoconstrictors to be common and not associated with increase in complications [14–17]. Paradoxically, there are papers demonstrating lower rates of flap failures in groups who received intraoperative vasopressors [18]. The lack of consensus on this subject results in varying practices based on anecdotal evidence and personal surgeon experience. Recently, an expert consensus statement from the Journal of Head and Neck Anesthesia recommended the use of hemodynamic monitoring with an arterial line to allow for goal-oriented fluid repletion, while recognizing that as of yet there are no studies demonstrating superior outcomes with this method [19].

Goal-Directed Fluid Repletion

The objective of goal-directed fluid therapy (GDT) is to provide effective fluid resuscitation based on measured and objective hemodynamic parameters. Traditional monitoring of intraoperative fluid needs has been done via estimated blood loss, urine output, and determination of insensible losses. Unfortunately, these methods are inaccurate and may not represent the hemodynamic needs of the patient. GDT instead uses objective cardiac measures, including stroke volume and stroke volume index, as discrete endpoints for fluid administration. GDT has become increasingly more common with the implementation of Enhanced Recovery After Surgery (ERAS) protocols.

GDT begins in the preoperative area. While patients are traditionally expected to fast prior to surgery, GDT protocols encourage a preoperative carbohydrate drink to ensure a euvolemic status prior to surgery. Once in the operating room, the goal should be a "zero balance," which is provided by appropriate hemodynamic monitoring and measured fluid resuscitation. Both invasive and noninvasive monitoring methods exist and include devices such as the EV1000 (Edwards Lifesciences, USA) and FloTrac (Edwards Lifesciences). The former system can be completely noninvasive via a digital sensor and wrist cuff (ClearSight). FloTrac monitors fluid dynamics via a pre-placed arterial line. Both systems provide information on cardiac output, stroke volume and stroke volume variation, systemic vascular resistance, and mean arterial pressure.

Given the risks of fluid over-administration during free flap cases, there has been great interest in assessing the use of GDT to improve patient outcomes for these procedures. An early pilot study showed that GDT use during head and neck free tissue transfer surgery resulted in significantly less perioperative fluid administration (6.4 ± 1.9 mL/kg/h versus 10.2 ± mL/kg/h in GDT versus control groups, respectively) [20]. Several subsequent studies have confirmed that GDT during head and neck free flap surgery can reduce perioperative fluid administration as well as decrease the duration of ICU stay [21, 22]. It should be mentioned that GDT often depends on the use of vasopressors to support intraoperative hemodynamics in lieu of fluid-based support. As such, the interest in GDT for head and neck free flap surgeries has led to an increasing body of research surrounding the safety of vasopressors in head and neck reconstruction. The use of vasopressors during free tissue transfer has historically been avoided due to concerns surrounding vascular insufficiency. The most commonly used vasoactive agents during surgery include phenylephrine and norepinephrine, both of which preferentially act on alpha-receptors and cause vasoconstriction. Due to the mechanism of action, there has been historic concern around avoiding these medications out of natural con-

cern for constriction of the flap perforators or vascular anastomosis. Despite these concerns, a large body of studies going back to the early 2000s have failed to find an association of vasopressor use with adverse outcomes in free flap surgery [10, 14, 23–26]. In contrast, recent studies have found that vasopressor use during reconstructive procedures can positively impact a patient's hemodynamic status [24]. In addition, GDT in conjunction with vasopressor use does not increase flap complications and can decrease ICU and hospital stay [21, 27]. Furthermore, the type and duration of vasopressor administration do not appear to impact flap outcomes in the perioperative period [28]. Given the large body of data behind the safety of vasoactive agents in free flap surgery, surgeons should feel comfortable with vasoactive agents being a part of their patients' perioperative care.

Intraoperative Temperature Management

Patients undergoing free tissue transfer are susceptible to intraoperative hypothermia due to case duration and prolonged exposure at multiple operative sites. With regard to free flap reconstruction, overt hypothermia has been additionally associated with arterial thrombosis, flap infection, and flap loss [29, 30]. Given this, surgeons have traditionally tried to keep operating rooms warm and enable patient warming during the perioperative period. In addition to preventing flap thrombosis, this practice has been thought to promote vasodilation. However, warming has been associated with its own risks of surgical site infections [31]. As an alternative, permissive mild hypothermia has been explored as a method of improving patient outcomes. Several studies have looked at this practice in head and neck free flap patients. A retrospective review found that vessel thrombosis rate was decreased for patients maintained between 36.0 °C and 36.4 °C [32]. A larger review supported this finding and suggested that an average intraoperative patient temperature around 36.0 °C was associated with lower flap-related outcomes [33]. While further work remains to be done in this area, the ideal intraoperative temperature during a free flap surgery may be best within this range. In practice, temperature maintenance within a small range may not be practical. At minimum, normothermia should be maintained and overt hypothermia (<36.0 °C) should be avoided during free flap surgeries.

Pain Management

Adequate postoperative pain management is essential to improving overall patient outcomes. In the USA, opioid use for head and neck patients has been shown to be significantly higher when compared to Italy (6X), Argentina (4X), and India (2X) [34]. Aside from the risk of developing opioid dependence, acute effects of opioids in the immediate postoperative period, such as sedation, nausea, and vomiting, can lead to prolonged ICU stay requiring ventilator support, delay of patient mobilization, and consequently increase in surgical complications. Utilization of the multimodal pain management approach and nerve blocks has demonstrated reduction in opioid use and decreased hospital length of stay in numerous other surgical specialties as well as head and neck microvascular reconstruction patients [35–37].

Multimodal analgesia (MMA) regimens most commonly include gabapentin, NSAIDs (celecoxib, ibuprofen), and Tylenol with various other adjunct medications, including opioids. Gabapentin is an anticonvulsant medication that has also demonstrated effectiveness in pain control. The precise mechanism of action of gabapentin has not been explained; however, the existing theories include potentiation of GABA-mediated pathways, indirect antagonism of NMDA receptors, calcium channels, and inhibition of peripheral nerves [38]. Preoperative use of gabapentin in doses of 600–1200 mg has been associated with decreased postoperative opioid requirement [39–41]. A meta-analysis conducted on a mixed surgical cohort showed no effect on pain scores but demonstrated earlier withdrawal from opioids in patients who took perioperative gabapentin [42].

Nonetheless, other studies have demonstrated no effect on postoperative opioid use and pain scores [43]. Overall, gabapentin is a well-tolerated drug with low side effect profile. The most commonly cited adverse effect of gabapentin is sedation, which may be of benefit in the acute postoperative setting, but should be taken into account where airway obstruction may be of concern. Given the likely benefits of preemptive administration of gabapentin and low risks associated with its use, it is difficult to argue against its use.

Use of regional nerve blocks in the head and neck is limited due to the unique anatomy of the region. However, as most head and neck surgeons have experienced, patients most often complain of pain at the donor site. A study by Le et al. demonstrated that preoperative administration of brachial plexus, lateral femoral cutaneous, and sciatic nerve blocks for harvest of radial forearm, anterolateral thigh, and fibula free flap has demonstrated significant reduction in opioid requirements [44]. Availability of anesthesia personnel skilled in regional block administration may be a limiting factor in some institutions. As the nerve block administration must be completed preoperatively, additional time either in pre-op or prior to surgical incision in the operating room must be anticipated.

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Surgical Optimization

5

Laurent Ganry and Anastasiya Quimby

Introduction

Preoperative planning in head and neck reconstruction with microvascular flaps should be considered as important as surgery itself. Precise and straightforward surgical plan is mandatory as head and neck represents one of the most challenging parts of the human body to reconstruct.

> *The Devil is in the details. Ludwig Mies van der Rohe (1886–1969)*

We are fortunate to live in an era of new technology that is easily accessible in many countries. These innovations allow for efficient preoperative planning, help design accurate surgical plans, and thus help improve the surgeries and outcomes [1, 2]. Before these advances, surgeons had to perform complex conformation of osseous flaps manually or design soft tissue flaps with anatomical landmarks that did not always correlate with the patient's individual anatomy. It is quite common nowadays to be guided by a preoperative virtual surgical planning (VSP) with perioperative 3D printed guides or virtual/augmented reality. However, these technological advances cannot replace the surgeon's need to know how to perform head and neck reconstruction without the modern approaches. "Freehand" surgery can be the only way to proceed in certain circumstances (in case of emergency surgery or free flap failure, or in case of unexpected perioperative change of plans). Mapping of perforators for soft tissue free flaps is also an extremely important aspect, which can be performed with the help of preoperative angio-CT scan, acoustic Doppler sonography, color duplex Doppler, indocyanine green, augmented reality, reliable anatomical landmarks, or a combination of the above techniques [3–6].

Unfavorable outcomes are described as the result of poor or inadequate planning, design, and execution, working together in a triangular relationship [7].

Preoperative surgical planning should always include meticulous evaluation of the patient's needs and medical history, family history (especially of hereditary thrombophilia), evaluation of the donor-site morbidity, as well as evaluation of risk factors. Risk factors for perioperative complications in patients with head and neck cancer receiving free flaps include the following [8]:

- Medical: age, comorbidities (ASA 3–4, Kaplan-Feinstein index 2–3), BMI (malnutrition), tracheostomy
- Surgical: comorbidities (ASA 3–4), preoperative hemoglobin level

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Different surgical plans should be executed depending on the type of flaps and the level of dissection needed, from a straightforward musculocutaneous pedicle flap to a more tedious perforator or prelaminated flap. Assessment of previously irradiated field and availability of the cervical recipient vessels are also a major consideration for the procedure success in head and neck surgery regarding the choice of flap and its pedicle's length [9]. Age or diabetes mellitus is never a contraindication for flap harvest [10], but vascular calcifications and stenosis due to chronic diabetes mellitus should modify the flaps' donor site choice toward the upper body, less prone to atherosclerosis disease, as fibula and even thigh flaps (such as ALT) could present with severely calcified arteries (from Monckeberg's arteriosclerosis) [11] (Figs. 5.1 and 5.2).

It is of paramount importance to avoid any free flap failures, as free flap complications lead to [12, 13]:

- Longer ICU and hospital stays
- Poorer functional outcomes that will decrease the quality of life
- More surgical interventions under general anesthesia for an already frail population
- Delay in adjuvant therapy, amongst other factors, that may result in failure of oncological treatment and ultimately higher mortality rates

With regard to the choice of the donor site, the human body offers an incredible number of choices and refinements of different tissues to harvest. Usually, the selection depends on the preference and surgeon's experience and should always be discussed and balanced with the patient's needs. As an example, the classic reconstructive ladder should not be followed as a must, as it is nowadays only useful to describe in clinical practice a classification of reconstruction levels. If the best reconstruction for a patient involves the use of a free flap, and if this solution is a reasonable choice taking into consideration patients' comorbidities, it should be performed first.

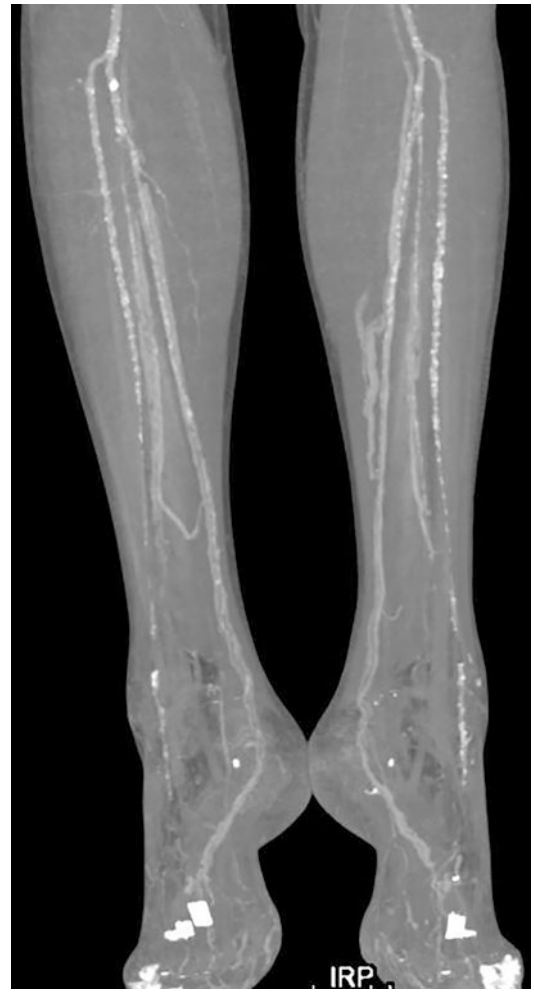

Fig. 5.1 Advance arteriosclerosis of the lower extremity—relative contraindication of a fibula free flap harvesting

A Few General Considerations

- Choose a subscapular system free flap rather than a fibula free flap in case of arteriosclerosis or vascular anomalies of the lower extremities, such as anatomical variations or popliteal aneurysm, even though it compromises the bone stock available for dental rehabilitation (Fig. 5.3).
- Perform soft tissue-only free flap and a reconstructive plate for cases without any dental rehabilitation planned, with low probability of postoperative radiotherapy, or with anticipated poor overall survival outcomes.

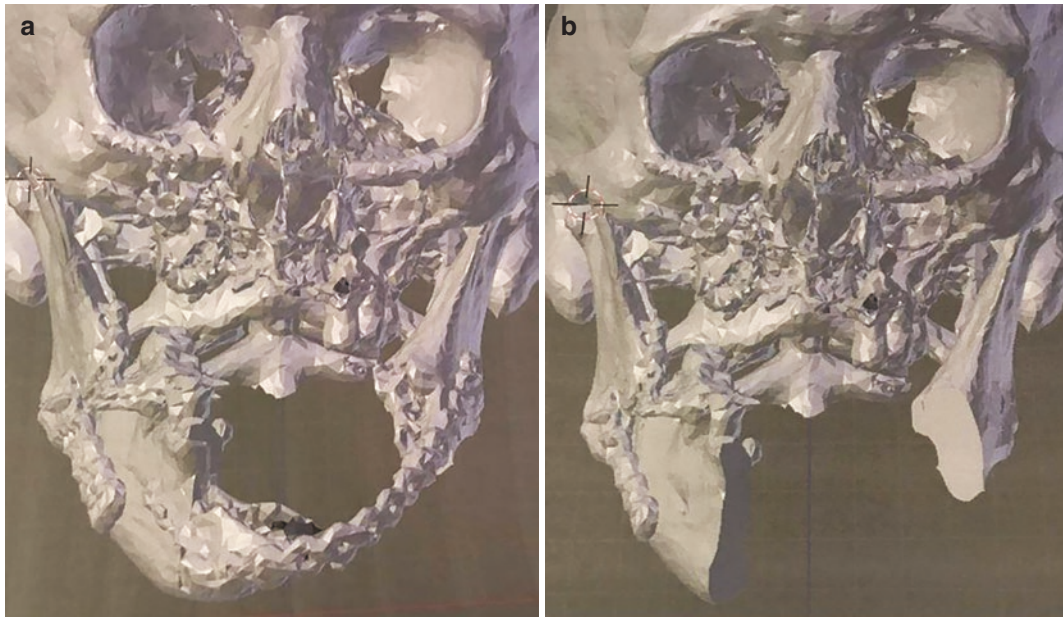

Fig. 5.2 (**a, b**) Mandibular segmental defect on a gunshot wound (GSW)

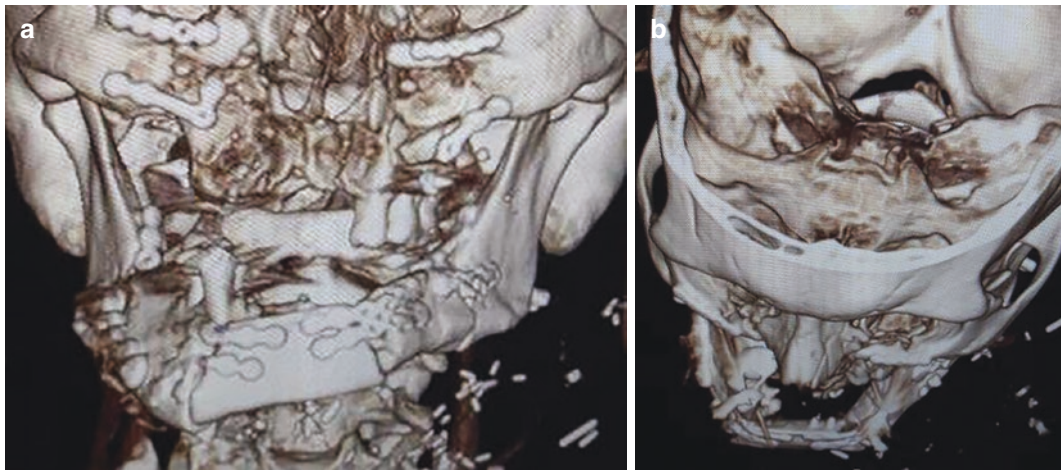

Fig. 5.3 (**a, b**) Reconstruction of the mandible with a scapula free flap (from angle to contralateral parasymphysis)

- Consider a free flap with very low donor-site morbidity (e.g., ALT) rather than a pedicle flap, which may lead to higher relative donor-site morbidity than a free flap (e.g., PMMC, especially in female patients), or higher risk of partial necrosis.
- Proceed as staged procedures.

There are three classic clinical presentations and three specific comorbidities that should be considered when deciding on the type of reconstruction for head and neck patients:

The Three Clinical Presentations

1. *The "classic" oncologic patient* who will frequently benefit from adjuvant therapy such as radiotherapy, for whom aesthetic and function outcomes will be more challenging to preserve due to oncologic treatment side effects. The main focus should be driven toward straightforward and safe procedures (as patients might have numerous comorbidities). It should never be forgotten that the main goal is to cure cancer and aim for a higher quality

of life and dignity for the patient. Therefore, the first choice should be to use flaps and free flaps, which are known for their reliable anatomy, large and long pedicle, and harvest ease, providing larger amount of tissue if needed (to anticipate muscular atrophy and tissue retraction due to the radiotherapy) and team preferences (fibula free flap (FFF), scapula free flap (SFF), anterolateral thigh (ALT) free flap, radial forearm free flap (RFFF), pectoralis major myocutaneous (PMMC) flap, latissimus dorsi (LD) free flap, etc.).

2. *The post-traumatic patients or those with benign but locally aggressive tumors*, who usually have a younger presentation, for whom aesthetic and functional considerations are of much greater importance (e.g., high-velocity trauma, gunshot wound, ameloblastoma, giant-cell tumors, myxoid tumor). These patients can benefit from flaps with higher bone stock (e.g., deep circumflex iliac artery (DCIA) free flap), perforator free flaps with less morbidity or thinner skin paddles choosing different elevation planes (above fascia or above fascia superficialis), prelaminated free flaps, jaw-in-a-day procedure with dental implants and dental prosthesis, or immediate nerve reconstruction with autogenous nerves or allograft. These patients should benefit from procedures without the need for skin paddle debulking if possible and lower donor-site morbidity as they are usually more active (socially and professionally).
3. *The "non-classic" oncologic patient group*, a young patient with a complex oncologic disease or an older active and healthy patient looking for a more complex procedure to improve his/her quality of life.

The Three Specific Head and Neck Comorbidities

1. Previously irradiated patient or presenting with osteoradionecrotic (ORN) disease

   This patient group has a higher rate of flap failure and wound complications in free flap reconstruction [14]. Benefit versus risk equation of any surgical procedure should be carefully balanced:

   - Flap failure rate is about 9.8%, and postoperative complication rate is around 39.7% with the most common being fistula formation (8.4%), hardware plate exposure (7.1%), and wound infections (6.5%).
   - Lack of normal and pliable cervical/external skin results in tissue rigidity, delayed healing, low resistance to swelling, difficult tissue handling, and surgical plane distortion. Direct closure of the irradiated neck of the external skin flaps often leads to skin flap necrosis, wound breakdown, and even free flap failure due to compression of the vascular pedicle. It is recommended to always plan for an external skin island flap from the free flap to facilitate external skin tension-free closure.

2. Vessel-depleted neck

   This presentation leads to a higher mortality rate and is a more likely clinical scenario these days due to progress in head and neck cancer treatment with longer survival rate and better local tumor control. Indications for free flap surgery in vessel-depleted neck patients include new resections due to tumor recurrence, new tumor, or as consequences of treatment sequelae and represent about 7% of all microvascular reconstructions in head and neck cancer patients [15]. Although interpositional vein grafts are necessary at times, due to their association with poorer outcomes, it is warranted to attempt to minimize their need [16]:

   - Select flaps with long pedicle (LFCA system, FFF, subscapular system, RFFF).
   - Design the flap to optimize maximum length of the pedicle.
   - Use recipient vessels that could be reversed to reach the neck and the neo-mandible if needed, especially the internal mammary pedicle [17]. The downside of such procedure could be the close proximity of the microvascular anastomosis with a tracheostomy.

     Additionally, it is important to plan for reconstruction of the secondary defect of the external cervical skin to cover the vascular pedicle [18] or a deeper flap:

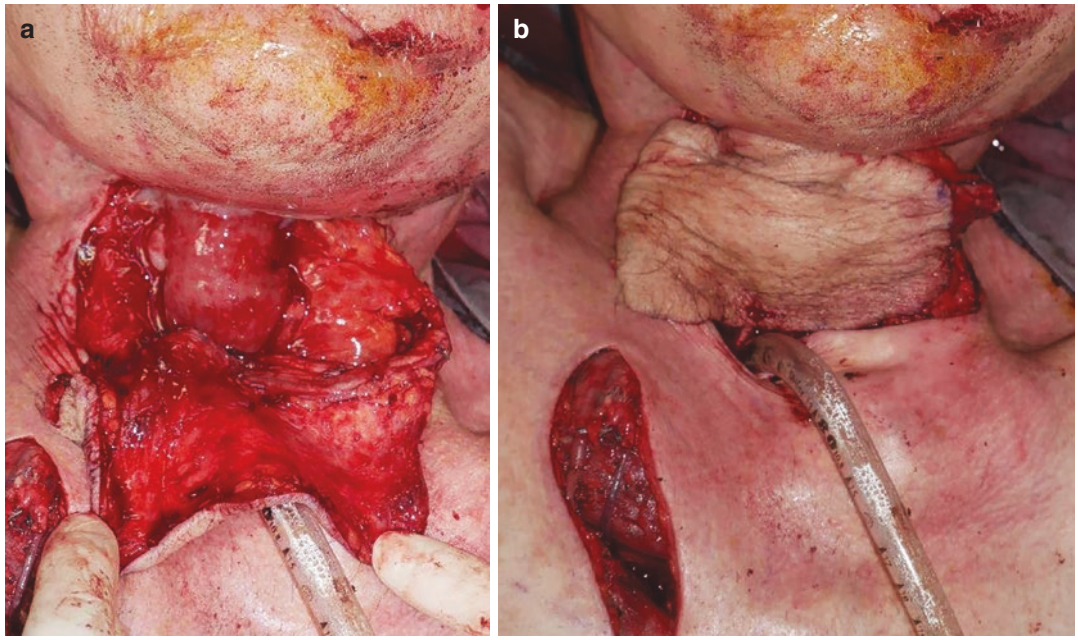

Fig. 5.4 (**a, b**) Esophageal reconstruction with a jejunum free flap, covered by an RFFF anastomosed to the right internal mammary pedicle for reconstruction of the external skin of the neck, and coverage of the underlying esophageal reconstruction

- Flap design with separate flap component (chimeric)
- Second flap to cover the pedicle or a deeper flap (additional free flap as carrier of vessels like an RFFF onto internal mammary artery to help bring vessels in the neck and add the external skin layer on the neck to release the pressure) (Fig. 5.4)

3. Salvage surgery group

   Things to consider in this group are the following:

   - Time to recurrence (disease-free interval) [19, 20]: the longer, the better for the survival (>6–12 months).
   - Stage of recurrence [21]: 73.7% of patients will present with stage III–IV disease.
   - Prior treatment [22]: neck dissection should only be considered in advanced T3/T4 stages. The risk of neck metastasis found during salvage surgery for local recurrence in patients treated initially with radiation for N0 is low. Complication rate of selective neck dissection is up to 40% in this group.
   - Primary tumor site [23, 24]: laryngeal tumor recurrence has the best prognosis for overall survival at 5 years after surgery (85% for early stage, 48% for advanced stage), and the site with the worst prognosis is the hypopharynx (22–33% for early stage, 0–17% for advanced stage). Oral cavity and oropharyngeal recurrences have an overall survival of 43% and 23%, respectively. In case of a local neck recurrence, the overall survival after surgery is 36% at 3 years, with those patients who recurred late (>6 months) and had low-volume disease (N1) having the best chance of surgical salvage [25].
   - Aggressiveness of the salvage surgery: re-irradiation is an option when surgery is not possible due to anticipated high rate of complications (>20% of mortality) [26]. Those patients who underwent R0 salvage resection but were noted to have extranodal extension, perineural invasion or lymphovascular invasion re-irradiation are recommended [27]. If performed post-

salvage surgery with R1 resections (even combined with adjuvant chemotherapy), there is no benefit to the overall survival rate [28].

- Quality of life post-salvage.

Without a doubt, a head and neck surgeon will attempt to provide the best outcomes for his/her patient on every occasion, but it should be remembered that "good is sometimes better than great," as great associated with severe or life-threatening complications is too high of a risk with questionable benefit.

> *No matter what measures are taken, doctors will sometimes falter, and it isn't reasonable to ask that we achieve perfection. What it is reasonable is to ask that we never cease to aim for it." Atul Gawande from "Complications: A Surgeon's Notes of an Imperfect Science*

Improving socializing with more acceptable facial contours and allowing a patient to be living free of a tracheotomy and/or a PEG tube have a significant influence on their overall quality of life.

The reader should also be made aware of a possible higher risk of complications with refined procedures such as perforators flaps [29], and a possible higher risk of partial peripheral skin loss with thin flaps (defined by harvest above the fascia superficialis), especially for non-axial perforator thin flap [30]. This is of paramount importance, especially in a time when multiple authors are harvesting thin flaps above the fascia superficialis, and when fascial perforator flaps are growing in popularity. However, this type of flap refinements are an absolute must in highly selected cases, especially when there is a need for external flat resurfacing. However, it is the feeling of the authors, even if there is no data on such a topic, that whenever these thin flaps are folded into complex structures such as a tongue, or used to resurface complex 3D cavities, the risk of partial failure with venous congestion seems to be higher.

The main rule of preoperative planning in microsurgery should always include a plan B or C to deal with a possible failure and to carefully evaluate the balance between benefit and risk of any reconstructive procedure. As an interesting example, total mandibular reconstruction is an extreme challenge and is classically encountered with extensive ORN disease. Rather than performing a double-osseous free flap, it may be wiser to raise only one osteocutaneous fibula free flap for bony and intra/extraoral soft tissue reconstruction, including the reconstruction of only one temporomandibular joint (TMJ), associated with a prosthetic reconstruction of the contralateral TMJ (Fig. 5.5). In case of insufficient extraoral soft tissue coverage, an associated soft tissue-only second free flap (e.g., ALT) or a locoregional pedicled flap (e.g., supraclavicular flap) could be performed. With such procedure, a second fibula free flap could be preserved to deal with complications and to minimize the procedure morbidity (only one lower extremity would be the donor site in this example).

Performing thin flap elevation and refined head and neck perforator flap harvest should always be encouraged in any case, but only if it can bring a clear and safe benefit to the patient with an acceptable success rate and a robust plan B in case of any failure.

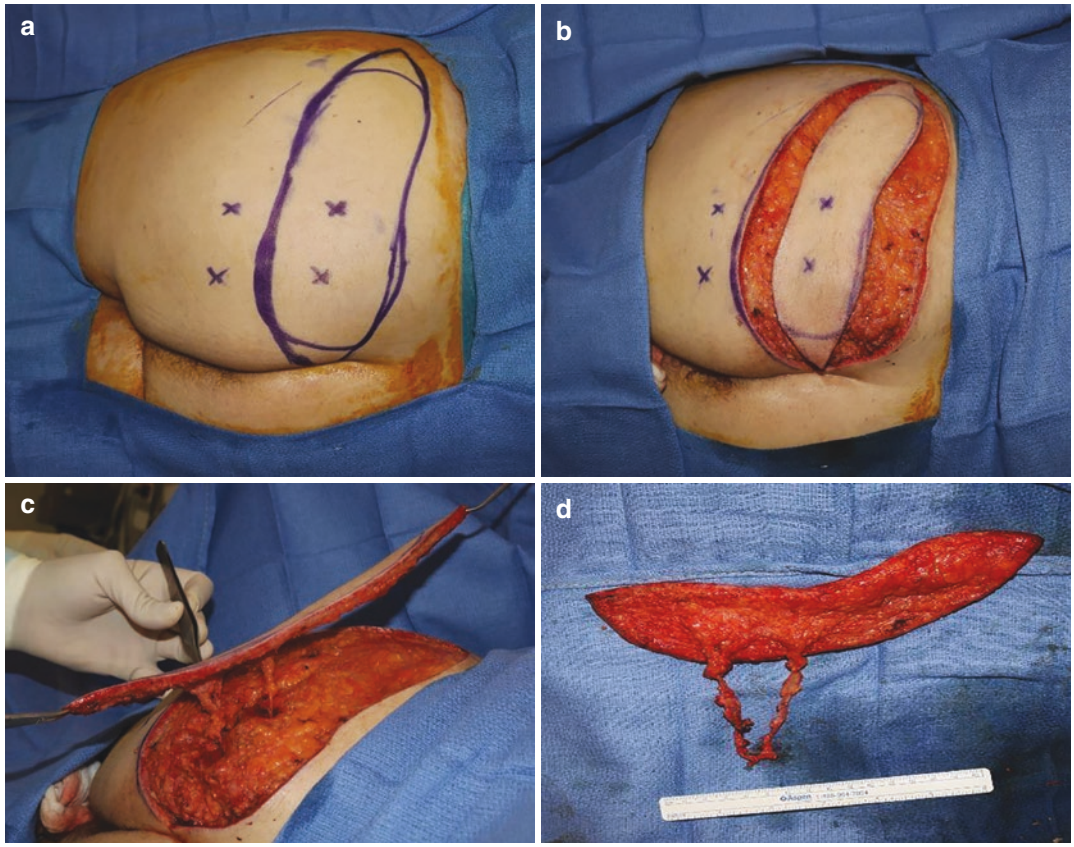

Fig. 5.5 (**a–d**) Example of a thin SGAP flap raised above the fascia superficialis [31]

Reconstructive Procedure Preoperative Assessment

- *If soft tissue donor site only:*
  - Preoperative angio-CT scan for vessel and perforator evaluation and virtual surgical mapping if needed.
  - Acoustic Doppler sonography by the surgeon to identify a pedicle or fasciocutaneous perforator in a large flap with reliable anatomy (classic situation).
  - Color Doppler dual process by the surgeon to identify a perforator, its perforation of the fascia, and its direction in the fat layers. Acoustic signal only does not help to gather this information. Can also be used in flaps with variable anatomy (e.g., SCIP, ALT, DIEP) or specific situation (prelaminated flap).
- *If bone tissue donor site:*
  - Preoperative angio-CT scan for vessel evaluation (atherosclerosis and anatomical variation) and bone virtual surgical planning if needed.
  - Preoperative vascular US of the lower extremities in case of a fibula free flap for a better evaluation of the blood flow (depending on the team practice).
- *Recipient site:*
  - Cervico-facial angio-CT scan for vessel evaluation and bone or soft tissue virtual surgical planning (also part of the pathological assessment—trauma/tumoral/congenital).
  - Color Doppler dual-process or the supra-aortic vessels, to assess arterial stenosis and blood flow not seen with an angio-CT scan (depending on the team practice).

Angio-MRI is a good alternative for vessel evaluation in case of a contraindication of an angio-CT (e.g., dye allergy).

Preoperative Specific Considerations

Tracheostomy

The use of elective tracheostomy in major head and neck surgery is well established, although practice varies between units [32]. Simple and effective scoring systems are published and could help to guide decision-making in the management of the airway for head and neck case with flap reconstruction. They take into consideration the tumor staging, type of reconstruction, location of the tumor, coexisting comorbidities, history of previous treatment for head and neck cancer, and laterality as bilateral neck dissection [33]. However, given the significant heterogeneity of currently available scoring systems (TRACHY, Cameron, CASST), they prove to be inadequate for decision-making and predictive modeling of tracheostomy [34].

It is important to decide on tracheostomy preoperatively as it is usually the first step of the procedure to be performed. If performed at the end of the procedure, it will extend the time between the completion of free flap anastomosis and the return to spontaneous ventilation by the patient after extubation. There is no data evaluating the length of time between the completion of the anastomosis and awakening of the patient from general anesthesia, and free flap failure. However, it would make sense to think that in head and neck surgery, a patient would benefit from a faster awakening after the completion of the microanastomosis. Due to positive-pressure ventilation and resulting increased venous pressure, venous backflow may develop. If the arterial blood flow in the flap is weak (due to small microanastomosis diameter, patient low systolic pressure, or arterial vasoconstriction), this prolonged elevated venous pressure with possible venous backflow could lead to venous thrombosis leading to failure of the reconstruction (in free flap surgery, but also very well studied in lymphaticovenous anastomosis) [35, 36]. Finally, the late tracheostomy procedure could lead to accidental compression of the microanastomosis with the retractors, leading to possible higher risk of free flap failure.

- Classic tracheostomy indications
  - *When there is a high risk of postoperative aspiration (due to anatomical modifications, glossoptosis, or postoperative edema):*
    Posterior and large maxillectomy
    Anterior mandibulectomy
    Large glossectomy
    Oropharyngeal and laryngeal surgeries
    Patient neurological baseline (previous stroke, Parkinson, etc.)
  - *When there is a high risk of postoperative surgical complications:*
    Neck hematoma or edema: consider a tracheostomy in case of bilateral neck dissection depending on the size and location of the primary tumor. Bilateral node dissection on its own is not a reliable predictor for elective tracheostomy.
    Infection or wound dehiscence: consider a tracheostomy in ORN patients associated with a large reconstruction and a neck dissection. Frozen neck and severe trismus work against postoperative edema formation by fixation of the soft tissues, but this patient's group may have other comorbidities with higher risk of aspiration and should always be considered for a tracheostomy.
    Postoperative respiratory failure: consider a tracheostomy in patients with nasal intubation who are at risk for pulmonary complications. Development of secondary pneumonia may require repeated bronchial interrogations, which a nasal tube is not amenable to. Additionally, a tracheostomy should be considered if severe postoperative trismus may be anticipated or large reconstruction of the anterior part of the oral cavity or lips (cross-lip surgery) is

planned. In case of respiratory failure, post-op intubation and/or tracheostomy are high risk for flap compromise.

- *Special consideration for airways management in oncologic surgical larynx*
  - Preoperative tracheostomy for airway management in such settings is associated with worth disease-free survival rate in laryngeal cancer before its management for a primary tumor as for a recurrent cancer [37]. Indeed, it can lead to faster spread of a subglottic tumor through open anatomical barriers. A tracheostomy performed in such a life-threatening situation should lead to a management of the tumor in the next 15 days if possible [38].
- *When not to consider a tracheostomy*
  - In lateral segmental mandibulectomy without lingual extension of the tumor and unilateral neck dissection
  - In surgeries with low postoperative risk of aspiration
  - In situation where the patient can be safely ventilated postoperatively

Hereditary Thrombophilia

In the case of previous multiple free flap failures in the same patient, screening for genetic hypercoagulable conditions and hereditary thrombophilia screening should always be performed before planning any new procedure (Tables 5.1 and 5.2). Being more opinion-based than evidence-based discussion, microsurgeons in general agree to perform thrombophilia screening after an arterial thrombotic event during the procedure or < 1 Hour, after one acute unexplained free flap lost, or after two free flap losses in the same patient [40]. Recommendation against routine hereditary thrombophilia testing is accepted because the results are unlikely to affect management and may lead to harm [39].

One should keep in mind the potentially devastating cause of free flap loss, due to heparin-induced thrombocytopenia and thrombosis (HIT). It is an immune complex-mediated phenomenon with antiplatelet factor-4 (PF-4) antibodies and usually an underreported cause of early flap failure due to subclinical manifesta-

Table 5.1 Relative risk and prevalence of selected hereditary thrombophilias [39]

Thrombophilia	Prevalence (%)	Relative Risk for VTE
Prothrombin G20210A carrier	1–5 in Caucasians	2.8
Factor V Leiden carrier	5–8 in Caucasians	4.9
Protein C deficiency	0.2–0.5	7.3
Antithrombin III deficiency	0.2–0.5	8.1
Protein S deficiency	0.03–0.13	8.5
Prothrombin G20210A/factor V Leiden heterozygosity	0.1	20.0
Factor V Leiden homozygosity	0.06–0.25	80

VTE, venous thromboembolism.

The standard battery of tests include testing for antithrombin III deficiency, protein C and S deficiency, factor V Leiden, and homocysteine levels.

Table 5.2 Tests for genetically determined hypercoagulable states [40]

Factor V Leiden gene mutation
Prothrombin *A20210G* gene mutation
MTHFR gene mutation
PAI-1 gene mutation
Protein C and S activity deficiency
Antithrombin III deficiency
Lupus anticoagulant
Plasma homocysteine level
Anticardiolipin antibody
Antiphospholipid antibody
β2-glycoprotein antibody

tions at the time of flap loss. Maintaining a high index of suspicion for HIT in free flap failures is important, especially in unexplained early thrombosis, as its onset is unpredictable [41].

Avoid Vein Graft if Possible and Plan for Sufficient Pedicle Length

Extra-luminal mechanical complications such as pedicle kinking, compression, or twisting are the main causes of flap re-exploration (68–83% of re-exploration cases) [42, 43].

Preventive strategies to avoid these major complications can be taken during preoperative planning: for example, with VSP of the pedicle length and position in an FFF before the surgery, or just with an appropriate free flap design including vessel side to avoid unnecessary kinking, and good length of the pedicle to avoid any vein graft. An intermediate RFFF is a classic solution to bridge a vascular defect, working as a "flow-through" free flap.

Vein grafts are known to be linked with higher rate of free flap failure in head and neck surgery. It is thought to be due to the increased number of anastomoses, and it also correlates to the length of the vein graft itself [16, 44, 45].

A specific head and neck vascular loop known as the "Corlett loop" [46] is probably safer than regular arteriovenous vascular loops for extremity reconstructions [47] and utilizes a long length of cephalic vein to achieve both arterial and venous anastomosis. This solution should be avoided if possible. It is a last solution in vessel-depleted neck, or in some cases of skull reconstruction when the superficial temporal pedicle is not available anymore.

Preoperative Planning of Free Flap Design, "How to Do It"

Planning for Soft Tissue-Only Reconstruction

The challenge in soft tissue-only reconstruction is to map the pedicle or perforators of interest to maximize the chance of a minimally invasive skin design and to properly orient the pedicle, especially if multiple skin paddles are planned.

Freestyle harvest can be safely executed in flaps with reliable anatomy and perforasomes, especially in case of a large skin paddle harvest, as it may lead to larger surgical access and better visualization of the patient anatomy. For example, a freestyle harvest is usually performed in ALT, fasciocutaneous skin paddle of an FFF, and thin free flap elevation depending on the surgeon's experience. For thin free flap elevation, it is recommended to follow the concept of cold and hot zones [48].

- How to perform a pedicle/perforator mapping?
  - *Handheld acoustic Doppler sonography only*—It remains as the most widely used tool due to its low cost, fast learning, hand portable design, and ease of use despite an undesirable number of false-positive (it does not allow the surgeon to evaluate the real anatomy of the perforator) [49] (Fig. 5.6).
  - *Color duplex Doppler only*—In the preoperative mapping, it helps in identifying high velocity/flow/diameter of a perforator (physiology) and mapping the pattern of perforator (anatomy) (Fig. 5.7). It is a game changer for preoperative flap mapping, especially in unreliable donor-site anatomy. Knowing preoperatively the location where a perforator is going through the deep fascia allows a faster and safer sur-

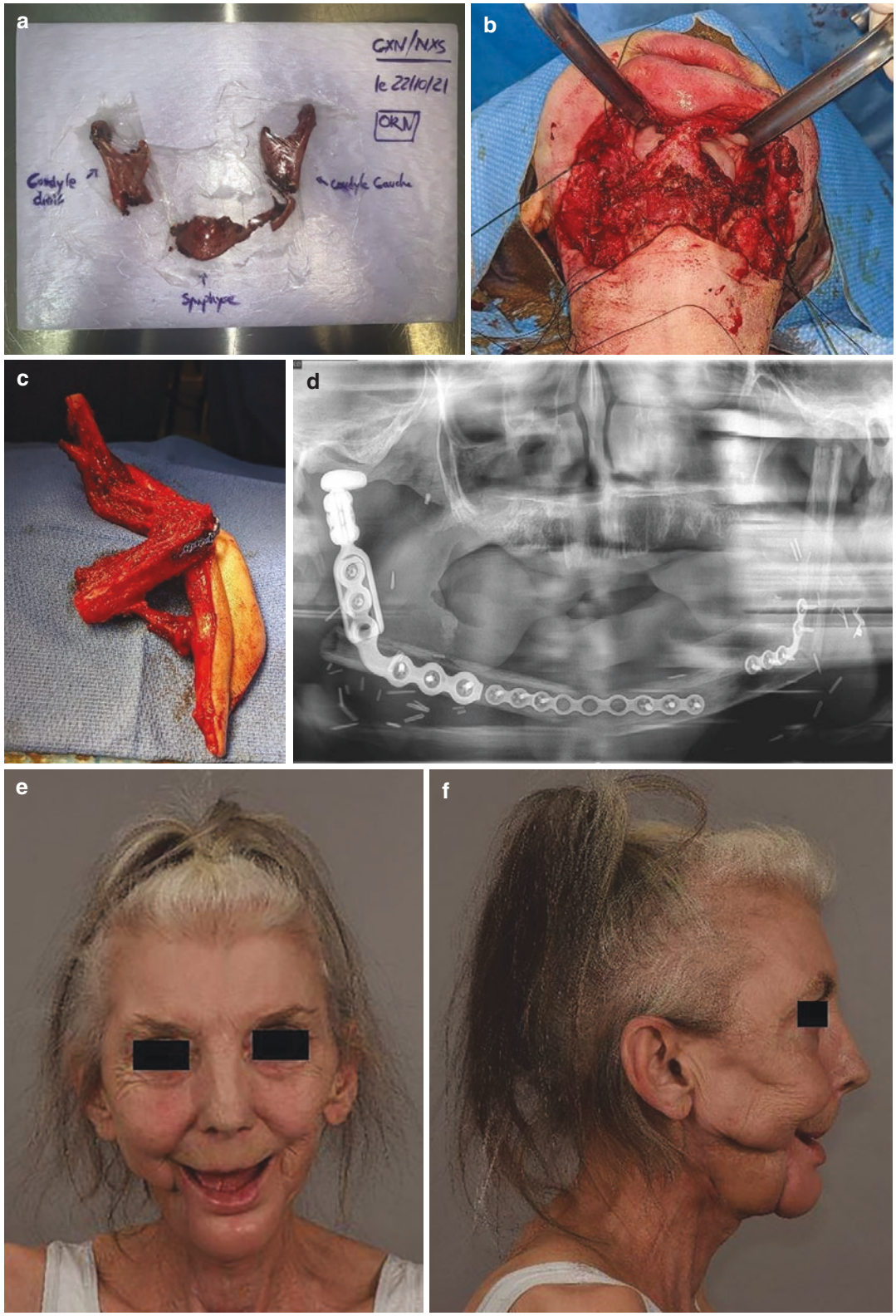

Fig. 5.6 (**a–f**) Total mandibular resection for bilateral ORN, reconstructed with one FFF, associated with a total TMJ prosthesis

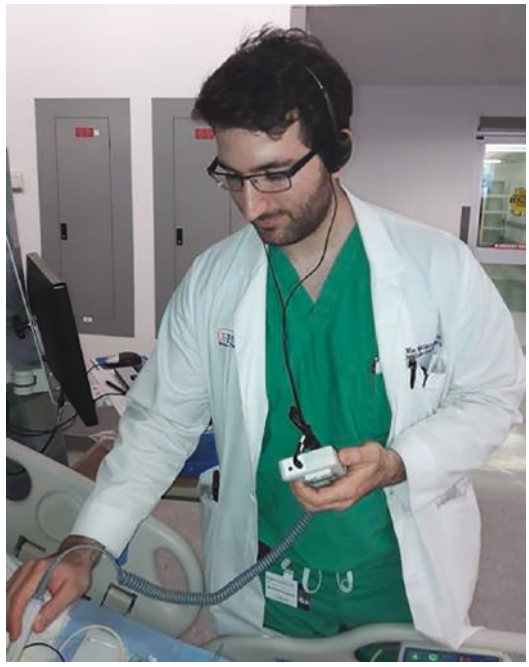

Fig. 5.7 Postoperative assessment of a free flap in PACU with an acoustic Doppler

gery with the possibility for refinement such as a more superficial plane of elevation [50]. It can also help localize the dominant perforator (based on the size and the inflow velocity and volume) to the subdermal plexus of the skin or find the perforator with the less muscular pathway for simpler dissection. It is also useful to locate superficial veins to include into the flap to avoid any venous congestion (RFFF in obese patients, SCIP flap) [3] and allows screening for anatomical variation (e.g., fascial pedicle).

Use a regular or hockey-style probe of 15 MHz to be able to visualize and evaluate perforator's inflow (higher resolution with higher frequency can be used for smaller superficial vessels—for example a 45–75 MHz probe is used for superficial lymphatic vessels of 0.2–0.3 mm in diameter).

Best preset programs are « breast », « thyroid », and « vascular ». Favorable device properties are depth focused to 2–5 cm, pulse repetition frequency (PRF/scale) set low to 0.5–1.5 kHz/3–10 cm/s, color gain high, and wall filter (WF) low/off (<50 Hz) [51].

The threshold perforator's inflow velocity for a reliable flap is a minimum of 15 cm/s [52], as for the recipient vessel—higher flow of 25 or 30 cm/s is not always better as it depends on the flap design, size, and components. For example, a larger flap should benefit from a higher flow velocity (or multiple perforators), to avoid peripheral necrosis. In the situation of a perforator-only cutaneous free flap, if the perforator is anastomosed with an axial larger vessel, the flap may undergo non-physiologic overflow and vascular congestion. This concept is not true with a muscle-only free flap as it has very low vascular resistance in high flow setting and will not suffer from any congestion. This is the reason why it is better to connect a perforator-only cutaneous free flap in an end-to-side fashion to obtain a more physiological perfusion and avoid any overflow congestion, leading to a possible partial or total failure, especially in thin free flaps. The true question is: "What is the best inflow for a particular flap?" However, this question cannot be answered yet in the literature. If the recipient vessel has a flow velocity of 15 cm/s, it can be used, and over 20 cm/s, it is very safe.

– *Acoustic or color duplex Doppler to confirm the findings on an angio-CT scan*—in case of an ambiguous anatomy. Angio-CT scan is currently considered as the gold standard imaging tool in revealing the three-dimensional anatomical details of perforators over 1 mm in diameter precisely [53, 54].

– *Preoperative perforator mapping technique with indocyanine green (ICG) angiography*—intraoperative assessment and postoperative monitoring of the viability of free flaps are of high relevance in reconstructive microsurgery and can be assessed with ICG angiography [55] (Fig. 5.8). It can also assess microanastomosis patency, using a microscope-integrated near-infrared angiography [56]. In preoperative settings, it may provide information about perforator mapping and selection before the beginning of the case [57].
– *Augmented reality*—This technology uses virtual planning with perforator mapping in 2D or 3D, typically from an angio-CT scan, where perforators are located in the 3D soft tissue image. The best way to project this data on a patient for a true mapping solution in augmented reality should be a user-friendly tool:

  By smartphone/tablet: Thanks to the « Fino » application in a smartphone, projecting in the device the perforator mapping from an angio-CT scan [58] (Fig. 5.9). It is an easy, noninvasive, and accurate method for preoperative planning, showing a very high correlation level with intraoperative findings.

  By projection mapping: It uses the same concept as above with the superposition of a vessel directly onto the patient, but using a simple device called a pico projector and lights [59] (Fig. 5.10). We were able to project efficiently the perforators for DIEP and SCIP flaps in our practice. Advantages are to have a direct vision of the mapping without any devices in between like a smartphone or a tablet [60].

  By smart glasses: It uses one or multiple markers directly onto the skin of the patient to align properly the VSP (perforators and anatomical structures) onto the patient (Fig. 5.11). Usually, a phase of data acquisition,

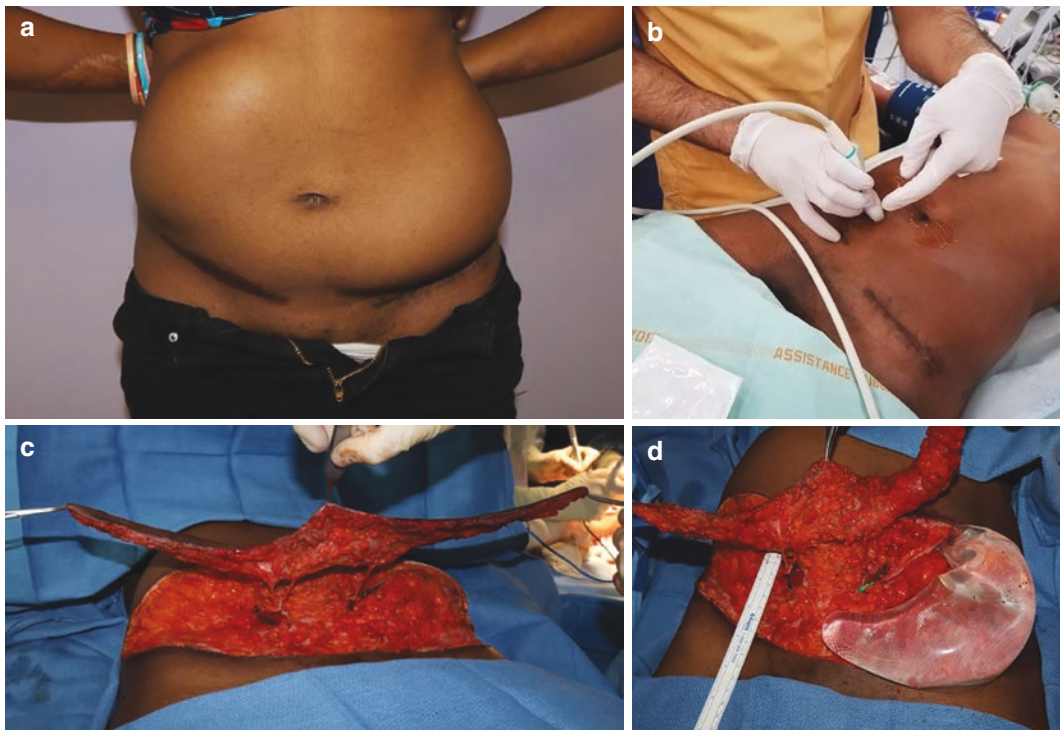

Fig. 5.8 (**a–d**) Planning of perforator's anatomy with color duplex Doppler in a pre-expanded and thin DIEP flap harvest in a pediatric scenario, to allow primary closure of the donor site with appropriate contour of the defect

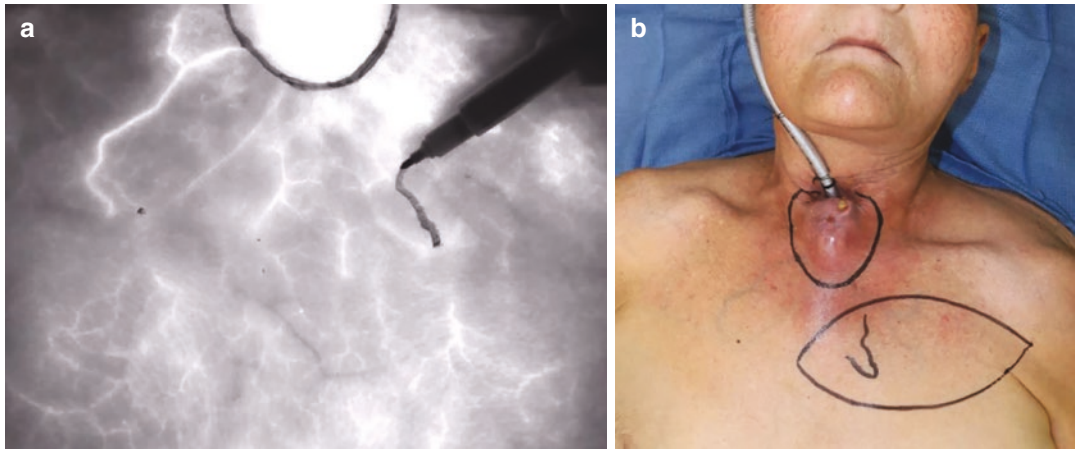

Fig. 5.9 (**a, b**) Preoperative marking of an IMAP left perforator with ICG, for reconstruction of an infrastomal recurrence

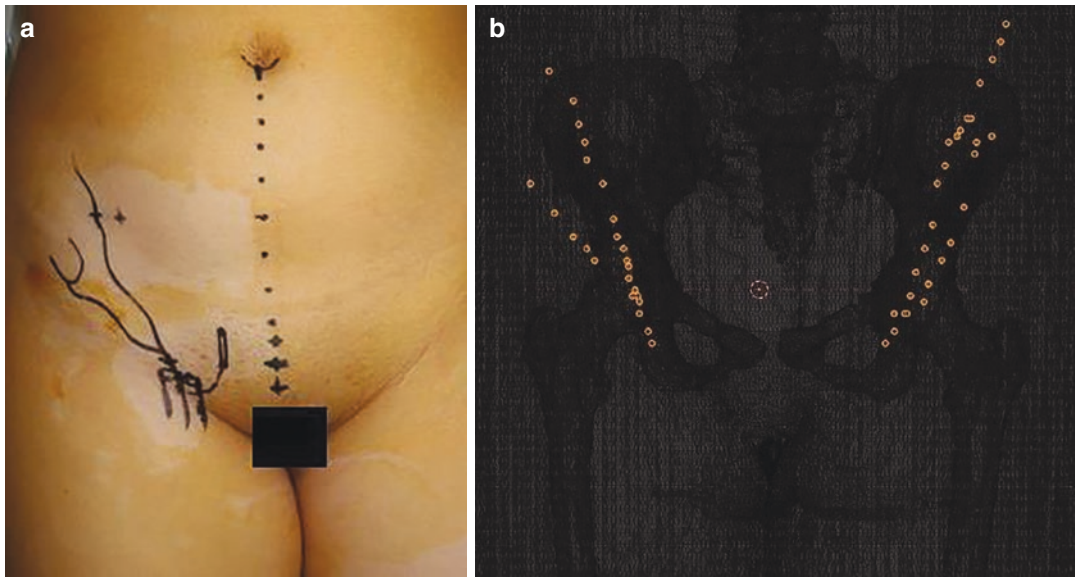

Fig. 5.10 (**a, b**) Preoperative mapping of a right SCIP flap vascularization using the Fino app with a smartphone

like in infrared navigation, is mandatory for the alignment [61]. The downside of this approach is its complexity and the fact that a surgeon cannot use microvascular loupes at the same time, which may be problematic during a surgery.

- Specific considerations for soft tissue flaps
  - *Radial forearm free flap (RFFF) and the rarer dorsalis pedis free flap (DPFF, in case RFFF is not available):*

Provide very thin fasciocutaneous free flaps with good skin paddle size and long pedicle.

Downside is the donor-site morbidity for both.

Perform clinical Allen test for RFFF (or using pulse oximeter/color duplex Doppler) and an angio-CT scan for DPFF (to evaluate for lower extremity vascular axis to the foot and anatomical variations).

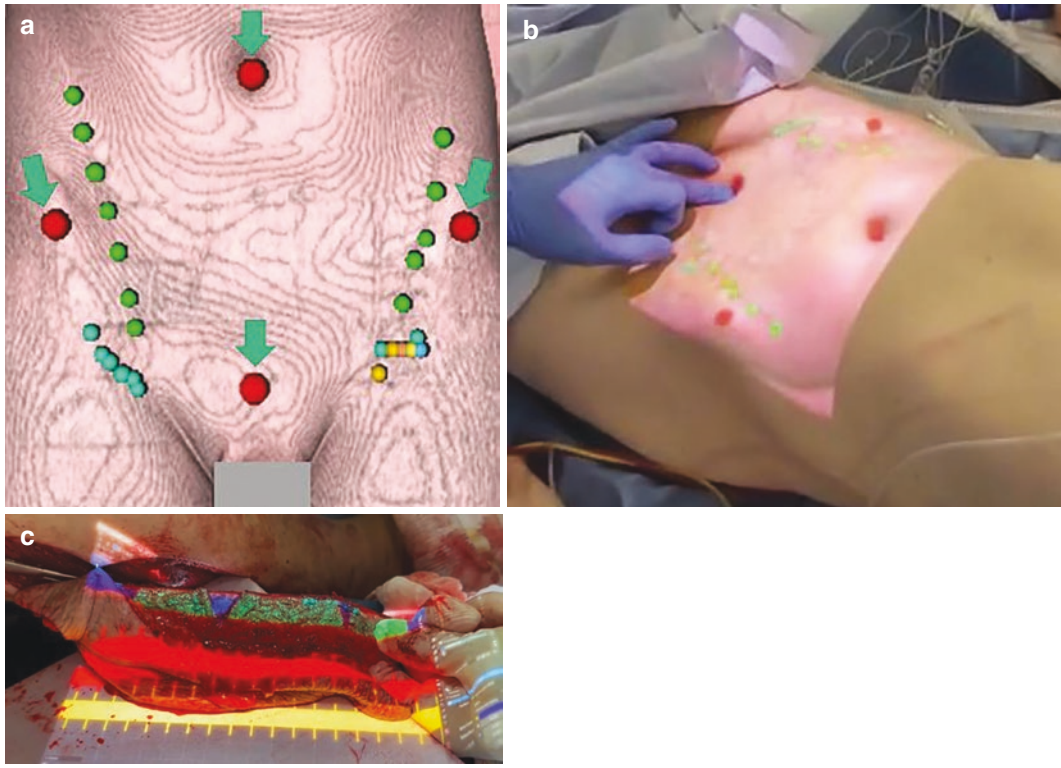

Fig. 5.11 (**a–c**) Preoperative mapping of a SCIP flap vascularization using a pico projector and the concept of projection mapping for FFF osteotomies

The design of the skin paddle should be on top of the arterial and deep venous pedicle course.

Harvest of the superficial venous system is mandatory to possibly avoid venous congestion (cephalic vein for RFFF, saphenous vein for DPFF). The design can be outside of the superficial venous system, but a cuff of subcutaneous tissue should be preserved between the edge of the flap and the distant superficial venous system.

In the RFFF, the cephalic vein is connected at the elbow level with the radial deep venous system (venae comitantes) by the coalesced vein, joining to form the median cubital vein, vein which therefore supports both venous systems (Fig. 5.12).

RFFF can be harvested with bone, but it greatly increases the donor-site morbidity (need to plate the remaining radius to prevent postoperative fracture) and should not be considered the first choice for vascularized bone reconstruction.

Both flaps can be harvested with a tendon (palmaris longus tendon in RFFF, extensor hallucis brevis tendon in DPFF) (Fig. 5.13).

Both flaps usually need split-thickness skin graft (STSG) for donor-site closure (or a domino approach with a SCIP flap for example) (Fig. 5.14).

– *Ulnar forearm free flap (UFFF):*

Benefits compared to RFFF: same tissue quality with a glabrous skin, useful in case where postoperative radiotherapy is less likely (to avoid an intraoral hairy reconstruction)

Cons compared to RFFF: dissection close to the ulnar nerve, smaller pedicle

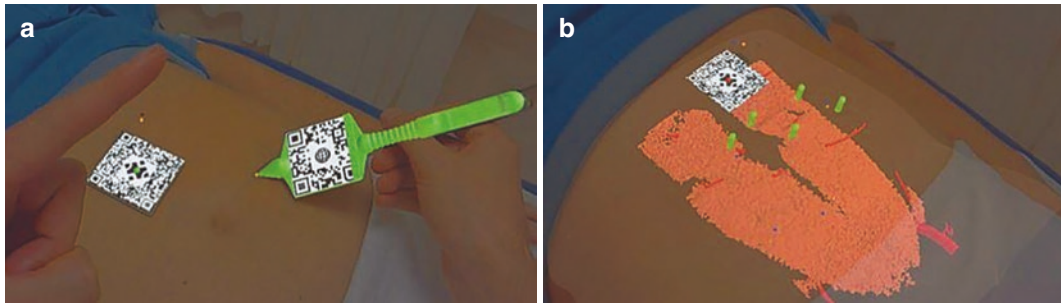

Fig. 5.12 (**a, b**) Preoperative mapping of a DIEP flap vascularization using smart glasses

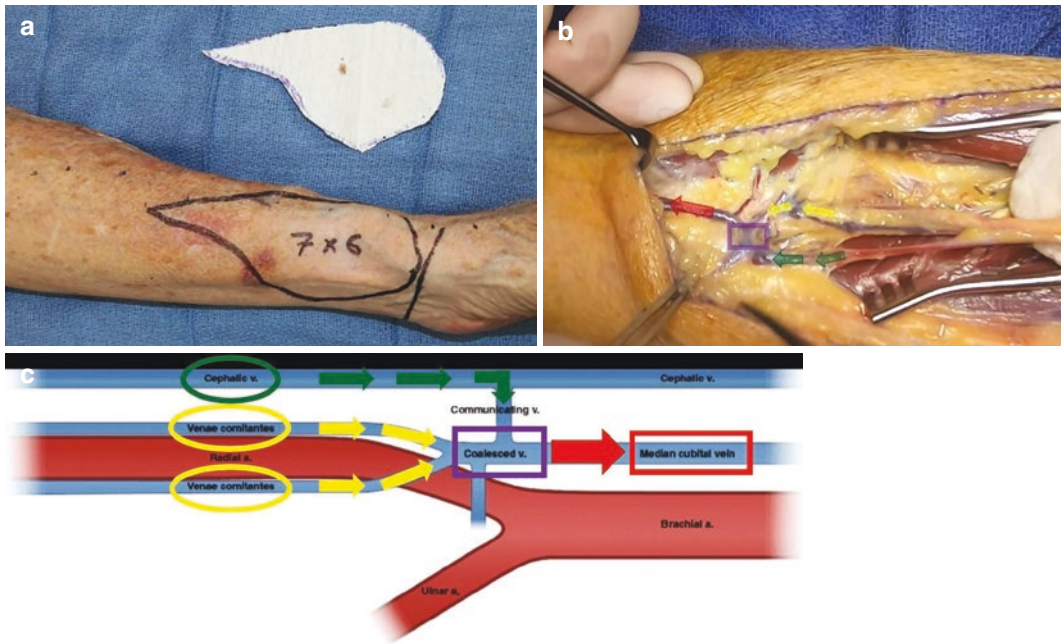

Fig. 5.13 (**a**) RFFF marking, with the classic inclusion of cephalic vein on the radial side. (**b** and **c**) Dissection of the RFFF pedicle at the level of the cubital fossa, where the superficial cephalic vein (green) and the deep venae comitantes (yellow) joined to become the median cubital vein (red)

diameter without superficial venous drainage (anastomosis on the venae comitantes needed)

– *Medial sural artery perforator (MSAP) free flap:*

A fasciocutaneous perforator free flap which can provide a 12 cm of pedicle length with good size match for head and neck.

Patient in supine position, with hip and knee externally rotated.

Perforators are found on a line drawn from the midline of the popliteal crease to the medial malleolus. Perforators are usually located proximally 8–18 cm from the popliteal fossa.

This flap harvest transects one of the major lymphatic drainage pathways of the lower extremity.

Intramuscular dissection is needed to separate perforators from the gastrocnemius muscle.

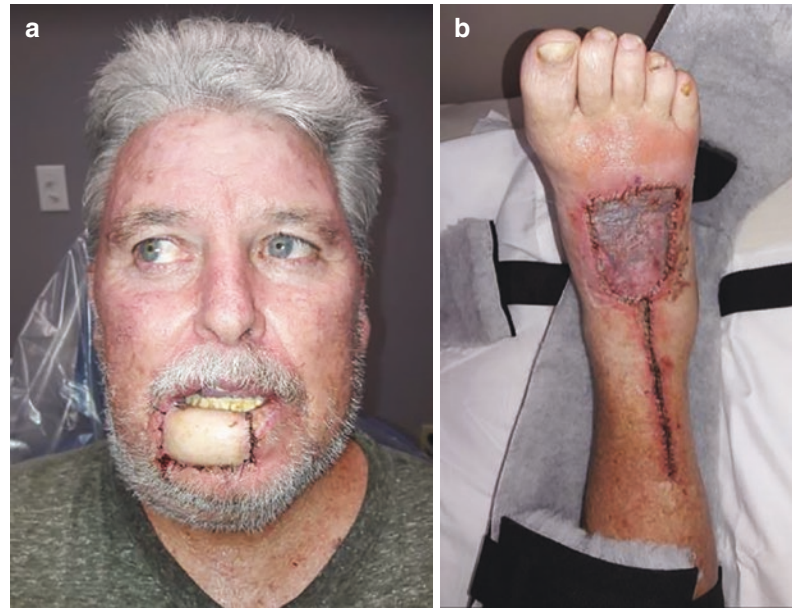

Fig. 5.14 (**a, b**) DPFF for lower lip defect using the extensor hallucis brevis tendon. Donor site reconstructed with STSG

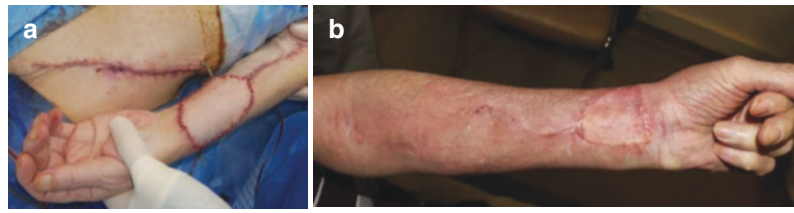

Fig. 5.15 (**a**) Reconstruction of an RFFF donor site with a domino SCIP free flap closed primarily. (b) Reconstruction of an RFFF donor site with an STSG

– *Anterior lateral thigh (ALT)/tensor fascia lata (TFL)/iliac crest free flaps:*

The lateral femoral circumflex system provides medium-to-large skin paddle size, of medium thickness, with a long and good size match pedicle for head and neck, and minimal donor-site morbidity. Designs can include skin paddle, fascia, muscle, and bone (Figs. 5.15 and 5.16).

Patient in supine position, with neutral leg rotation (great toe facing the celling), hip externally rotated.

Draping of both ALT and TFL flaps should always be encouraged, as the TFL free flap can be harvested with an ALT or can be a backup solution in case an ALT cannot be harvested as planned. ALT free flap can be the location of Monckeberg's atherosclerosis and can present with variable perforator types, sometimes leading to a failure of the harvest.

For ALT: Perforators are found on a line drawn from the superior and lateral border of the patella to superior and anterior iliac spine. Perforators are usually located at the midpoint of the line, in a circle of 3–4 cm in diameter. Other minor perforasome locations are 5 cm proximally or 5 cm distally to this circle.

If decent sized perforators are not found, the skin paddle should be harvested with the underlying vastus lateralis muscle with the septum still attached to avoid any skin necrosis.

For TFL free flap: In supine position, the pedicle is always found 8–10 cm

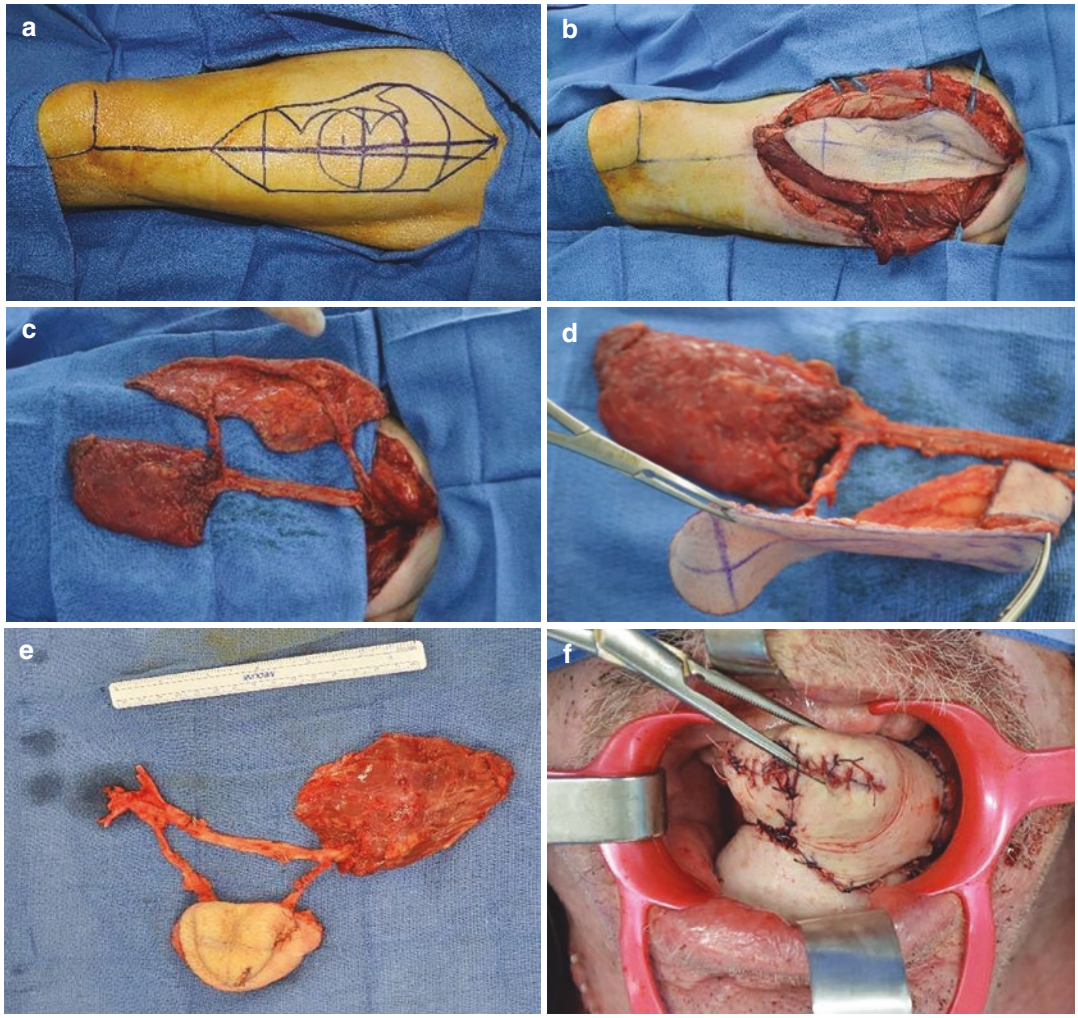

Fig. 5.16 (**a–f**) Thin ALT chimeric free flap (raised above the fascia superficialis) with thin skin paddle and vastus lateralis muscle, for anterior tongue and floor-of-the-mouth (FOM) reconstruction[63]

below the superior and anterior iliac spine, on a line drawn from this spine to the anterior and lateral border of the patella. It runs below the rectus femoris muscle. The design of this flap can be as long as the proximal 2/3 of the lateral thigh.

– *The Gracilis muscle/PAP free flaps:*
  Innervated muscle free flap transfer.
  Gold standard for smile reconstruction in long-term facial paralysis with facial muscle atrophy (<12 months).
  Can be harvested and designed with multiple muscular vectors for complex smile reconstruction (Fig. 5.17).
  Recipient motor nerve can be the remaining ipsilateral facial nerve, contralateral cross-facial nerve graft, and ipsilateral masseteric nerve, and some authors advocate for the ipsilateral hypoglossal nerve.
  Skin paddle is unreliable on top of the gracilis muscle, especially if small. If a skin paddle is also needed, the flap

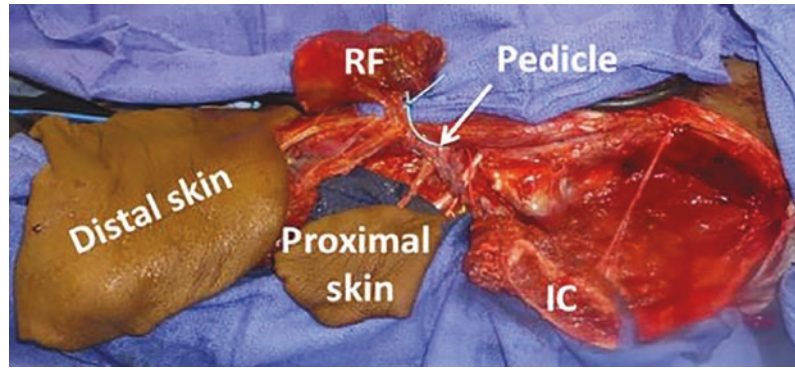

Fig. 5.17 (Intrinsic lateral femoral circumflex (LFC) flap based on the lateral femoral circumflex system with iliac crest, two separate skin paddles, and rectus femoris muscle

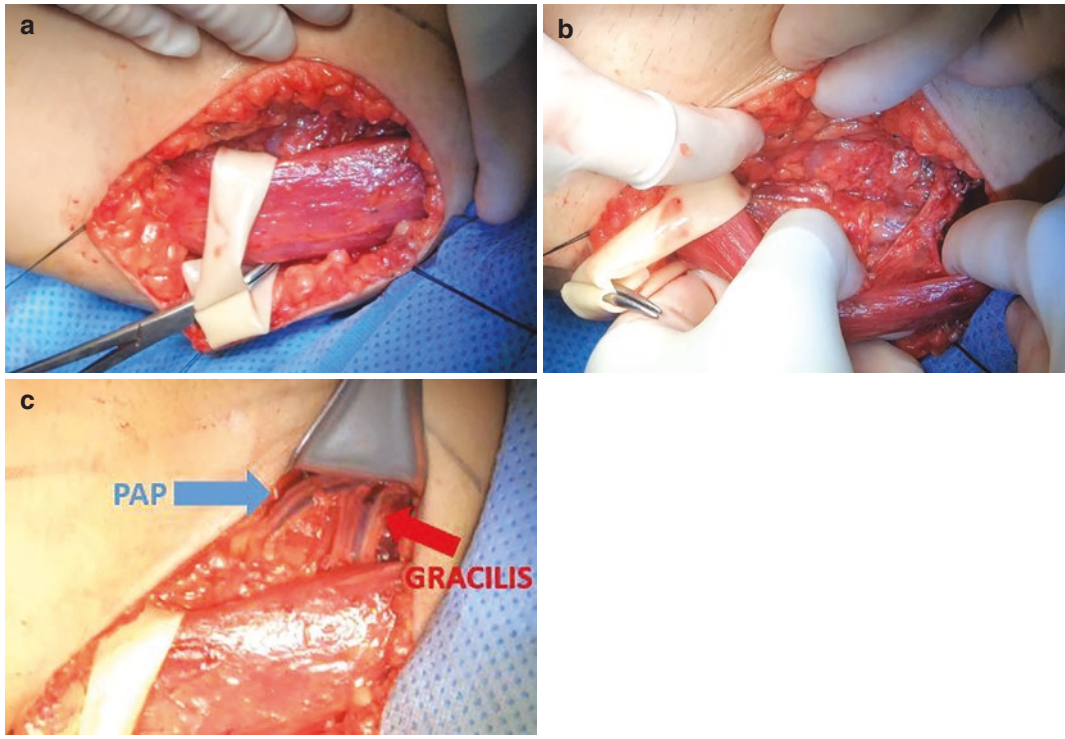

Fig. 5.18 (**a–c**) Gracilis muscle free flap, with exposure of the anterior aspect of the muscle and exposure of its pedicle (fused with the PAP pedicle in the superior and proximal aspects of the muscle)

should be designed with a *profunda artery perforator (PAP)* free flap as a chimeric flap (Fig. 5.18).

Gracilis muscle landmark is usually on 3–4 cm below a line going from the medial condyle to the pubic bone on a patient in supine position. The PAP flap is usually 5–8 cm below the same line.

– *Lateral arm free flap (LAFF):*

Best indication in head and neck could be for a tongue reconstruction due to the medium bulk and minimum donor-site morbidity provided by this flap.

It is a less popular choice as it may be sometimes difficult to harvest in a double-team approach, and due to its

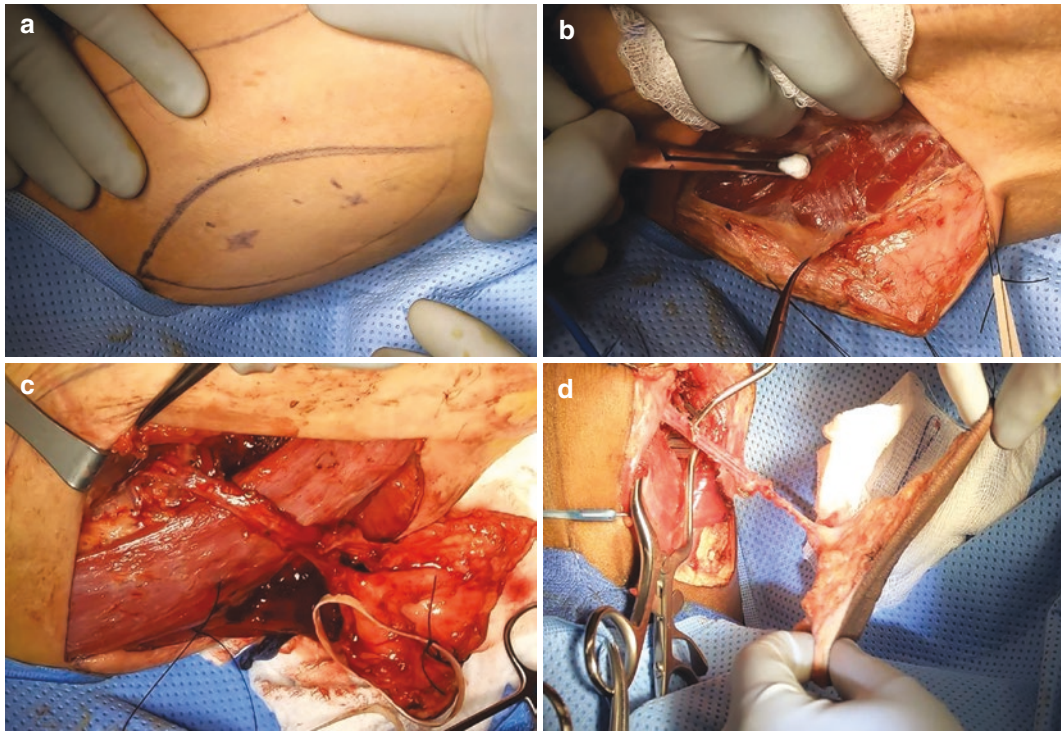

Fig. 5.19 (**a–d**) Horizontal PAP free flap with dissection of its pedicle from below and deeper to the gracilis muscle. The flap can be raised with the gracilis muscle or as a fasciocutaneous flap only

smaller pedicle length, ~7–8 cm, with a smaller pedicle diameter (close to 1 mm). The radial nerve is also at risk during the harvest, as it crosses the humeral bone close to the pedicle (Fig. 5.19).

Its design is on a line drawn from the lateral epicondyle to the midline of the deltoid muscle. Pedicle can be artificially lengthened by designing the flap closer to the elbow lateral epicondyle, and the skin can also be raised on the lateral epicondyle and below.

It can be harvested with bone if needed, but like for the RFFF, it should not be the first choice in vascularized bone free flap.

However, it is a donor site which could become a possible first choice for a vascular periosteal free flap (from the distal aspect of the humeral bone), typically indicated for ORN treatment.

– *Superficial circumflex iliac perforator (SCIP) free flap:*

One of the most versatile free flaps, but less popular in head and neck as it provides a short pedicle and small-size vessels [64].

Chimeric presentation: can harvest very thin skin paddle, with vascularized nerve (lateral femoral cutaneous nerve), muscle (sartorius muscle), bone (anterior and superior iliac spine), and lymph nodes.

Donor site is inconspicuous with minimal donor-site morbidity.

Anatomy is versatile as it can present as an axial flap (can be harvested above the fascia superficialis) or as a direct perforator flap. It can present with a superficial venous drainage too.

Multiple skin paddle design is possible.

A common confusion exists regarding the SCIP free flap: whether it is raised

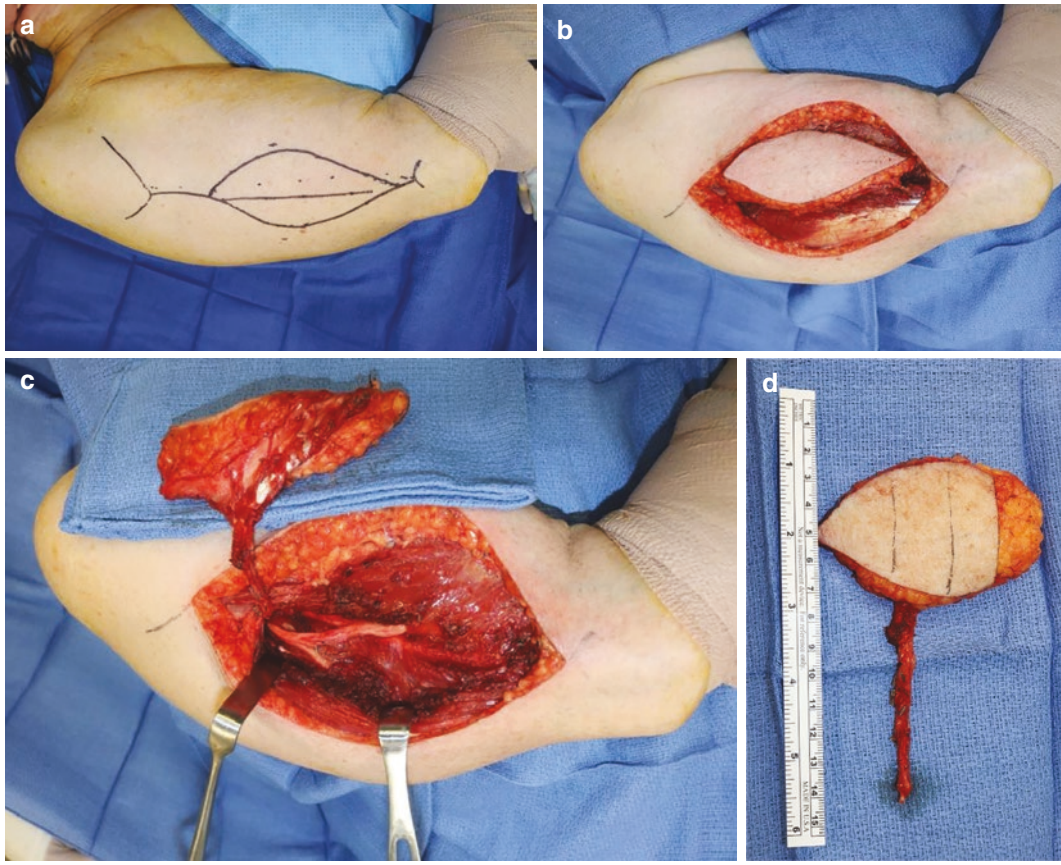

Fig. 5.20 (**a–d**) Lateral arm free flap, with exposure of the radial nerve at the lateral aspect of the humeral bone

from the superficial branch of the superficial circumflex iliac pedicle or deep branch. Another challenge is due to the presence of the Scarpa fascia (or deep fascia), an unusual layer of connective tissue found deeper to the fascia superficialis in the pelvic region, and above the fascia of the external oblique muscle (Fig. 5.20).

– *Subscapular system:*
  One of the most versatile parts of the human body, especially for soft tissue.
  Can harvest large muscles with skin paddle, such as the musculocutaneous *latissimus dorsi (LD)* free flap or as a perforator flap for skin paddle only (*thoracodorsal artery perforator flap, TDAP*). Less commonly, a fasciocutaneous skin paddle only from the circumflex scapular artery can also be harvested but with the need for a lateral decubitus position, making this isolated choice less popular in head and neck surgery (Figs. 5.21 and 5.22).
  TDAP perforator is always found 8 cm below the axillary fossa and 2 cm behind the anterior border of the LD muscle.
  Can be combined with other muscles and bone from the subscapular system (scapula tip, lateral border, or a combination of both).
  Can provide a *vascularized LD nerve* for complete vascularized facial nerve reconstruction (Fig. 5.23).

- Other soft tissue free flaps and pedicle flaps for head and neck reconstruction

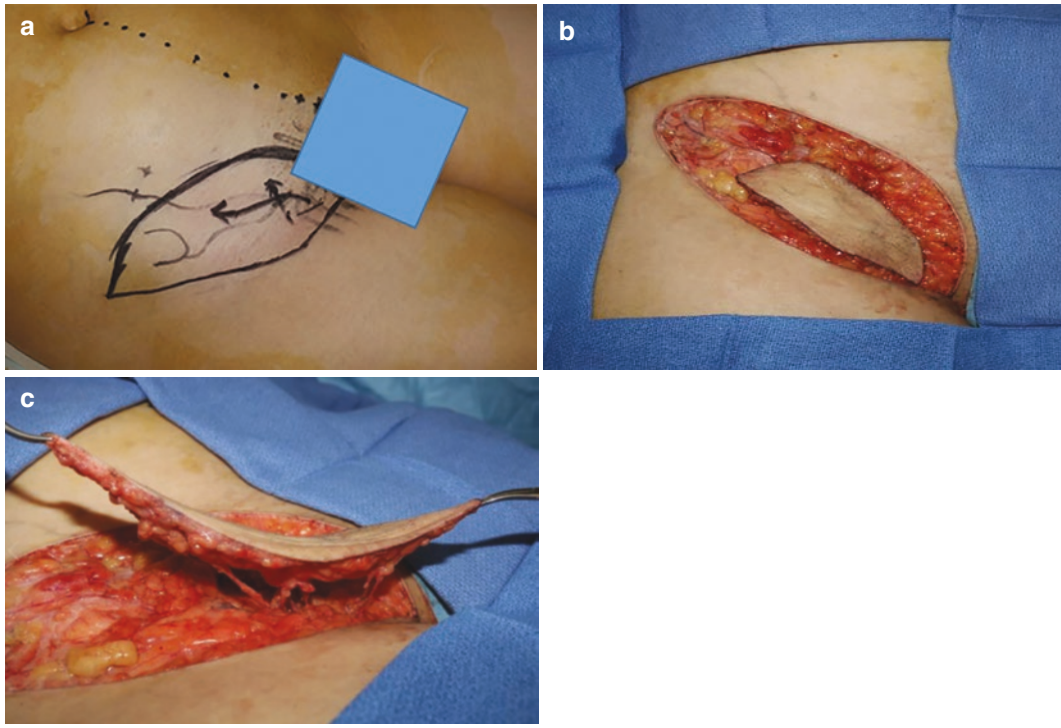

Fig. 5.21 (**a–c**) SCIP free flap raised as a thin flap above the fascia superficialis, on the superficial branch of the superficial circumflex iliac pedicle

- *Superior gluteal artery perforator (SGAP) free flap* is not popular in head and neck reconstruction, as it implies a lateral decubitus position to be harvested. The benefit of this flap is that it has very thick dermis, which is preferred for extremity reconstruction, typically the volar aspect of the foot (Fig. 5.24).
- *Pedicled flaps are also a major aspect of head and neck reconstruction, but not the topic here:*

  Trapezius flap for posterior scalp reconstruction

  Pedicle pectoralis major musculocutaneous (PMMC) flap for neck and lower face reconstruction

  Supraclavicular flap for neck and lower face reconstruction

  Internal mammary artery perforator (IMAP) flap for neck reconstruction

  Submental/infrahyoid flap for intraoral and lower/midface reconstruction

  LD flap for lateral skull base defect

  Facial cutaneous perforator/propeller/axial flaps such as *rotational flap, paramedian forehead flap, melolabial flap, and nasolabial flap* for oncodermatologic/trauma cases

- Specific considerations for bony flaps

  In the vast majority of cases, the pedicle position is one of the most important considerations in free flap design. The pedicle should be positioned in such a way that it will avoid any unnecessary loops to reach the ipsilateral recipient vessels, while still maintaining an adequate length to reach contralateral recipient vessels without tension.

  Bony free flaps are contoured to match the facial defect. Accounting for spatial position of the pedicle is of paramount importance, as it will be dictated by the reconstructive needs.
- Fibula Free Flap (FFF)
  - *Planning osteotomies without VSP for mandibular reconstruction:*

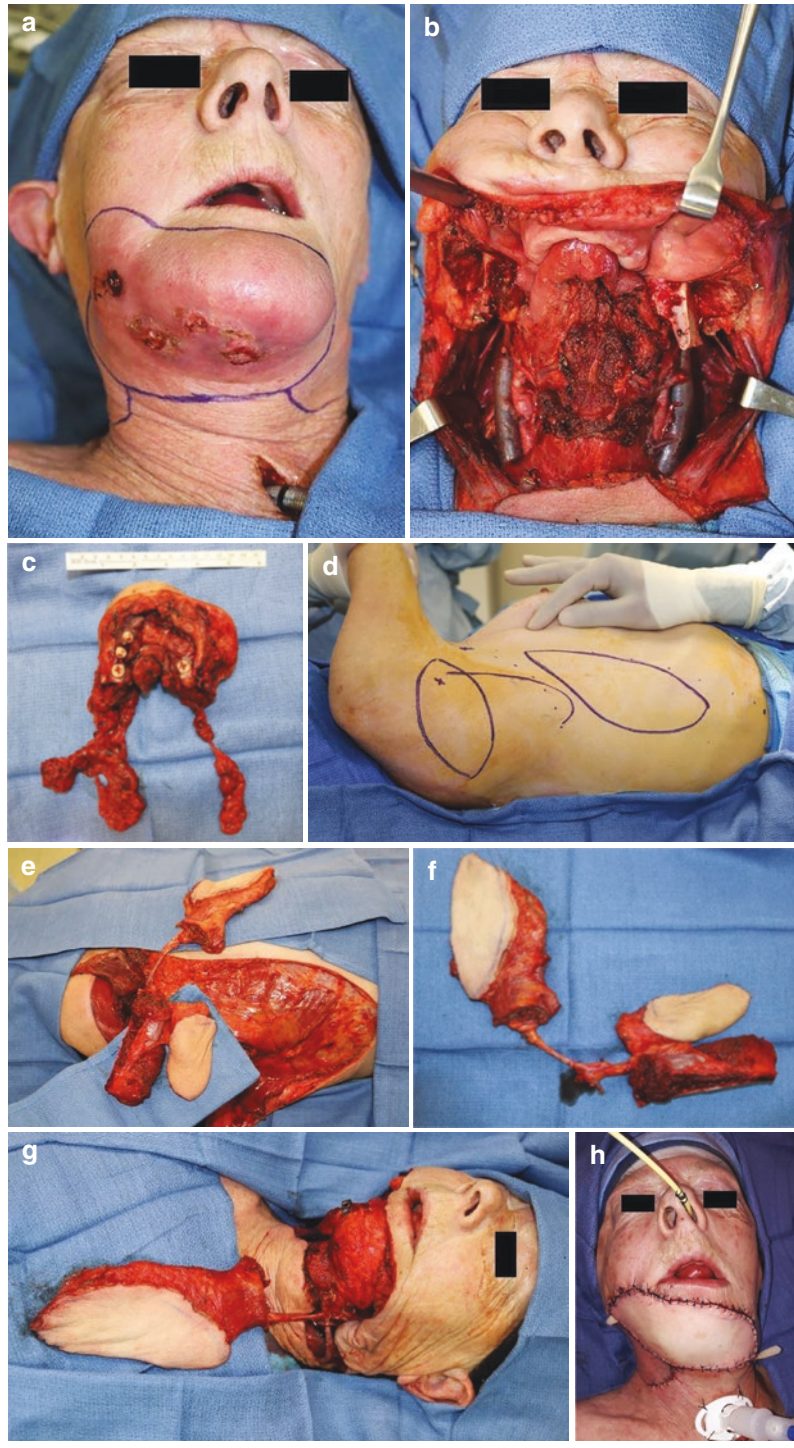

Fig. 5.22 (**a–h**) Scapulo-dorsal chimeric free flap with latissimus dorsi musculocutaneous flap and osseous lateral border of the scapula combined with a circumflex skin paddle—needs two positions in such setting to be able to dissect the circumflex skin paddle and close the donor site

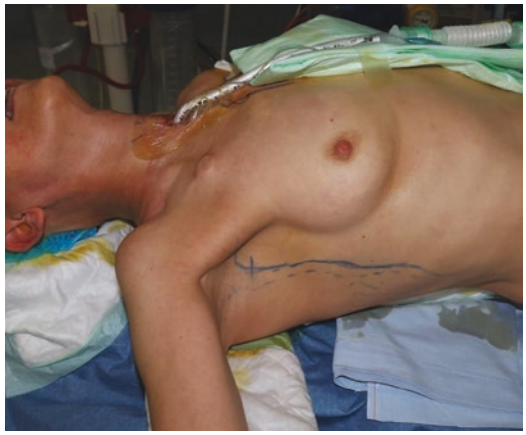

Fig. 5.23 Scapulo-dorsal chimeric free flap with latissimus dorsi musculocutaneous flap and TDAP skin paddle— needs only one position of the patient

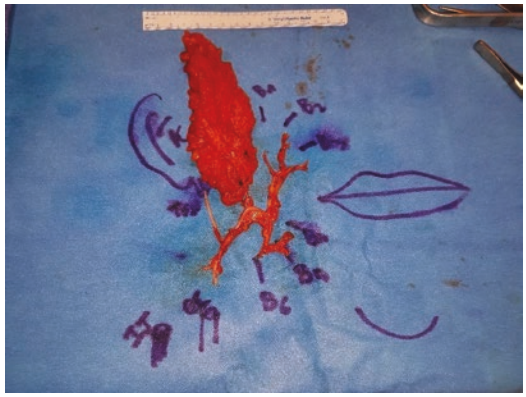

Fig. 5.24 Vascularized latissimus dorsi motor nerve and TDAP adipose paddle for facial nerve reconstruction

Choose the leg side, the pedicle side, and the rotation of the bone into the defect using the "hand" trick by Al Deek et al. [65]: the surgeon's hand from the same side of the chosen fibula forms a fist with the thumb up. The thumb represents the peroneal vessels and the proximal end of the bone, and the dorsal surface of the proximal phalanges represents the lateral surface of the fibula bone. This very simple and efficient concept has been modified and is now represented by the "rock-paper-scissors" concept. The fibula is the "rock" as previously described symbolized by the fist with the thumb up [66] (Fig. 5.25).

For a freestyle approach, we are using the mandibular defect classification by Urken et al. [67] (condyle, ramus, body, and symphysis) to anticipate before the surgery the resected segment(s) length and to adapt our reconstruction.

The resection length can be measured, between symphysis (2.0–3 cm on the vestibular side), body (7.5–8.5 cm), and ramus-condyle complex to reconstruct the same length of the bone. The neo-condyle should be suspended and seated in the fossa but never be in contact with the skull base to avoid any interference. The angles ramus-body or body-symphysis happen to be without significant variations between gender and morphology in European population [68] or North American population [69]. The ramus-body angle is around 120–125°, and body-symphysis angle is also around 115–120°:

- *For ramus-body angle construction:* use a 60° angle template (one angle of an equilateral large triangle, for example) to remove a cuneiform bony segment of 60°, which will create an angle of 120 with the two fragments of bone (Figs. 5.26a and 5.27a).
- *For a body-symphysis angle construction:* same procedure in a different position for this angle. The mandibular arch usually has a bigonial length between 8.5 and 9.5 cm. In case the surgeon needs to deproject the neo-mandible (e.g., irradiated field), an angle of 135° can be obtained with a 45° template (by cutting in half a 90° angle template) (Figs. 5.26b and 5.27b).

Minimum length of fibula bone fragments is around 2.0 cm on the pedicle side (usually the lingual side) to allow efficient vascularization to the bone. However, evidence of fragments <2 cm, especially seen in maxillary reconstruc-

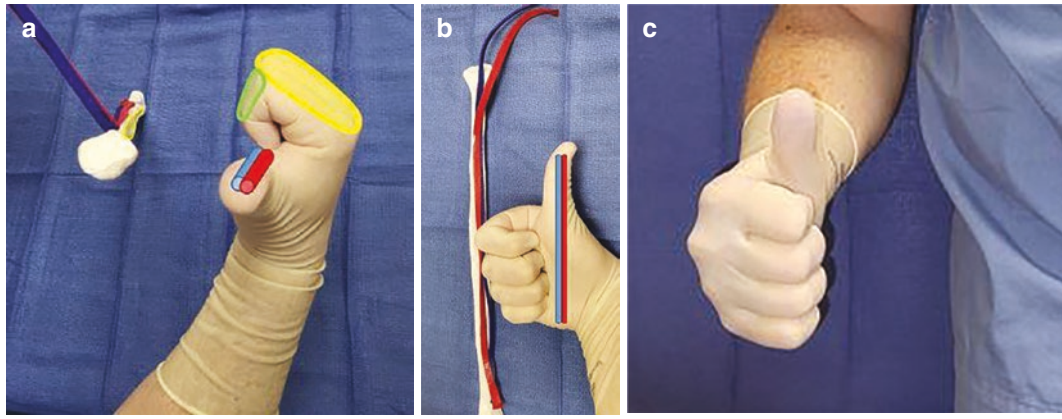

Fig. 5.25 (**a–c**) The "rock" in "rock-paper-scissors" concept for orientation of the fibula free flap. (**a**) In a superior view, with yellow surface = lateral aspect of the fibula, green surface = medial aspect of the fibula, with the thumb mimicking the pedicle. (**b**) In a medial view, (**c**) position of the ipsilateral hand to match the fibula in a standing position

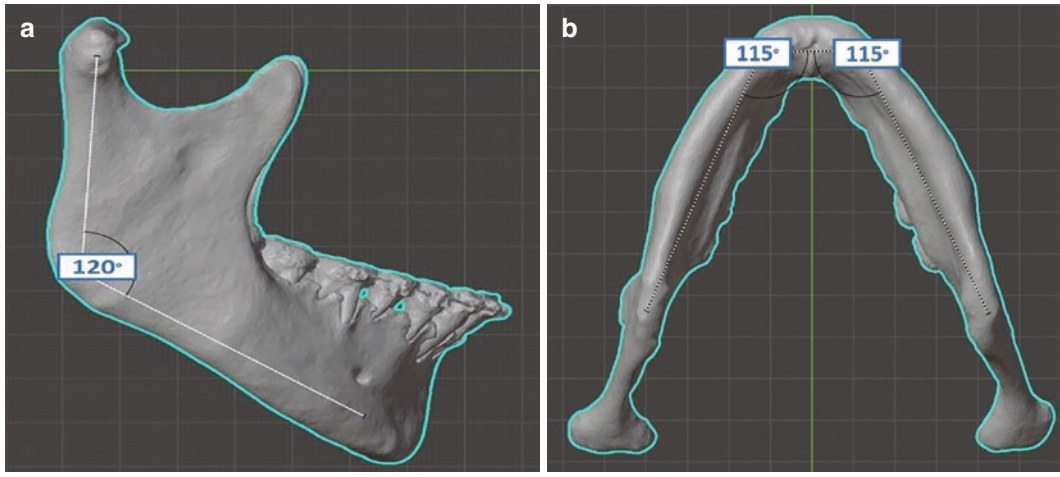

Fig. 5.26 (**a, b**) Ramus-body/body-symphysis angles in a 1.95 m tall European male patient

tion, seems to present the same vascular outcome.

Anterior projection should match the mandibular teeth arcade to avoid unnecessary overprojection of the chin in non-irradiated case.

The position of the neo-mandible is usually matched to the inferior border of the mandible, as the majority of patients will not benefit from dental rehabilitation, especially in oncological cases. However, the goal of every mandibular reconstruction should aim for dental rehabilitation, and therefore, the fibula free flap can be raised 5–10 mm above the inferior border of the native mandible to improve dental rehabilitation without losing lower facial contour. This strategy avoids the need for a double-barrel fibula. However, it should not be attempted in lean patients with thin soft tissue envelope, regardless of

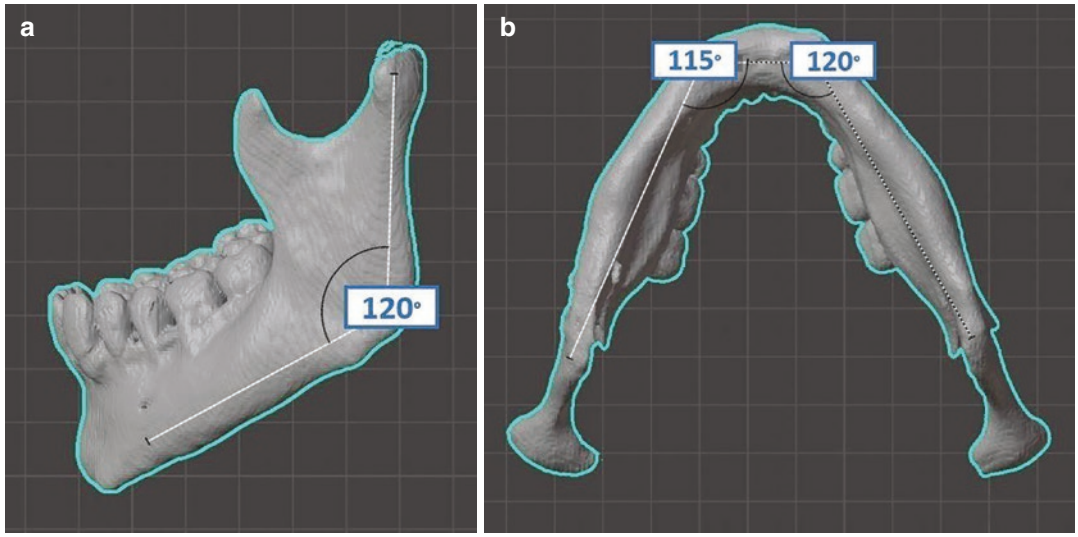

Fig. 5.27 (**a, b**) Ramus-body/body-symphysis angles in a 1.51 m tall European female patient

postoperative radiotherapy requirement, due to the visible loss of lower facial contour.

The distal fibula osteotomy should preserve 6–7 cm of bone in adults to maintain ankle stability, and 6–7 cm at the proximal osteotomy to avoid injury to the common fibular nerve.

– Maximum length of bone for mandibular reconstruction (see Fig. 5.5):

Usually can reconstruct from a condyle to contralateral parasymphysis with a symphysis in a U-shape. Alternatively, a condyle to a contralateral angle with a V-shape

An angle to angle or more, especially with deprojection of the chin (typically in ORN cases)

Can be combined with unilateral or bilateral TMJ prosthesis for a total mandibular reconstruction

– Can be raised as a chimeric free flap with:

Fasciocutaneous skin paddle from the fibula pedicle

Fasciocutaneous skin paddle from the soleus system

Fasciocutaneous skin paddle from the supramalleolar system

Muscle cuffs from the soleus system or the flexor hallux longus (taking the FHL muscle will avoid hallux claw deformation due to scars and fibrosis in the remaining muscle, but the patient will lose some degree of flexion) (Fig. 5.28)

Vascularized sural nerve included with the skin paddle

– Choice between miniplate osteosynthesis in load sharing (risk of plate fracture) and large reconstructive bar in load bearing (risk of plate exposition) depends on the patient presentation, need for radiotherapy, and team preference

– Can support dental implant during the same procedure (bicortical implantation), with or without immediate prosthesis ("jaw-in-a-day" procedure), allowing an immediate lip or cheek support

• Subscapular system—Scapula Free Flap (SFF)

– *Planning osteotomies without VSP for maxillary reconstruction:*

Choose the scapula side and the pedicle side using the same hand concept. The convexity of the scapula tip and the side chosen depend on the pedicle position and use for oral cavity reconstruction. The open "hand" trick, also used as the "paper" in the "rock-paper-scissors" concept [70], helps to guide the inset of the scapula, which could be the convex

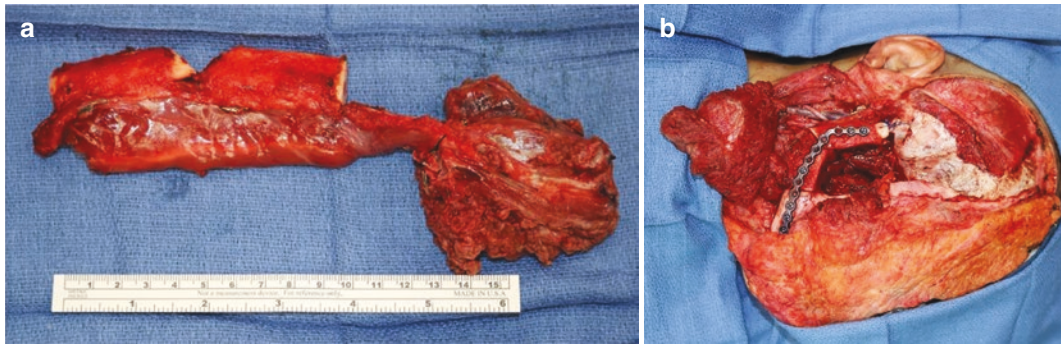

Fig. 5.28 (**a, b**) Chimeric osseo-muscular fibula free flap, including FHL and soleus muscles, for reconstruction of a lateral mandibular defect associated with an infratemporal fossa resection

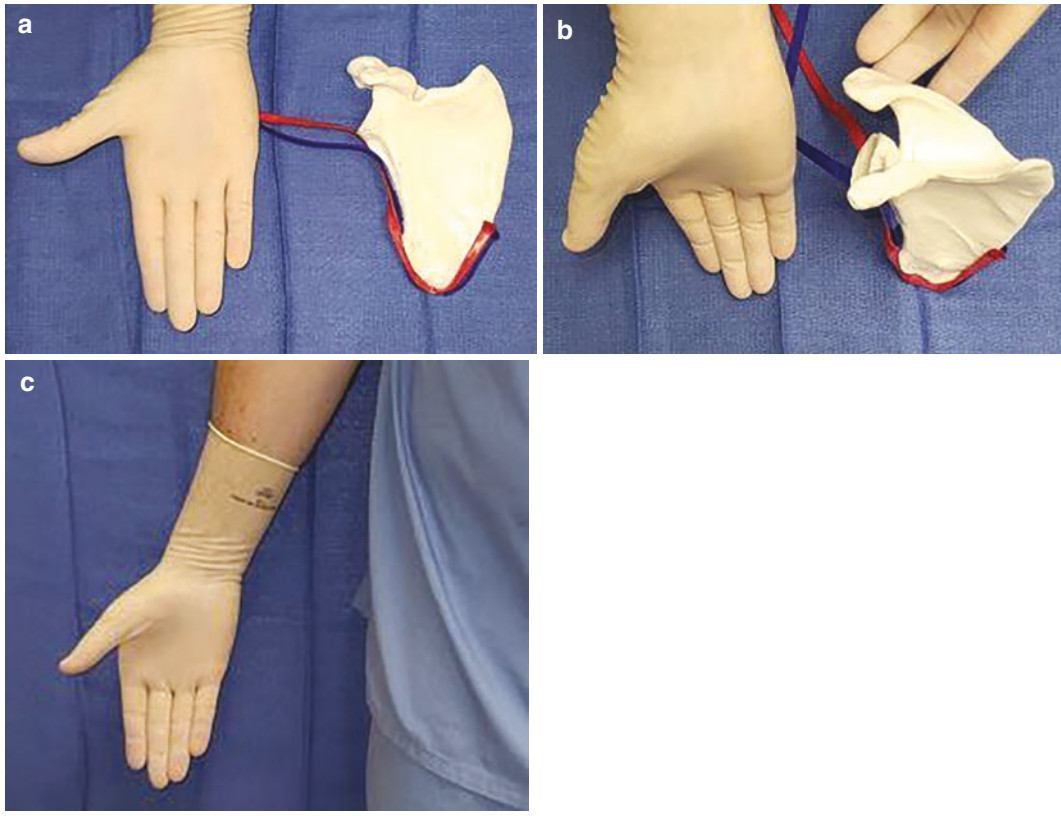

Fig. 5.29 (**a–c**) The "paper" in "rock-paper-scissors" concept for orientation of the scapula free flap. (**a**) In an anterior view, with the thumb mimicking the pedicle (**b**) in a superior view, showing the concavity of the hand mimicking the scapula, (**c**) position of the ipsilateral hand to match the scapula in a standing position

tip or the straight lateral border. The thumb orients the pedicle laterally and posteriorly, and the hand mimics the curvature of the scapula bone (Fig. 5.29). A scapula tip is usually well suited for a palatal reconstruction of the horizontal aspect:

- For a total palatal reconstruction, the posterior aspect of the tip should benefit from a rigid stabilization if possible, using a groove designed into the pterygoid plates, or a robust anterior fixation typically with patient-specific plates extended to

robust remaining pillars of the midface like zygomatic bones.
- The tip of the scapula is classically left without any skin paddle in the oral or nasal cavity, allowing spontaneous mucoepithelialization.

A scapula lateral border is usually well suited for a mandibular reconstruction.
- The proximal osteotomy should preserve 2 cm of bone from the glenoid fossa to avoid any intra-articular fracture.

It is typically a free flap used for midface reconstruction, when the need of soft tissue is an important component of the reconstruction, or as a second or third choice in mandibular reconstruction, when the fibula free flap is not available.

Combination of the scapula tip and lateral side is possible for extensive defects, or to reconstruct a midface pillar and a palate.

Both osseous fragments are usually vascularized by two independent systems (the angular branch for the tip, and the deep periosteal branches of the circumflex branch for the lateral border).

– With regard to the need for bone vascularized free flap in maxillary reconstruction, many options are possible. This means that no option is optimal for a particular defect. With the emergence of zygomatic implants, bone reconstruction needs in palatal defect (infrastructure) are becoming more obvious for defects greater than 50% (class D in the new J.S. Brown classification [71]). Vascularized bone support may be needed in class II or III, but also in case of class C with anterior palatal defect (including advanced cleft defect), which may benefit from a robust bony support to stabilize the projection of the tip of the nose and the upper lip and allows for dental rehabilitation. Soft tissue-only free flaps would be sufficient otherwise in maxillectomy without the need for an orbital support (class I and II). Soft tissue palatal reconstruction can be combined with zygomatic implants if dental rehabilitation is desired. It can also be combined with an autograft or patient-specific implant for the lower orbital rim reconstruction (e.g., free rib graft, free bone graft, PEEK implant). Non-vascularized autograft to the lower orbital rim can bring numerous complications in case of postoperative radiotherapy (wound dehiscence, skin necrosis, resorption, lack of orbital content support). Maxillary reconstruction can also be staged with a soft tissue-only free flap first (e.g., ALT), followed by a revision with a bony free flap for better facial support, contours, and dental rehabilitation. This can be considered 6 months after the radiotherapy, ensuring that the patient remains disease free. One should remember that dental and facial prostheses could be very successful in selected cases, and also that reconstruction of a midface is always far more complex in staged procedures rather than primary reconstruction.
– Maximum length of bone for a mandibular reconstruction:

  It can usually reconstruct from a contralateral parasymphysis to a contralateral angle (Fig. 5.30).

  A wedge bony resection can be performed in a lateral border. However, simple multiple monocortical fractures should be performed to bend the bone into multiple fragments without losing any length (Fig. 5.31).

  A design using a reverse flow through the thoracodorsal pedicle is possible to maximize the length of pedicle (consider otherwise short for the lateral border of the scapula, and long for the scapula tip).
– Can be raised as a chimeric free flap with (see Fig. 5.21):

  Vascularized innervated serratus (and ribs)

  Vascularized LD/TDAP

  Vascularized circumflex skin paddles (can be bifold)

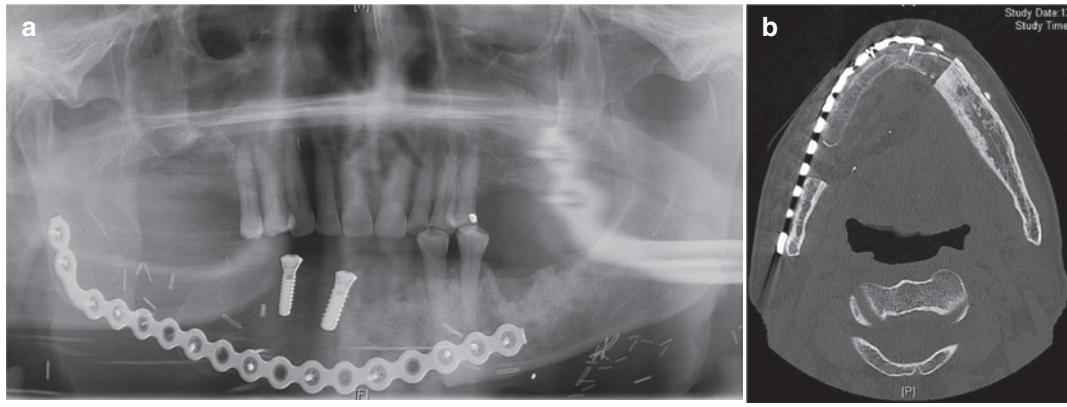

Fig. 5.30 (**a, b**) Inaccurate plan resulting in insufficient neo-mandible length with a scapular free flap

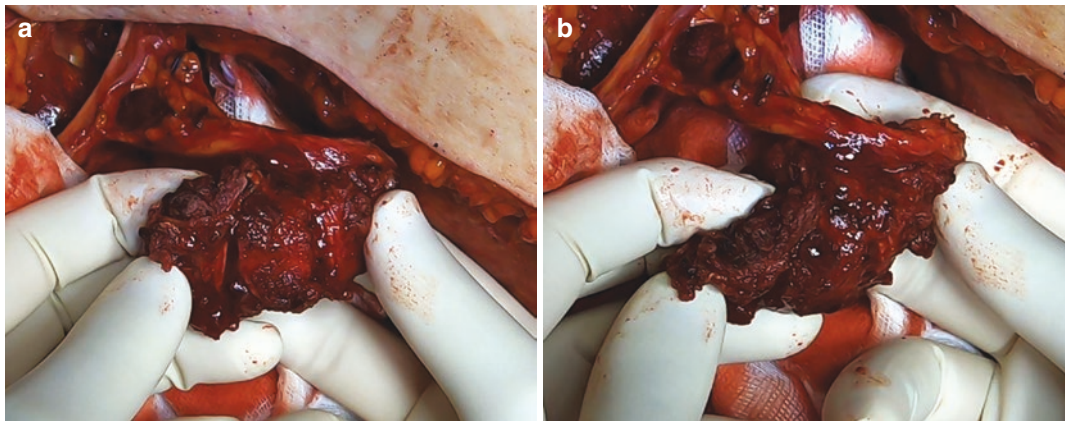

Fig. 5.31 (**a, b**) Monocortical osteotomies in scapula osseous lateral border, obtaining a curvature for mandibular reconstruction without bone loss

Can always be raised in a double-team approach, in dorsal decubitus, with the exception of the fasciocutaneous skin paddle from the circumflex pedicle, which will need a lateral decubitus to be harvested and to close the donor site

  - Can support dental implants during the same procedure, but usually performed in a second surgery with zygomatic implants or regular dental implants for maxillary reconstruction

- DCIA free flap
  - *Planning osteotomies without VSP for maxillary or mandibular reconstruction:*

    Choose the iliac crest side and the pedicle side using the same hand concept. The convexity of the iliac crest and the side chosen depend on the pedicle position and use for oral cavity reconstruction. The open "hand" trick, also used as the "scissors" in the "rock-paper-scissors" concept [66], helps to guide the inset of the DCIA. The thumb orients the pedicle in an anterior direction, the curvature of the hand mimics the curvature of the iliac crest, and the tip of the second and third digits represents the anterosuperior and inferior iliac crest spines (Fig. 5.32).

    The superior part of the cortex of the iliac crest is usually used for the alveolar bone in maxillary reconstruction and for the basilar aspect in mandibular reconstruction.

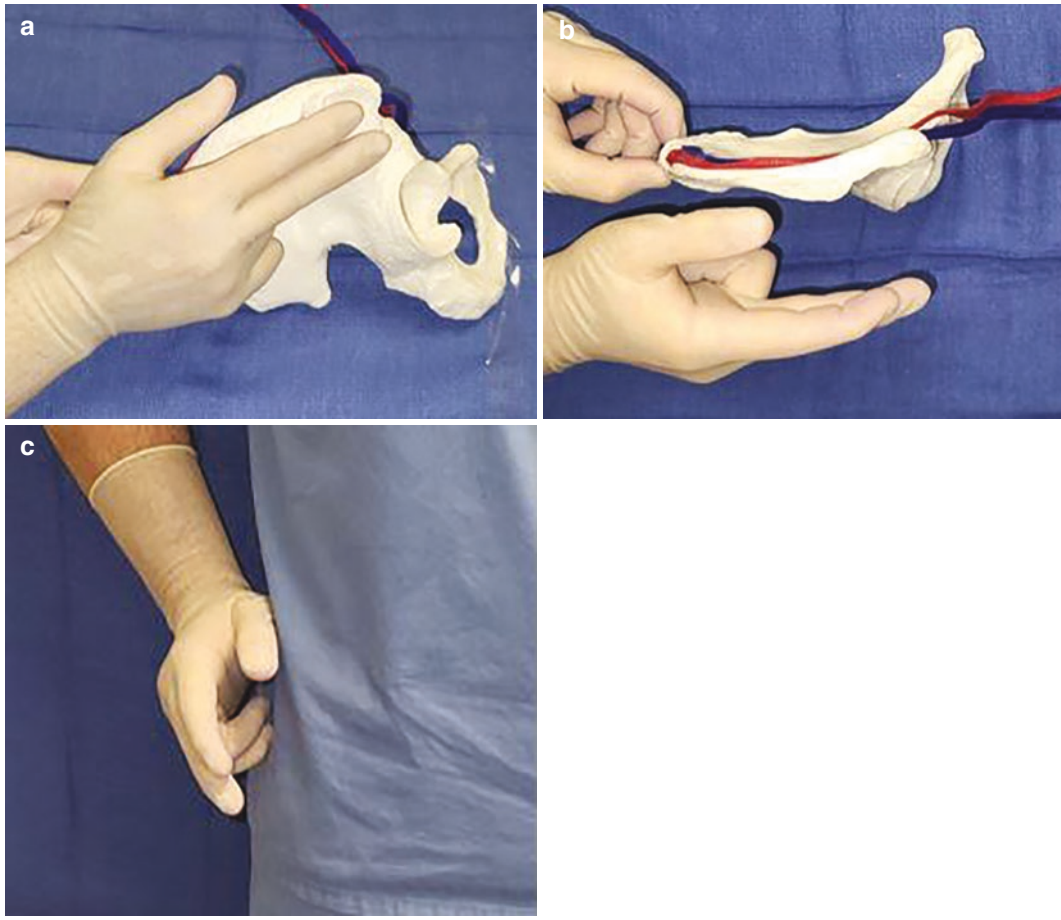

Fig. 5.32 (**a–c**) The "scissors" in "rock-paper-scissors" concept for orientation of the DCIA free flap—(**a**) in a lateral view, where the two fingers mimic the anterosuperior and anteroinferior spines of the iliac crest; (**b**) in a superior view, showing the concavity of the hand mimicking the iliac crest, and the thumb mimicking the pedicle; (**c**) position of the ipsilateral hand to match the scapula in a standing position

The convexity of the iliac crest is matched with the dental arch, midface, and lower face reconstruction.

The pedicle is short (5 cm) and small (1–1.5 mm in diameter), but designing the bone flap more posteriorly allows for greater pedicle length (up to 10 cm).

The donor site needs to be repaired with a non-resorbable mesh.

- A good indication of this flap is for reconstruction of the mandible on a benign tumor, with complete dental rehabilitation, especially in a young male patient (to avoid abdominal wall weakness and possible lateral hernia in a young female with future pregnancy plans), or for cases requiring high bone volume, typically a large maxillary defect with infraorbital rim reconstruction and without the need for large soft tissue reconstruction (depending on the team experience).
- Morbidity management of the donor site:

  The skin paddle is classically not as reliable as in other osseous free flaps, unless a perforator from the DCIA ascending branch is encountered.

  The internal oblique muscle is usually taken during the harvest, to be wrapped around the bone, providing soft tissue coverage and allowing spontaneous mucoepithelialization in the oral or nasal cavity.

Non-resorbable mesh is always needed to reconstruct the internal oblique muscle harvest.

Resuspension of the inguinal ligament is also mandatory in case where the anterosuperior iliac spine was used to reconstruct the mandible.

– Management of pedicle length for maxillary reconstruction:

Facial pedicle should be prepared high above the inferior border of the mandible, taking great care to visualize and protect the marginal mandibular branch of the facial nerve.

In case of short pedicle which cannot reach the neck, there are at least four solutions to overcome this problem:

○ Perform intraoral anastomosis.
○ Perform extraoral anastomosis at the level of the cheek (at the cost of a small facial scar).
○ Perform extraoral anastomosis at the level of the superficial temporal vessels.
○ Perform an arterial and venous vein graft (last resource).

– Maximum length of bone in mandibular reconstruction:

As previously said, a design 4–5 cm behind the anterosuperior iliac spine can maximize the length of the pedicle, being cognizant that the further back you go, the thinnest the iliac crest cortex will be, and that the DCIA will also be more superficial.

The maximum bony reconstruction can be a hemimandible, from a condyle to a symphysis, but is usually used for smaller defect (<10 cm of bony reconstruction).

One wedge osteotomy can be done safely to reconstruct an angle without the need for anterosuperior iliac spine harvest, or multiple linear monocortical osteotomies (as for the scapula lateral border osseous free flap) for better curvature of the bone.

– Can support dental implants during the same procedure, but usually performed in a second surgery with regular dental implants for maxillary reconstruction. In immediate mandibular reconstruction, dental implants are placed in cancellous bone (loose bone) not allowing immediate prosthesis like the fibula free flap for example.

• Medial Condyle Free Flap: It is an unusual free flap used in the head and neck region. However, two major indications seem to benefit from this donor site:

– Cleft reconstruction, typically in double-cleft cases, in which avascularized graft may be particularly challenging to be performed in the setting of chronic fistulas and large defect. This free flap can bring a 2 × 2 cm of vascularized bone.
– ORN defect, to reconstruct a bone defect, or for the robust vascularized periosteum, which can be harvested from this donor site. In this setting, a skin paddle from the medial thigh should be used.
– This free flap has a pedicle of 5–7 cm, but small vessels (<1 mm in diameter). Therefore, intraoral anastomosis to the facial pedicle should be used for maxillary reconstruction.

Defect Type	Left Mandible		Right Mandible		Left Maxilla		Right Maxilla	
Flap Harvest Laterality /Pedicle direction	Pedicle Posterior	Pedicle Anterior	Pedicle Posterior	Pedicle Anterior	Pedicle Posterior	Pedicle Anterior	Pedicle Posterior	Pedicle Anterior
Fibula	Left	Right	Right	Left	Left	Right	Right	Left
Scapula (Lateral border)	Left	Right	Right	Left	see comment	see comment	see comment	see comment
Deep Circumflex Iliac Artery	Left	Right	Right	Left	Left	Right	Right	Left

Table summerizing osseous free flap orientations

Comments

Left maxillary defect for scapula: scapula tip (horizontal reconstruction) = left side with pedicle on the right side (anterior if hemi-tip, posterior if full tip), right side with pedicle on the left side (anterior if hemi-tip, posterior if full tip)

Right maxillary defect for scapula: scapula tip (horizontal reconstruction) = right side with pedicle on the left side (anterior if hemi-tip, posterior if full tip), left side with pedicle on the right side (anterior if hemi-tip, posterior if full tip)

- Unusual Free Flap Harvest Planning from the Head and Neck Area
- Flaps harvested from head and neck allow for reconstruction of like tissues with like tissues. These specific free flaps are designed from the superficial temporal system:
  - *Superficial temporalis fascia (STF) free flap*: an extremely thin fascia to reconstruct the nasal cavity (such as the septum), the orbital cavity, or the contralateral ear in case the ipsilateral superficial temporal pedicle is not available (due to burn/trauma/previous ipsilateral failure) (Fig. 5.33)
  - *Temporal artery posterior auricular perforator skin (TAPAS) free flap*: to reconstruct a maximum of 5 × 7 cm glabrous skin or mucosal defect, with thin and color match aspect. Can also be used for a septal reconstruction and nose reconstruction (with vascularized cartilage) (Fig. 5.34)
  - *Anterior helix free flap*: skin and cartilage to reconstruct an alar base defect of the nose (Figs. 5.35, 5.36, and 5.37)
- Composition of new flaps When the solution is Not straight forward :
  - *Train or bridge free flaps (second flap connected into the distal pedicle of the first one):*

    Usually, RFFF is used as a bridge connected to any other free flap. This may be needed to be able to reach the defect and/or bring the specific tissue needed (e.g., RFFF and helix free flap for complex nose and midface reconstruction).
  - *Prelamination with or without expansion:*

    Example of a jaw-in-a-day procedure with skin graft (Figs. 5.38 and 5.39)

    Example of a PIE flap, for facial burn, where the skin of the neck is expanded over a superficial temporalis fascia flap before its transfer
  - *Delayed phenomenon:*

    Example of a Juri flap for hairy scalp reconstruction, where incisions of the tip of the flap are made 3 weeks before the surgery to improve its distal vascular reliability, or the classic example of the older tubular flap

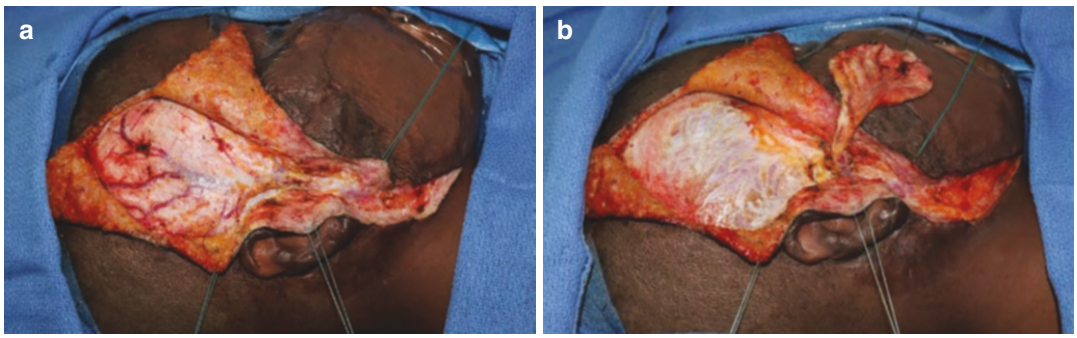

Fig. 5.33 (**a, b**) Superficial temporalis fascia flap, before its transfer

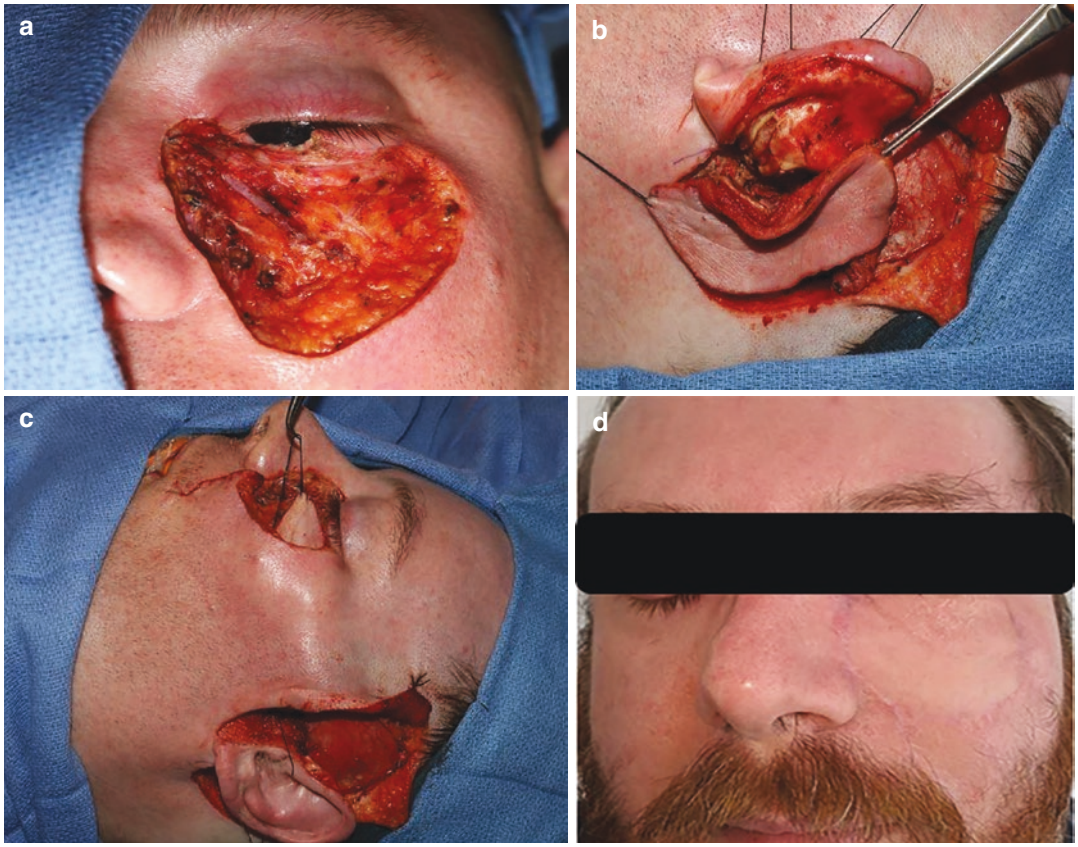

Fig. 5.34 (**a–d**) Chimeric TAPAS flap stage 3 (with cartilage), pedicle to the superficial temporal vessel [72]

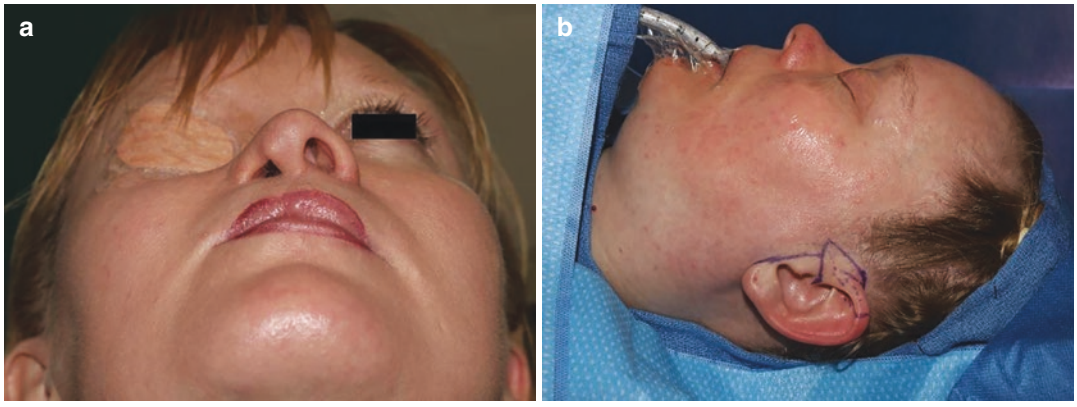

Fig. 5.35 (**a, b**) Helix free flap for alar base reconstruction, in a facial cleft patient

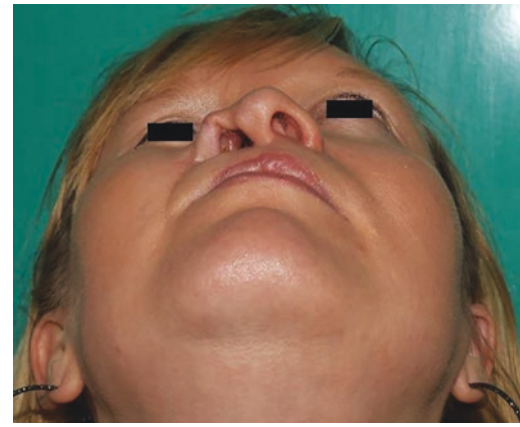

Fig. 5.36 Intermediate result of a helix free flap before secondary rhinoplasty

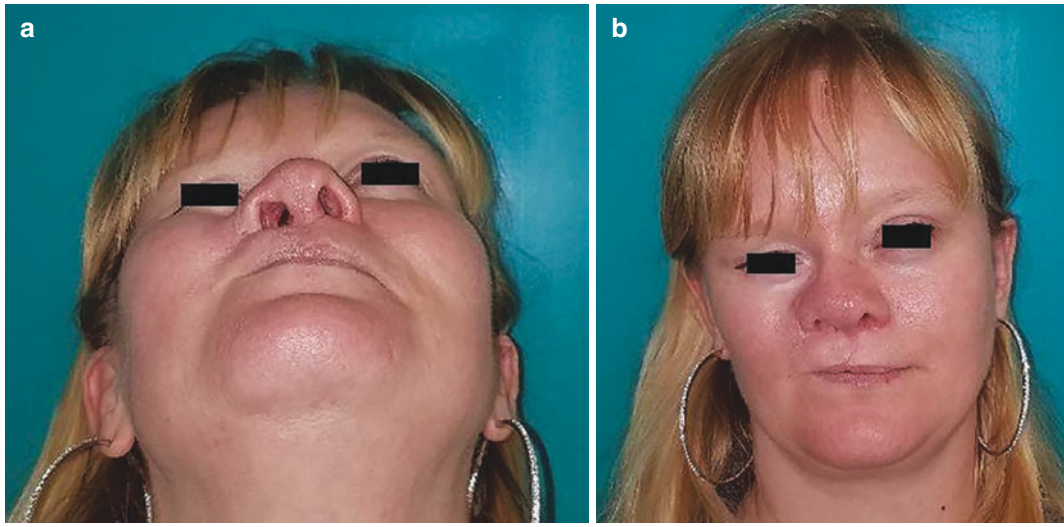

Fig. 5.37 (**a, b**) Result after secondary rhinoplasty

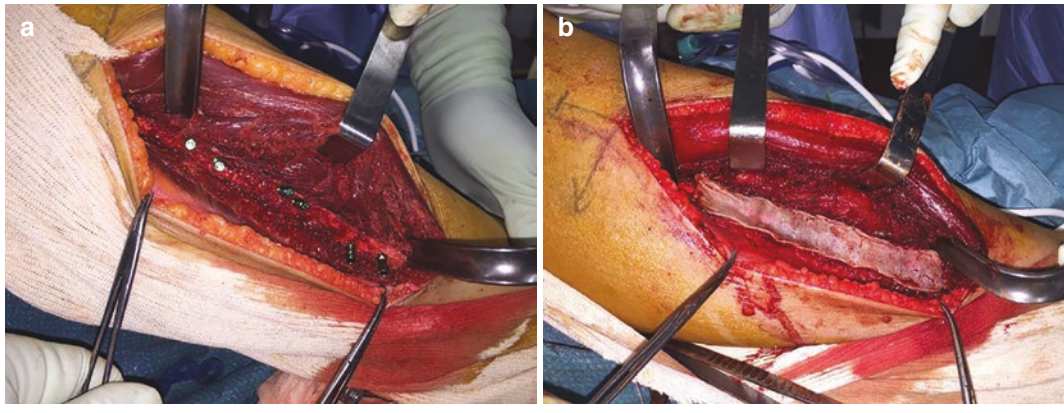

Fig. 5.38 (**a, b**) Dental implants and STSG placed as a first step of an FFF prelamination

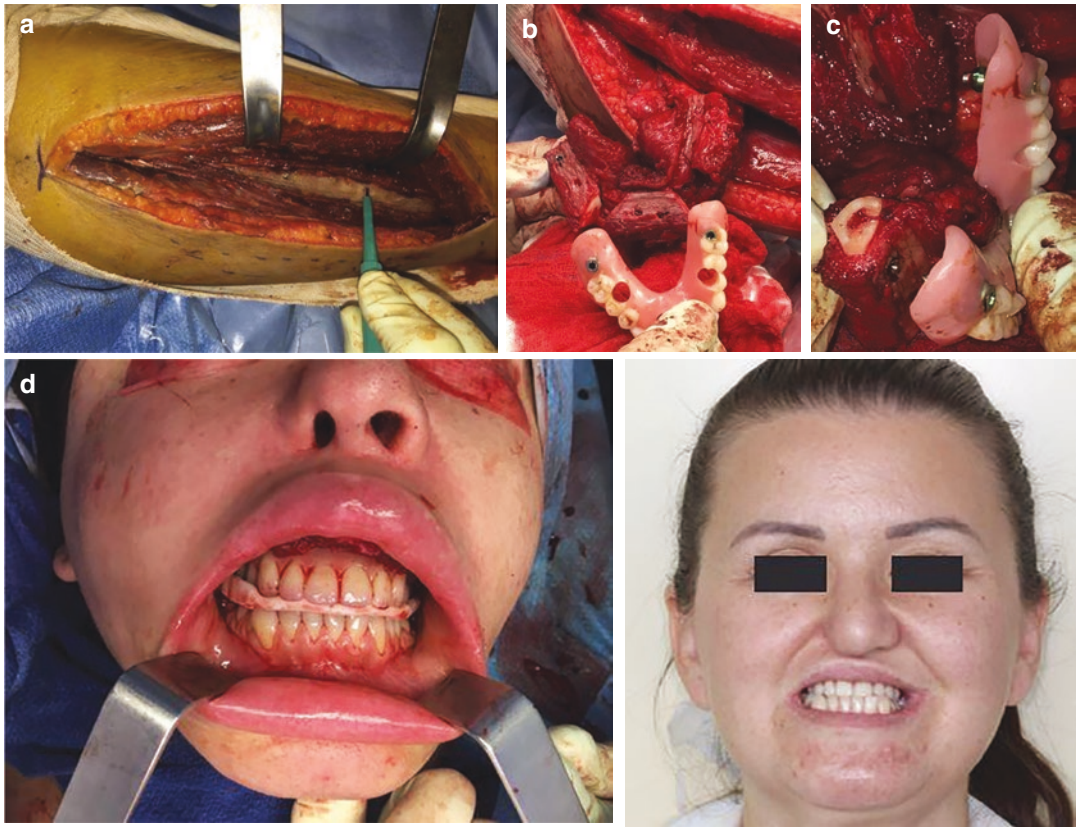

Fig. 5.39 (**a–d**) FFF procedure 3 weeks after the prelamination, where the STSG is firmly attached to the periosteum, mimicking attached gingiva

Double-Team Approach

In free flap procedures, donor sites are usually accessible for a double-team approach. The most challenging area would be where the donor site is from the proximal upper extremity such as for a lateral arm free flap or from the proximal trunk such as a scapula free flap.

In such settings, the reconstructive team may be challenged to harvest the free flap, while the head and neck team performs an ipsilateral neck dissection. It is the same problem in neurosurgical/skull base surgery when the position of the head may be fixed by the neurosurgeon (especially for trapezius muscle in posterior skull base surgery). Such a situation is unfortunately classic, and the double-team approach is still possible thanks to good communication and using only TDAP and LD fasciocutaneous skin paddles rather than from the circumflex system in scapula free flap.

Acknowledging and predicting high risk of intra- and postoperative complications by having planned strategies to avoid or how to deal with them can decrease their rate and improve the patient's reconstructive journey in head and neck reconstruction.

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Free Flap Considerations and Complications

6

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Complications in Head and Neck Microvascular Free Tissue Transfer

Introduction

Microvascular reconstruction of the head and neck has become a mainstay in the management of large, complex, and composite defects of the head and neck, with the average free flap success rate now at about 95% [1], with higher success rates reported up to 99% in the literature [2]. Despite the low rate of complications reported in the literature and well-documented success rates, even the most experienced of surgeons often face the potential of complications, either in the preoperative phase, in the OR, or after surgery. These complications can result in the need for additional procedures and can result in partial or complete loss of the free flap, necessitating surgeons to perform salvage surgery. These complications can result in increased morbidity, length of hospital stay, treatment cost, and overall compromised functional and esthetic results.

Preoperative Phase

When considering the management of free flap complications in the preoperative period, it is important in our experience that the surgeon consider four distinct points: (1) recognition that complications can and do happen to the best surgeons, (2) anticipation of possible sources of complications specific to each patient, (3) actively take steps to prevent these complications from occurring or to minimize the risk, and (4) institute a plan for monitoring for the presence of these complications including consideration of alternative treatments in the event of flap failure. The active plan should include patient education and advice as part of the consent process. Free flap surgery is a

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daunting prospect for the patient, and even minor complications can be very challenging for patients and family. Appropriate patient and staff education in the preoperative period not only is key in preventing complications from arising, but also increases the success of interventions that may be required. In effect, the preoperative management plan serves to set one up for the best possible success in managing any intraoperative or postoperative challenges that may arise.

It is helpful to think about complications in three broad categories: (a) patient related, (b) donor site related, and (c) free flap related. The best and most effective management of complications is to prevent them from happening, and this is the central aim of the preoperative workup. Patient-related characteristics can contribute significantly to anesthetic and surgical risk, as well as predispose the patient to the development of complications in the immediate postoperative period. These are well characterized, and workup for these conditions is described in other chapters of this book covering medical and surgical assessment and optimization as well as patient education. With respect to donor site-related challenges, the choice of the reconstructive flap determines the donor site. It is prudent to consider several donor sites in the same patient in case of flap failure, or the need for alternative or additional free tissue transfer. The chapter in this book on surgical assessment describes an approach to addressing possible risks. Finally, in regard to free flap-related issues, Corbitt et al. [3] describe the causes of head and neck free flap failure in their series as follows: infection—25%, kinked or compressed pedicle—23%, flap design- and harvest-related issues—15%, hemorrhage—7%, and hypercoagulable disorders—5%. It is important that the patient who is predisposed to infection or might have an undiagnosed systemic clotting or bleeding disorder is identified in the preoperative period. The patient who has had previous free flap failures should, in our opinion, be considered for a nutrition screen and hypercoagulability workup prior to surgery. CT angiograms of the planned flap site as well as the neck vessels may be of some benefit in this cohort of patients.

Management of flap complications will often involve a return to the operating room with the need for salvage procedures and, in the event of catastrophic failure, institution of the "reverse reconstructive ladder" [4]. The surgeon should understand that the likely alternative treatments could involve, in descending order of preference, a second free flap, a regional flap, conservative care with debridement and closure with local flaps, and skin grafts or healing via secondary intention. In some cases, a combination of several of these modalities may be required [5].

Intraoperative Phase

Intraoperative complications for free tissue transfer have been well established in the literature, and common intraoperative causes of flap failure must be noted by the treating surgeon so that steps can be taken to avoid them or at the very least minimize them. Several factors must be considered, and these include prolonged operative time, morphology and position of the vascular pedicle at the recipient site, patients who have been previously irradiated in the recipient site, the surgeon's level of experience, operative techniques, the incidence of vessel spasms, formation of thromboses, as well as the development of hematomas.

Prolonged Operative Time

A prolonged operative time has been identified as an independent risk factor for failure in head and neck free flap surgery. In a retrospective national database study conducted by Ishimaru et al. [6], 2846 patients were identified and found that a prolonged operative time was significantly associated with free flap failure. Serletti et al. [7] reported that an operative time longer than 10 h was associated with an increased risk of postoperative complications including thrombosis, hematoma, bleeding, and ultimately free flap failure. Longer operative times resulting in prolonged ischemic periods increase the incidence of flap damage due to tissue hypoxia and anoxia [8]. In order to reduce operative and ischemic times, a two-team approach and the availability of dual-recipient vessels, especially in irradiated patients, are recommended.

Surgeon's Expertise

It has been reported that surgical technique constitutes the most important component of free

flap success [9]. In a study by Zhou et al. [10], the two surgeons who performed the microvascular anastomoses (XP and YW) both had more than 5 years of experience in microvascular anastomosis, and thus had a standardized protocol: (1) selection of a recipient vessel of the same diameter as the donor vessel, (2) removal of the attached soft tissue from the anastomosis site, (3) widening of the diameters of both the donor and recipient vessels by pressing microforceps against the inner membrane of the vessels, (4) irrigation with heparin before anastomosis, (5) gentle suturing of the vessels without tension, (6) checking the patency after vessel anastomosis, (7) adjusting the position of vessels to ensure no blind bend, and (8) use of papaverine to prevent vasospasm. Good vessel selection plays a significant role in the success of free tissue transfer. Most surgeons agree that the facial and superior thyroid arteries, as well as the common facial vein and internal jugular vein branches, are the most suitable for anastomosis. In a study conducted in Shanghai covering a 34-year period and including 4640 flaps, authors showed that the facial and superior thyroid vessels were the most reliable, as these vessels are in close proximity to head and neck defects and the caliber of these vessels is similar to that of the donor vessels often used in reconstruction [11]. Having said this, irradiated patients can demonstrate significant changes in vessel quality, with increased friability, intimal changes, and calcifications, and as such, these vessels may not be adequate for anastomosis. In this case, the surgeon must be prepared to change vessels, electing to use the external carotid artery, contralateral vessels, ipsilateral transverse cervical vessels, or internal mammary vessels for anastomosis. The ability to pivot in this scenario becomes crucial to achieve higher success rates. It is important to note that the choice of flap type has not been associated with changes in free flap success rates. Kwok and Agarwal [12] examined overall flap failure rates based on the flap type (muscle, fascial, skin, bone, and bowel flap) in 1187 cases and concluded that there were no significant associations between flap type and known risk factors for flap failure ($p = 0.464$).

Vessel Spasm and Thrombosis

There are several causes of vessel spasms and thrombosis, in both arterial and venous systems, and these must be considered in all cases of free tissue transfer. First, hypotension is considered a common cause of arterial thrombosis in free flap transfers, with the reduction in blood flow through the anastomosed vessel increasing the propensity of thrombosis. A thrombosed artery will often appear as a bulge at the thrombosed site, many times permitting visual identification of the thrombus. Moreover, the use of a handheld Doppler will confirm whether blood flow is present or not. A second risk factor for thrombosis is called "back-walling," where the opposite side of the arterial wall is sutured by mistake, resulting in intimal damage and potential thrombosis. Vessel spasms in and of themselves also serve as risk factors for the development of clots, as they can stagnate blood flow. Another cause for arterial thrombosis is the presence of bends or inadequate removal of the attached tissue from the donor and recipient vessels. Therefore, if the handheld Doppler confirms inadequate blood flow after anastomosis, the surgeon must take steps to rectify the situation. This involves communication with the anesthesia team to increase the mean arterial pressure, applying papaverine to the anastomosis site, removal of excessive fascial tissue from the anastomosed vessel, as well as checking for any kinking in the vessels. If after all of this blood flow is still inadequate, anastomosis should be opened and redone, while checking for intimal damage and cutting back or changing vessels when necessary. The application of papaverine during anastomosis has been found to increase carotid artery blood flow in humans [13]. Similarly, it has been found that the local application of papaverine during vascular anastomosis could sustain anastomotic dilatation. In a systematic review of 20 articles, Vargas et al. [14] concluded that papaverine could produce a 66% increase in vessel diameter, and that it possesses significant vasodilatory effects on nonspastic vessels [15]. Papaverine acts directly on calcium channels causing a direct increase in cyclic adenosine monophosphate and subse-

quent increases in secondary messengers that leads to protein kinase activation and nonselective smooth muscle relaxation and vessel dilation. One practical way to reduce vessel spasm is to inject papaverine or lidocaine into the fascia of the pedicle during flap harvest. It is also important to mention that thrombosis will occur if the vessel endothelium is not intact during anastomosis; therefore, it is important to protect the intima without interruption or damage during anastomosis.

Venous failure can also occur due to compression, spasm, and thrombosis and is a common cause of intraoperative flap complications, as venous thrombosis occurs more frequently than arterial thrombosis. It is often very easy to kink or twist the vein during or after anastomosis, and careful attention should be paid to prevent this. Additionally, the choice of an adequate recipient vein is very important for flap success, with good vessel caliber matching and a tensionless anastomosis playing an important role. While the external jugular vein is often very easily accessible, sometimes authors do not recommend its use due to its superficial position in the neck with the risk of being easily compressible. Despite this, in our experience with the external jugular vein, we have not found this to be the case and have represented a reliable recipient vein. However, the lingual vein should also be avoided, as anastomosis to this vein may be difficult due to its cranial position under the mandible. At the conclusion of surgery, special attention should be made to monitor the patient while the anesthesia team is extubating the patient. As the patient emerges from anesthesia, it is important to stabilize the neck and observe for rises in the patient's blood pressure, as well as prevent patients from moving about forcefully, as these can result in increases in intravascular pressure, with the risk of bleeding and subsequent hematoma formation, which could lead to venous compression and thrombosis.

Intraoperative Fluid Administration

Another critical risk factor associated with intraoperative free flap failure is excessive intraoperative fluid administration. Haughey et al. [16] hypothesized that edema of the flap or recipient site can result from increased volumes of crystalloids, reporting a critical cutoff value of 7 l of crystalloids during surgery, with volumes higher than this linked to major flap complications. Moreover, Ruttmann et al. [17] suggested that the use of crystalloids, as compared to colloids, can result in a hypercoagulable state, especially when administered rapidly, thus increasing the risk of thrombosis intraoperatively. In their study, Brinkman et al. [18] recommended that basic fluid maintenance should not exceed 6 cc/kg/h and that normovolemic hemodilution is preferred, reporting that blood with a reduced hematocrit has a better flow profile than blood with a normal hematocrit.

Use of Vasopressors

The concept of vasopressors increasing the risk of free flap compromise has been one that has been discussed extensively for decades. Several studies have shown that intraoperative use of vasopressors does not increase the risk of free flap compromise and failure in head and neck cancer patients. In a retrospective study performed with 47 patients undergoing free tissue transfer for head, neck, and extremity reconstruction, Kelly et al. [19] reported that free flap survival was 97%, with 53.2% of cases showing the use of intraoperative vasopressors. There was no significant difference in the frequency of total or partial flap necrosis between patients who received intraoperative vasopressors and those who did not. Similarly, there was no statistical significance in the rate of arterial or venous thrombosis between the two groups ($p = 0.095$ and $p = 0.095$, respectively). In another study, Gardner et al. [20] reported that the use of vasopressors for extensive periods intraoperatively during free flap surgeries had no association with the rate of reoperation within 5 days of intervention, regardless of the type of vasopressor used, simultaneous use of multiple agents, and/or type of free flap surgery. This study included 449 free flap reconstructions with a total of 174 patients receiving continuous vasopressors during their reconstruction.

Postoperative Phase

By and large, the immediate postoperative period represents the most common time for complications to occur in free flap reconstruction. Close monitoring of patients in this time frame is crucial, as problems that are recognized and diagnosed early have much higher rates of successful salvage.

Vascular Thrombosis

Vascular thrombosis is a devastating complication in free flap surgery, with thrombosis rates in the literature ranging from 3.2% to 9.9% across various studies, with an average occurrence in 6.4% of free flaps [21], and this represents a major contributor to free flap failure [22, 23]. Thrombosis can occur either at the level of the pedicle or distally up to and including the microcirculation of the flap, and they can occur within the venous system, the arterial vessels, or a combination of the two. Salvage rates in these instances vary anywhere from 28% to 90%, depending on the etiology of the complication and the timing of salvage procedure [24]. Salvage in cases of venous thrombosis is significantly higher than in arterial thrombosis, partially attributed to the fact that compromised flaps due to venous congestion are more likely to occur within the first 72 h and are often easier to detect, as compared to arterial insufficiency, which is a more common cause of flap failure after the first 72 h [25, 26]. The rates of salvage when both venous and arterial systems demonstrate thromboses are, as expected, much lower [27]. Selber et al. [28] demonstrated that mean flap salvage rates in patients with microvascular flap compromise were 73% when returning once to the operating room, 34% when returning twice, and 27% when returning three times, declining with greater number of insults to the flap. The greatest chance of success will be in patients with a technical failure that is identified early, with an immediate return to the operating room. The time effect on salvage rates is likely associated with several factors, including irreversible ischemic injury to the flap and reperfusion injury with the "no-reflow" phenomenon after vascular patency has been re-established, and these are closely linked to secondary ischemia of the flap [29]. Primary ischemia is defined as the time between division of the vascular pedicle and re-establishment of blood flow after anastomosis. While generally accepted that the upper limit of this is approximately 4 h, it is ideal that this time is kept under 60 min. This also varies on the type of flap, as flaps involving muscle are more metabolically demanding and often do not tolerate more than 3 h of ischemia time, while the rate of fat necrosis in flaps such as deep inferior epigastric artery (DIEP) flaps increases after primary ischemia time exceeds 2 h [30]. The concept of secondary ischemia is one which is characterized by the time between the occurrence of vascular thrombosis and return of blood flow to the flap, most often after nonsurgical or surgical intervention. It has been described that secondary ischemia can be much more devastating for flap survival than the primary ischemic period, secondary to increases in interstitial edema, platelet and fibrinogen concentrations, and increased rates of thrombosis [31, 32]. Furthermore, it has also been shown that the time between primary and secondary ischemia also influences rates of flap survival. If the period between ischemic episodes is less than 24 h, secondary ischemia results in significantly more flap necrosis than if that inter-ischemic period was stretched to 72 h or more, likely linked to increased time to washout of damaging free radicals from primary ischemia [33]. Reperfusion injury is an inflammatory process which occurs when restored blood flow after a period of ischemia allows the influx of accumulated inflammatory and damaging substrates such as free radicals that can injure the flap and severely compromise its survival. The transition point between normal reperfusion and reperfusion injury is poorly defined and differs among various tissue types, with some tissues being more resistant to ischemia than others, as previously mentioned. For all tissues, however, the longer the periods of ischemia, the more likely they are to result in irreparable damage to the microcirculation and to the flap tissues. Stotland and Kerrigan [34] described damage caused by reperfusion injury as cell death by "bombard-

ment." Neutrophils become activated, inflammatory mediators accumulate, and oxygen-based free radicals and proteolytic enzymes are released, inducing tissue damage. The "no-reflow" phenomenon is often the result of reperfusion injury and was first described in 1967 as the "lack of nutritive capillary perfusion despite reperfusion of ischemic tissue" [35]. There have been several theories put forth on the physiologic nature of this phenomenon, involving things such as intravascular hemoconcentration, which changes the rheostatic properties of the blood, swelling of endothelial cells, increases in interstitial pressure and edema, and capillary obstruction by leukocytes [36].

The time to re-exploration has varied in the literature, ranging from peaking in the first 24 h [37, 38] up to 80% occurring within the first 5 days postoperatively [39]. Despite this, the incidence of late thrombosis after postoperative day 5 has been well documented and accounts for between 10% and 28% of all thromboses [40, 41]. Free flaps are thought to undergo revascularization by way of the surrounding tissues and have an increased ability to survive without pedicle flow within several days after surgery, and it has been shown to result in complete flap independence as early as 6–8 days postoperatively in experimental animal studies [42–45]. As such, some postulate that late thrombosis has a decreased incidence of flap loss even with conservative management [46–48]. However, most authors believe that revascularization can take significantly longer and can remain dependent of pedicle flow for several months to years [49–51]. The surgeon must differentiate between a true late thrombosis and delayed recognition of early thrombosis, as the latter has much lower salvage rates and likely accounts for the majority of "late" thrombosis diagnoses. Both early and late thromboses have been shown to be predominantly of the venous system. The type of flap has also been studied in regard to rates of collateral revascularization, with reports of osseous flaps having longer dependence on pedicle flow as compared to soft tissue flaps [52]. A major cause of late thrombosis is infection [53], with increases in the rate of thrombosis by 50–75% even up to 1 month postoperatively in this cohort [54]. A study by Sweeny et al. described a shift in the timing of free flap failures, demonstrating in their cohort that only 40% of failures occurred within the first 72 h, with the majority of late failures being arterial insufficiency in nature. They postulate that while early venous failures are due to its low-pressure characteristics being more susceptible to external compression and pedicle geometry, and early arterial failures are due to technical issues (often found with intraoperative arterial thrombosis as well), the later failures involving arterial thromboses are more often due to the poor quality of vessels, due to either presence of calcifications (Fig. 6.1), plaques, or other vessel wall compromise, which may also contribute to the lower rates of salvage of these flaps [55].

Venous thrombosis is by and large the most common vascular complication that is encountered in the postoperative period in free flap surgery, accounting for as much as 70% of indications for re-exploration, and often occurs within the first 48 h [56]. This is likely due to the fact that venous structures are more easily compressible by surrounding edema, hematoma formation, and/or tight skin closure; have higher rates of spasm; and can result in vascular stasis more easily with pedicle kinking and even transient periods of hypotension [57, 58]. Arterial thrombosis, however, is most often associated with technical factors at the level of the anastomosis, such as inadvertent damage to the intima during vessel manipulation, exposing the subendothelial connective tissues to circulating platelets and triggering the hemostatic cascade [59]. Other issues may include poor vessel apposition/mismatch, back-walling of the suture, vascular twisting, vasospasm, calcifications, as well as undue tension or compression at the anastomotic site, which can all contribute to clot formation [60]. This can result in multiple attempts at reanastomosis, resulting in prolonged ischemia times, reperfusion injury, and "no-reflow" phenomenon [61].

The earliest sign of venous congestion of a flap is the appearance of hyperemia, a slight darkening of flap color in some areas with appearance of pinpoint ecchymoses, with a "goosebump"

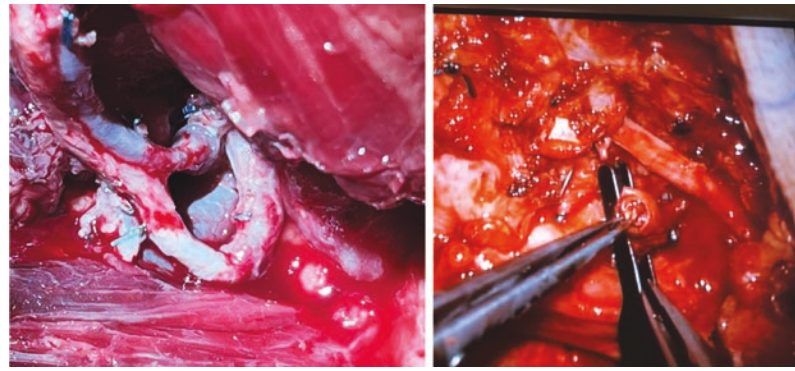

Fig. 6.1 Calcified vessels in patients receiving free flap reconstruction

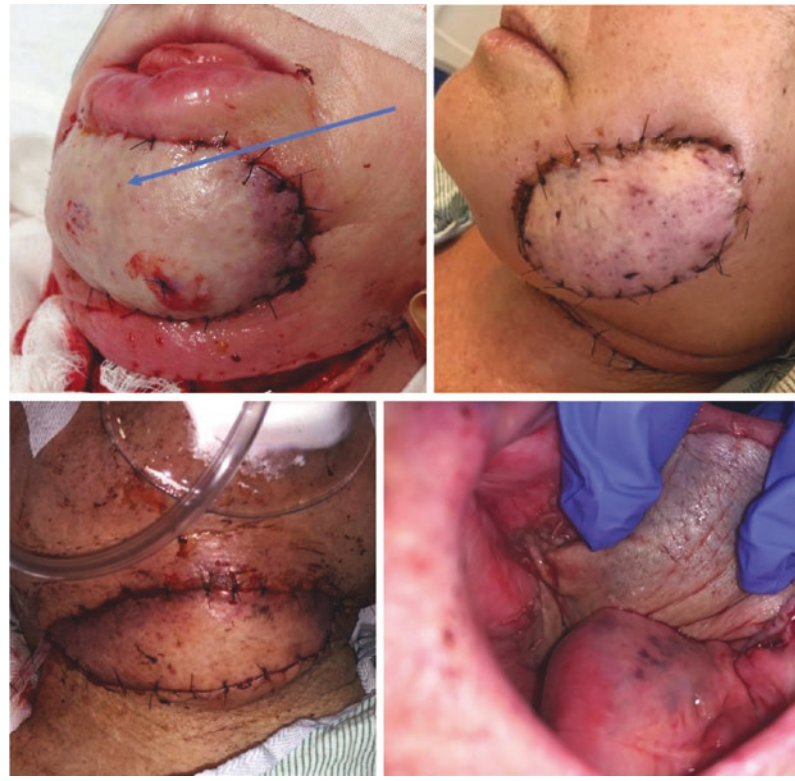

Fig. 6.2 Slight darkening of flap color with pinpoint ecchymoses (blue arrow) in early venous congestion

appearance (Fig. 6.2). Eventually, this leads to increased flap turgor with the flap appearing tense, more generalized changes in color from red to blue to purple (Fig. 6.3), brisk capillary refill of <2 s, and increased warmth of the flap. A scratch or pinprick test can be performed to further assess the flap, which would reveal a rapid return of dark-appearing blood (Fig. 6.4), indicating a lack of outflow of venous circulation. Arterial insufficiency of free flaps appears quite differently clinically than venous congestion, with a decrease or arrest in inflow of blood supply. This leads to flap that appears pale in color, is soft with decreased turgor, would feel cool to the touch, and have a prolonged capillary refill of >2–3 s. A scratch or pinprick test would reveal a very slow (or even absent) return of blood, indicating a lack of influx of sufficient blood supply (Fig. 6.5).

In the setting of venous compromise, one can consider bedside neck exploration under mild sedation if no clinical signs of flap congestion are

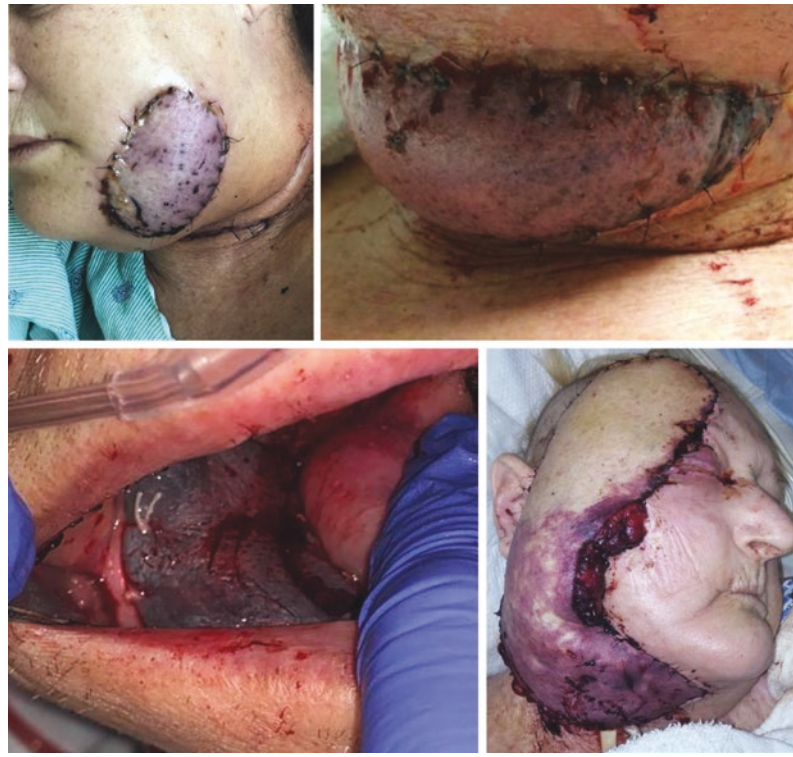

Fig. 6.3 Progression of venous congestion to more generalized blue/purple color change, and increased flap turgor

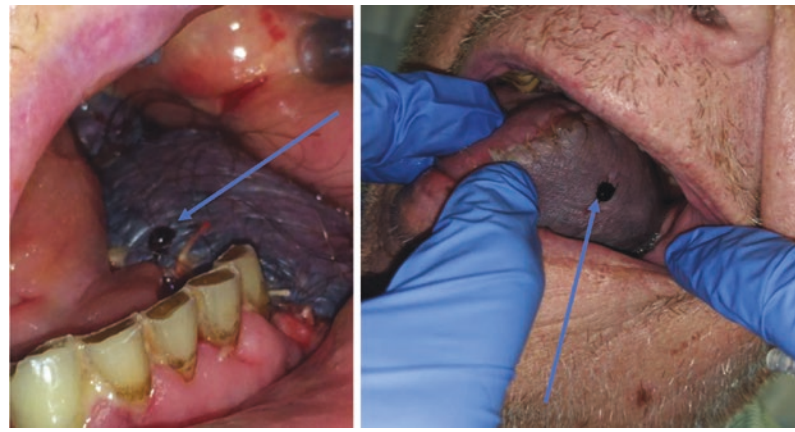

Fig. 6.4 Pinprick test reveals rapid return of dark-red blood (blue arrows) in venous congested flap

seen in the skin paddle, and all that is seen is a loss of the implantable Doppler signal, if one was used, as oftentimes this may simply be a coupler malfunction. If clinical signs of venous congestion are present in the flap, immediate take-back to the OR for exploration is warranted. Even in the case where return to the OR is planned, one can consider opening sutures bedside to see if taking some of the pressure off the venous circulation by surrounding edema, accumulation of interstitial fluid, or tight closure can potentially help relieve the external compression. The surgeon can also open the neck entirely bedside to visually examine the pedicle to see if there is a kink or twist that can be rectified bedside. If an obvious clot is present within the venous system, one can also consider opening the venous anastomosis to allow the flap to drain, thereby decreasing the potential for flap damage until the patient can be brought back to the OR for formal explo-

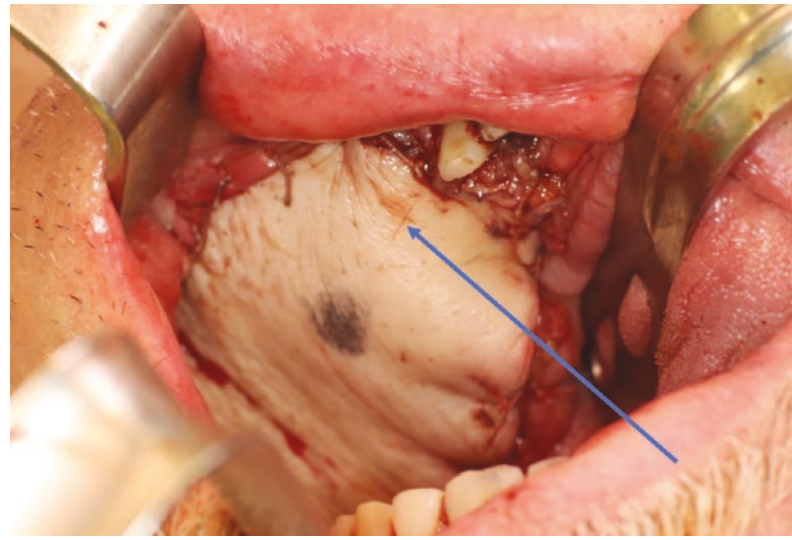

Fig. 6.5 Pale-appearing skin paddle, with decreased turgor, with minimal return of blood on scratch test (blue arrow), indicative of arterial insufficiency

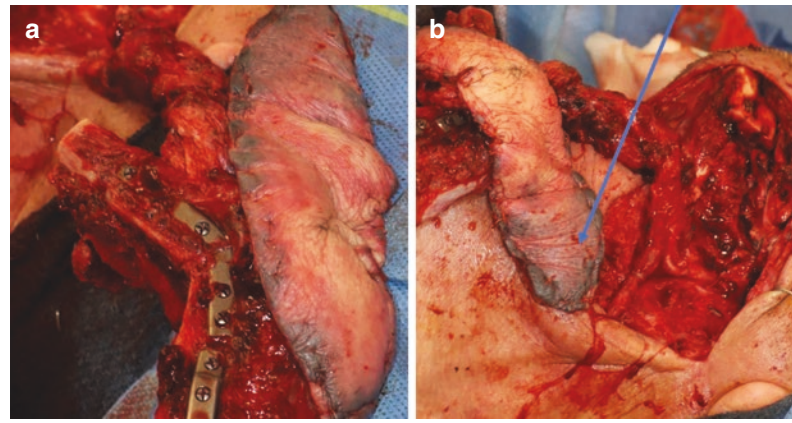

Fig. 6.6 (**a**) Takedown of flap to carefully examine and inspect to determine the cause of venous congestion. (**b**) Identification of venous thrombosis (blue arrow)

ration. The surgeon can gently pack the neck with gauze, while the flap continues to drain until return to the OR occurs. In the case of arterial compromise, immediate return to the OR for exploration is warranted.

When returning to the OR for exploration and possible revision, careful inspection of the entire flap and vascular pedicle is warranted, often necessitating flap takedown to accomplish this (Fig. 6.6a), and the cause of the vascular complication should be identified. Ensure that there are no kinks or twists in the pedicle and that the pedicle is not being externally compressed by surrounding tissues or hematoma. Once external causes are excluded, internal causes such as vasospasm, issues with the anastomosis, or thrombosis may be the culprit. If venous thrombosis is noted (Fig. 6.6b), opening of the anastomosis is warranted with mechanical thrombectomy either by way of milking out the clot manually (Fig. 6.7) or via Fogarty catheter (Fig. 6.8), irrigation with heparinized saline, cutback of thrombosed segment (with or without vein grafting as needed), and revision either with the same vein or another carefully selected recipient vein. In a comparison of 21 compromised flaps with thrombosis of either the venous or the arterial systems, the use of a Fogarty catheter for mechanical thrombectomy resulted in a 57% rate of successful flap salvage [62]. Risks of this technique however include further propagation of the thrombus, microtrauma to the ves-

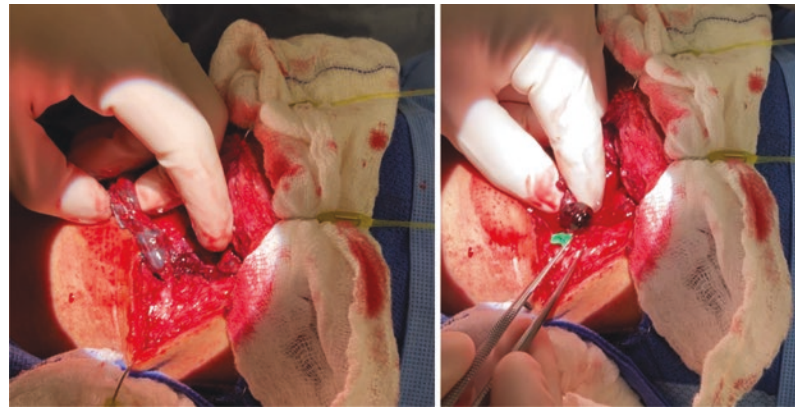

Fig. 6.7 Manual removal of venous thrombosis

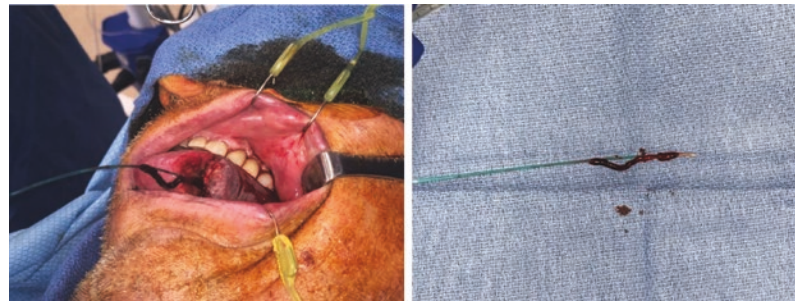

Fig. 6.8 Thrombectomy with Fogarty catheter

sel with possible intimal damage and dissection, vessel perforation, or device complications such as rupture or avulsion within the vessel [63]. Thrombolytics such as recombinant tissue plasminogen activator (Rt-PA) in conjunction with mechanical thrombectomy as a multimodal approach has also been used and has shown some promising improvements in flap salvage rates [64]. The debate on the use of one versus two venous anastomoses has been an ongoing one; on the one hand, two veins provide increased drainage and theoretically less risk of venous congestion, whereas single venous anastomosis reduces operating time and allows for easier flap inset [65]. Xu et al. [66] have reported that the use of one-vein anastomosis had significantly higher salvage rates and earlier time to detection of flap compromise than two-vein anastomoses in a cohort of 389 free flaps. Despite this, some studies have demonstrated no difference between the two [67], and some have shown that two veins are better than one in reducing the incidence of take-backs and failure rates [68, 69]. Good arterial pulsations should be present and might be weak or absent in the case of arterial thrombosis. In this case, takedown of the arterial anastomosis is warranted with removal of thrombus and cutback to healthy vessel prior to reanastomosis, or selection of another donor artery. If a length discrepancy or vessel caliber mismatch is present, consideration should be made to perform vein grafting and/or selection of a new donor artery. Systemic antithrombotic agents such as intravenous heparin in doses of 3000 or 5000 units at the time of venous or arterial reanastomosis may be employed in conjunction, particularly if thrombus formation rapidly reoccurs at the time of exploration and revision. If a venous coupler was used, surgeons can use the same size coupler or a larger one if proper anastomosis can be accomplished. To deal with vascular spasms, the pedicle can be irrigated with papaverine (alkaloid antispasmodic) to decrease the incidence of vascular spasm, the flap can be warmed, and the use of lidocaine and nicardipine has also been described [70].

Patients demonstrating a history of hypercoagulability (antiphospholipid syndrome, factor

V Leiden, factor C and S deficiency, etc.) have demonstrated increased rates of both arterial and venous thrombosis in free flap surgery [71, 72]. Moreover, patients with malignancies, which is a major indication for free flap reconstruction in the head and neck, have been shown to be hypercoagulable at baseline and thus are inherently at increased risk of thrombosis [73]. Additionally, patients who are treated intraoperatively and/or postoperatively with heparin are susceptible to thrombosis due to a rare side effect, heparin-induced thrombocytopenia and thrombosis (HITT), which can occur in about 0.1–1% of heparinized patients, with higher rates in patients receiving unfractionated heparin (UFH) as compared to low-molecular-weight heparin (LMWH) [74–76]. These patients should be switched to a non-heparin anticoagulant such as argatroban and likely will require long-term coumadin therapy. Patients who have repeated clotting, either intraoperatively or postoperatively, should have a hypercoagulability workup to determine if a thrombophilic disorder is present. Once successful flap salvage has been achieved, postoperative care becomes a vital component of maintenance of a healthy flap. Close observation of the flap within an intensive care unit (ICU) with trained personnel becomes vital, with careful attention to neck position to prevent kinking, twisting, or stretching of the vessels, as well as close monitoring of vitals, laboratory values, and overall patient status. Education of ICU staff on flap monitoring is crucial to ensure adequate care and early recognition of problematic issues. There currently exists a paucity of data and evidence-based research regarding the use of therapeutic anticoagulation after successful free flap salvage. Senchenkov et al. looked at a large series of 395 free flaps for breast reconstruction and advocated for routine postoperative anticoagulation with heparin in all patients who experienced both intraoperative and postoperative thrombotic events, with the addition of antiplatelet therapy for those with repeated thromboses. However, targeted protocols in this scenario in head and neck reconstructive surgery have not yet been established [77].

While surgical exploration and revision of compromised flaps remain the mainstay of management for these patients, there exist situations in which other options must be explored. In cases where the patient may be too unstable to return to the OR, or where thromboses are too numerous or too distal to warrant access and revision, or in case of repeated clotting, nonsurgical options are to be considered. These can include the use of thrombolytics, anticoagulants, hyperbaric oxygen therapy (HBOT), or medicinal leeches (*Hirudo medicinalis*).

The use of Rt-PA has been described in the literature for salvage of venous congested free flaps. Rt-PA is a thrombolytic that encourages the conversion of plasminogen to plasmin and initiates local fibrinolysis, thus aiding in the resolution of venous and arterial clotting. Not all patients are candidates for thrombolytic therapy, however, as patients with a history of bleeding diatheses and patients who are at high risk of intracranial, gastrointestinal, and other bleeds may represent absolute contraindications to this therapy. Tran et al. [78] have previously described successful use of subcutaneous injection of Rt-PA directly into flaps, with return of capillary refill and resolution of venous congestion. Often, this is not employed as a first option; however, after multiple attempts at venous revision, this becomes a consideration. Ayhan et al. [79] employed the use of Rt-PA after three attempts at venous anastomosis with recurrent venous congestion, where injection of 2 mg of Rt-PA into multiple areas of their flaps allowed for successful salvage. Ihler et al. [80] reported return of capillary refill between 4 and 8 h after injection, though this can vary depending on flap size and varying severity of flap thrombosis. Additionally, the use of thrombolytic therapy intra-arterially for flap salvage in the case of venous congestion was first described in 1987 by Lipton and Jupiter and is well described and utilized today [81–84]. This may help not only with thrombosis at the level of the pedicle, but also with clotting within the microcirculation of the flap itself, as this can be a significant cause of flap failure.

The use of heparin to relieve venous congestion was first described in 1989 in cases of digital

replantation [85], and the use of LMWH has been described in salvage of free flaps. Injection of LMWH directly into areas of the congested flap in a subcutaneous fashion has been described, with the onset of action and time to visible effect reported to be about 2 h, with peak effect occurring at about 4–5 h and duration of effect of about 12–24 h. It has been recommended that doses of 20–40 mg every 4–6 h should be implemented for the first 1–3 days, decreasing to 10–20 mg every 24 h around the 10–14-day mark [86]. Therapy should be continued for a minimum of 10 days, as studies have identified the time frame for the re-establishment of neovascularization to be around 7–10 days [87]. As with Rt-PA, the use of LMWH can be useful in cases of thrombosis both at the level of the pedicle and within the microcirculation of the flap, which may not be amenable to surgical exploration. In addition to its anticoagulant effects, heparin has been shown to reduce endothelial dysfunction within the microcirculation of postischemic flaps, thus providing a protection against reperfusion injury that is independent of its systemic anticoagulant effects, though the exact mechanism of this effect is yet unknown. It has been postulated to be linked to effects such as inhibition of leukocyte adhesion to postischemic endothelium via increases in nitric oxide synthesis, reduction of free radicals due to its capacity to release superoxide dismutase from the endothelium, as well as direct anti-inflammatory effects [88–90].

Leeches (hirudotherapy) have shown promise in the management of venous congested flaps, particularly as a bridge to formal surgical exploration and revision [91, 92]. Leech therapy is only useful, however, in cases where arterial inflow is patent and sufficient, and therapy is targeted at decreasing the accumulating venous pressure within the flap (Fig. 6.9). Leeches secrete a non-heparin anticoagulant called hirudin, which aids in the feeding process. Leeches are kept in refrigerated distilled water with Hirudo salt. Prior to application, any blood clots should be cleaned off with dry gauze (use of alcohol swabs may interfere with latching). The leech is grasped with gloves or non-toothed forceps and placed onto the flap. If the leech does not latch, the flap can be pricked to induce bleeding to encourage the leech to latch. The leech will generally detach once it is fully distended and must be monitored to prevent migration of the leech to other areas, with treatment lasting anywhere from 30 min to 4–5 h. Leeches are then euthanized in 70% isopropyl alcohol and discarded. All patients are placed on antibiotics prophylaxis for *Aeromonas hydrophila* for the duration of leech therapy, which consists of doxycycline, ciprofloxacin, ceftriaxone, or Bactrim, with prophylaxis continuing for 14 days after cessation of leech therapy. Furthermore, the patient's hemoglobin levels must be monitored throughout the treatment period every 6 h, and transfusion should be considered if levels drop below 10 g/dL in symptomatic patients [93]. It should be noted that leech therapy has not been shown to help salvage all venous congested tissues and as such should not be used as a primary method of flap salvage [94, 95].

HBOT has been shown to improve the survival of free flap failures in the setting of arterial, venous, and combined arteriovenous insufficiency; however, it has been validated primarily in animal models [96]. In contrast to leech therapy, HBOT has been shown to impact flap survival greatest in cases of arterial insufficiency, secondary to its ability to enhance fibroblasts and collagen synthesis, promote neovascularization, and reduce local hypoxic insults [97, 98]. Further

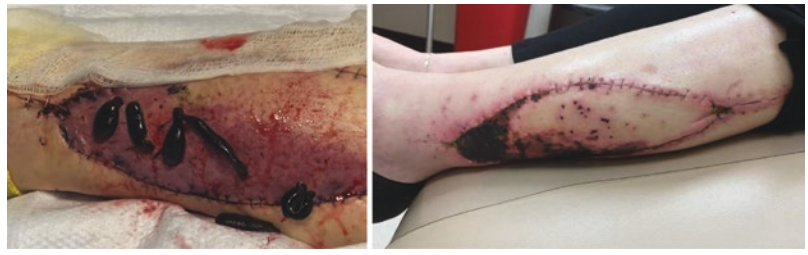

Fig. 6.9 Use of medicinal leeches on venous congested flap. Note the improvement of central portion of flap, with necrosis of limited to lateral edge and distal tip

investigation in human subjects is necessary at this time to better evaluate the efficacy of HBOT as an accepted mode of free flap salvage in head and neck reconstructive surgery.

Hematomas

The formation of hematomas not only compromises tissues by the extrinsic pressure effect they elicit, but they also induce a complex sequence of interrelated biochemical and cellular events, including neutrophil infiltration, cytokine-mediated inflammation, and a prothrombotic state, which leads to synthesis of reactive oxygen species and activation of the complement system, resulting in tissue injury, as well as vascular thrombosis [99, 100]. Sources of bleeding may include the vascular pedicle, tissue bed, as well as bleeding from flap edges. Postoperative hematoma formation (Fig. 6.10) accounts for anywhere between 0.2% and 30% [101] of postoperative complications relating to free flaps in head and neck reconstruction, representing the second most common postoperative complication in free flaps, just behind vascular thrombosis [102]. This is higher than other regions of the body, likely relating to increased dead space in the head and neck with more anatomical constraints, more complex vascular anatomy, as well as difficulty in immobilization and autonomic reflexes such as gagging and coughing, as well as vomiting, resulting in inadvertent pedicle disruption or vascular leakage [103]. Studies have shown that free flaps are compromised by hematomas 2–4% of the time within this cohort, most commonly resulting from compromise of venous outflow and flap congestion [104]. As such, early recognition of hematoma formation and management are crucial to free flap salvage. A study by Chen et al. concluded that if return to the OR for re-exploration and salvage was within 36 h, salvage rates were significantly higher at 84% as compared to 50% if return to OR was after this time frame, with salvage rates especially higher in cases where there was an absence of thrombosis [105]. Other studies have shown salvage rates of 93.3% if return to OR was within 5 h of detection, and 100% in the absence of thrombosis, as compared to 58.3% in the presence of vascular thrombosis [106]. The use of postoperative anticoagulation to decrease vascular thrombosis rates in free flaps remains a debated topic with no consensus as of yet. Studies have shown that in cases where no anticoagulation therapy was used, rates of free flap failure, thrombosis, as well as rates of hematoma formation were similar to rates of various anticoagulation therapies [107, 108]. However, a study by Kroll et al. demonstrated a statistically significant increase in rates of hematoma formation in patients who received high-dose heparin for pedicle thrombosis prophylaxis at 20% [109]. Moreover, other studies have shown that the use of NSAIDs postoperatively has been associated with higher rates of hematoma formation in this cohort, with aspirin showing the lowest rates of hematomas [110, 111]. All this may suggest that anticoagulation postoperatively offers no or minimal improvement in flap survival and minimal effect on flap-related complications in the postoperative setting [112]. Despite this, patients often require chemoprophylaxis for reasons other than prevention of flap thrombosis, such as prevention of VTE, and thus

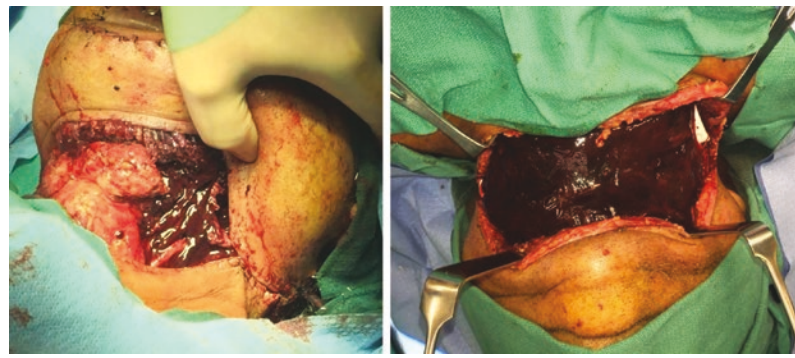

Fig. 6.10 Formation of postoperative hematomas in free flap patients

this should be taken into consideration. It has also been suggested that postoperative blood pressure control can influence rates of hematoma formation and should ideally be <150 mmHg systolic, as rates of hematoma formation can increase with even transient increases of about 165 mmHg systolic [113]. Despite this, maintaining a high enough blood pressure to maintain good flap perfusion and avoiding significant periods of hypotension are essential, with systolic blood pressure ideally maintained above 100 mmHg for this purpose [114].

Signs of the presence of a hematoma can sometimes be subtle, with just the localized development of ecchymosis in the cervical region or just the presence of a mild amount of edema. Other times, evidence of hematoma formation is more obvious, with the presence of a large swelling, ecchymosis, bleeding from between sutures, compression of the vascular pedicle, and venous outflow blockage.

One method by which to manage hematoma formation is the removal of sutures at bedside with evacuation of the hematoma. Some authors however have stated that given the cytotoxic nature of the effects of a hematoma, as well as the potential for incomplete hematoma evacuation, performing this maneuver is not sufficient and return to the OR for exploration and formal evacuation is recommended (Fig. 6.11) [115]. Additionally, formal exploration is often warranted in order to identify and obtain surgical control of bleeders if present, and to examine the vascular pedicle for potential thrombosis. If re-exploration is performed prior to the formation of vascular thrombosis, salvage rates are significantly higher, underscoring the importance of early detection.

Salvage Reconstruction

Unfortunately, there are the rare instances where flap salvage appears to be unlikely, and surgeons are left to make a tough decision, namely when to terminate salvage efforts and what steps to take next. In the case of partial flap failure, options for management depend primarily on the amount of residual defect after partial flap debridement or excision, location of the defect, as well as tissue availability. In cases where a small defect remains, local tissue rearrangement sometimes suffices for the purposes of wound coverage, whereas larger defects may necessitate the use of a regional flap. If the defect involves a communication of the oral cavity to the neck, salivary leak into the cervical tissues becomes a significant consideration, given the increased risk of infection and fistula formation. In the setting of total flap failure, one must balance the needs of the wound or defect for reconstruction with a goal of restoring form and function, with the ability of the patient to tolerate another extensive procedure and to decide what additional procedure should be undertaken. The reconstructive options remain similar, a second free tissue transfer, regional flap, or local tissue rearrangement (Fig. 6.12) [4]. In addition to the tolerance of a secondary procedure, consideration should be made for extended hospital stay with potential for

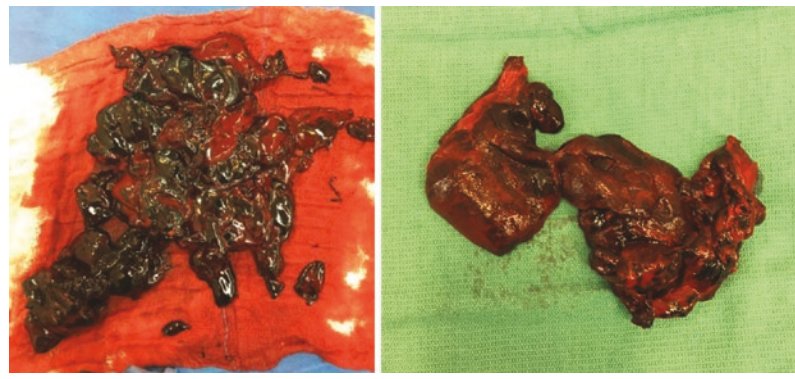

Fig. 6.11 Complete evacuation of hematoma during exploratory surgery in OR

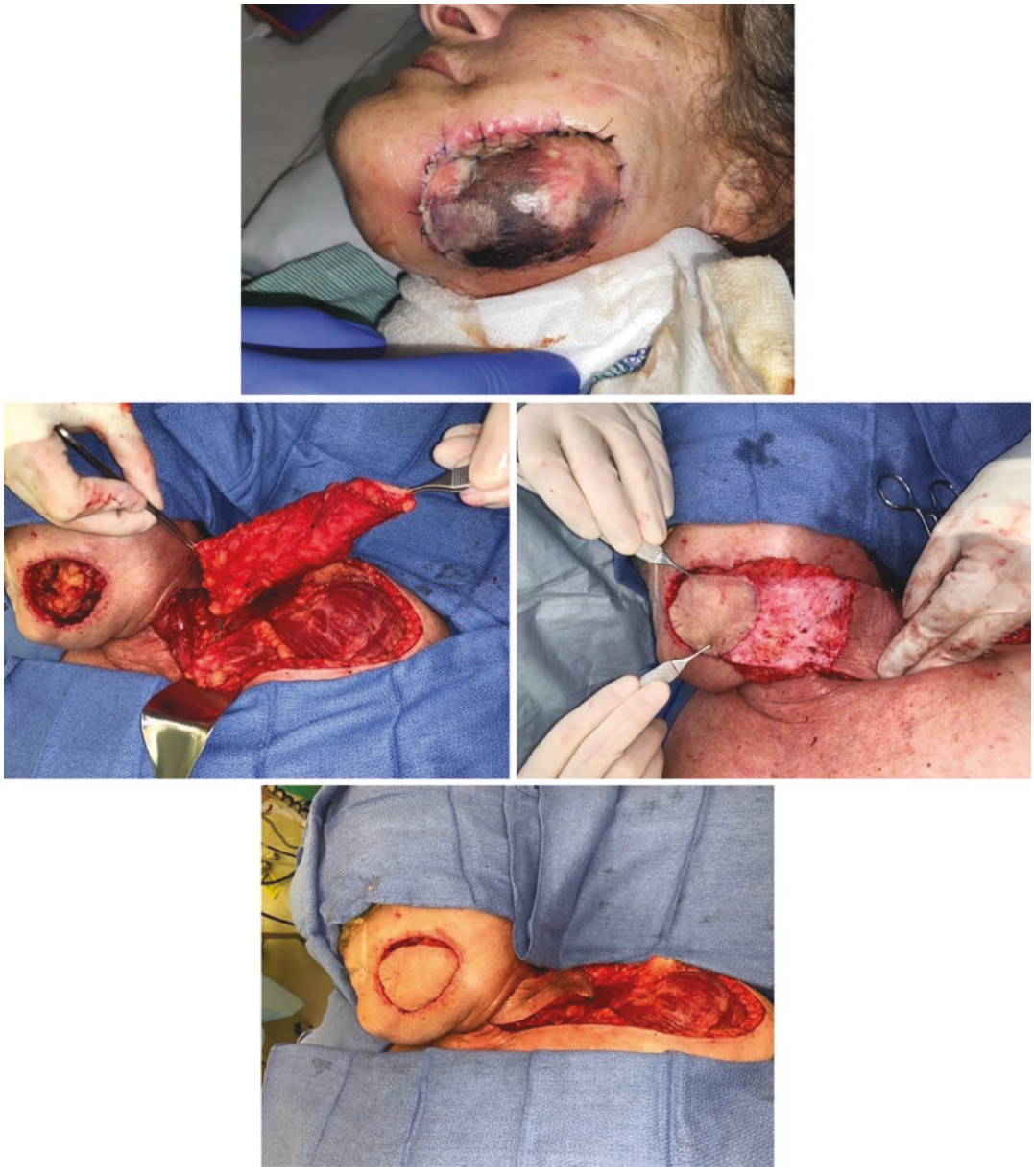

Fig. 6.12 Unsalvageable necrotic free flap with removal of flap, and salvage supraclavicular flap performed for cheek reconstruction

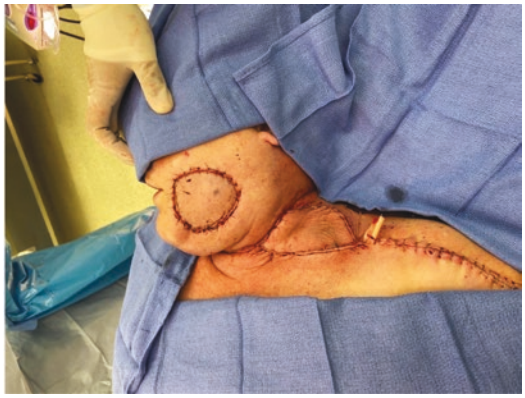

Fig. 6.12 (continued)

additional morbidity, as well as the timing of radiation, if applicable, as a delay in this treatment modality is not favorable. The decision of what type of secondary reconstruction should be done at this time depends on several factors, including the type and location of the original defect, number and amount of available tissues or flap options, and patient comorbidities and stability. The simplest reconstruction should be undertaken, one that has the highest chance of success and the minimum amount of additional patient morbidity. For example, in the case of maxillomandibular reconstruction with a free osteocutaneous fibula flap, in the event of fibula flap failure, the ideal salvage flap would be a second free fibula flap, as that has the highest chance of meeting the reconstructive requirements. However, if a second fibula flap cannot be harvested due to anatomic restrictions (lack of adequate three-vessel runoff), or due to the patient's fragility or inability to tolerate a second lengthy procedure, one should consider a soft tissue flap such as an anterolateral thigh flap or radial forearm free flap to obtain wound coverage, which would provide a shorter procedure and thus less morbidity for the patient. If the patient will be obtaining dental implants, secondary bone grafting can be considered at a later stage. Another option in this case can be a pedicled flap, such as a pectoralis myocutaneous flap if the surgeon chooses to avoid another free flap procedure because of a vessel-depleted neck, patient stability issues, diagnosis of thrombophilic disorder, severe infection, etc. Salvage reconstruction often presents a challenge as it occurs in a previously operated wound bed, often contaminated or infected, and the ideal flap has already been utilized. As such, success rates in the salvage setting often drop as compared to the primary reconstruction setting. Bozikov and Arnez found that flap failures in the salvage operation were 4.6× more likely, with a success rate of only 53.3% [116]. Salvage reconstruction can be done either in the immediate setting or in a delayed fashion, depending on these factors, though most surgeons will opt to perform it immediately. In the head and neck, this presents a particular challenge as specific issues come into consideration, such as dealing with vessel-depleted necks, salivary contamination/leak if a composite defect of the oral cavity is involved, patients having a history of prior radiation, patients with head and neck cancer who are often malnourished with poor wound healing, and need for coverage of the great vessels, among others [117]. In cases of limited availability of adequate vessels for anastomosis, due to radiation damage or depletion from previous free flap surgery, surgeons can consider options such as vein grafting; use of the internal mammary, thoracoacromial vessels, or transverse cervical vessels; and use of the contralateral neck vessels, or end-to-side anastomoses, in particular with the internal jugular vein, as this provides reliable drainage, good caliber, and consistent anatomy [118–121]. Though surgeons often desire to provide patients with the best reconstructive option possible, one must also consider that sometimes the best reconstruction … is *no* reconstruction. The use of synthetic prostheses, when available, often can represent excellent alternatives as prosthetic reconstruction, for patients in whom surgical reconstruction is not an option. A wide variety of options exist for orbital, nasal, maxillary, and auricular reconstruction, with or without implants for support and retention [122].

Conclusion

Free flap reconstruction of the head and neck represents a complex surgical endeavor and can be wrought with complications at any stage of patient care. Surgeons must be mindful and must employ careful patient selection and workup, as well as demonstrate excellent surgical technique, and patients should be carefully and constantly monitored in the immediate postoperative period to help mitigate, and ideally avoid, these complications. Surgeons must be adept at recognizing issues early that could potentially compromise flap viability and be prepared to perform additional salvage procedures to maximize success rates.

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Part III

Post-operative Considerations

Surgical Site Dressing

7

Dina Amin and Waleed Zaid

Head and neck cancer patients who require free flap reconstruction often have advanced disease that includes recommendations for concurrent adjuvant radiation and chemotherapy. Initiation of adjuvant therapy is recommended between 4 and 6 weeks postoperatively [1]. Decrease in the rate of overall survival was noted if adjuvant radiation therapy is started >6 weeks post-op [1]. Donor sites reconstructed with skin grafts as well as skin graft donor sites are considered to have high rates of healing complications, which may preclude timely initiation of adjuvant therapy [2]. Proper surgical dressing and wound management therefore play an integral role in facilitating the overall successful management of the head and neck cancer patients.

Majority of microvascular free flap harvesting techniques are standardized. However, donor-site defect reconstruction and management are controversial. Additionally, there is no consensus on surgical site dressing among the head and neck and reconstructive surgeons. Nonetheless, every reconstructive surgeon has encountered a failing skin graft or a nonhealing skin graft donor site. This chapter discusses the latest available evidence-based recommendations as well as authors' suggestions for recipient and donor surgical site dressings, with special attention to the skin graft donor sites and skin graft healing at the fibula and radial forearm flap donor sites.

Head and Neck (Recipient) Surgical Site

The cervical surgical site traditionally is closed primarily in a layered fashion with platysma reapproximation over closed suction or open drains. Although some concern for closed suction drain causing disruption to the newly sutured anastomoses exists among surgeons, a study by Madgar et al. demonstrated no significant differences in complication rates between the two suction systems [3]. Moreover, there was a tendency for lower infection rates with closed suctions; therefore, the authors advocated for its use [3]. Primarily closed incisions are typically managed with an antibiotic ointment application immediately post-op and then 3–4 times per day in a thin layer. No pressure dressings can be applied to the neck after microvascular anastomosis. Vascular compression is cited as one of the most common

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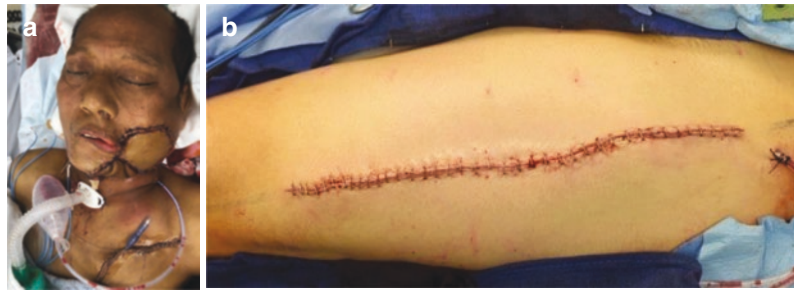

Fig. 7.1 Surgical site dressing for head and neck incisions is an antibiotic-based ointment. Notice that the tracheostomy tube is secured with four 2-0 nylon sutures (yellow arrows) to avoid compression to microvascular anastomosis site and free flap vascular pedicle with tracheostomy strap (**a**). Surgical site dressing for all donor-site incisions is an antibiotic-based ointment (anterolateral thigh flap, **b**), covered with 4 × 4 gauze and *Kerlix*™ gauze (**b**)

reasons for acute flap failure [4]. It is imperative to avoid coverage of neck incisions and avoid tracheostomy tube strap and/or any type of tape around or on the neck to avoid possible compression on the microvascular anastomosis site and free flap vascular pedicle (Fig. 7.1).

Skin Graft Donor-Site Dressing

Split-thickness skin grafts (STSGs) are commonly used to reconstruct the free flap donor sites. Donor-site re-epithelization is reported to usually occur within 2 weeks [5]. However, a recent systematic review highlighted the heterogeneity in definitions of re-epithelization and reported a range of 4.7–35 days to complete re-epithelization [6]. The frequently cited donor-site morbidity is pain, infection, and suboptimal esthetic outcomes due to hypertrophic scarring and pigmentation changes [6].

The ideal dressing should help quicken re-epithelialization without infection, inhibit leakage, and control the pain. It is recommended to use dressing that provides a moist environment [7, 8]. A myriad of dressings are commercially available and can be broadly divided into the following categories:

- Non-adherent dressings, such as ADAPTIC® and Xeroform™, are nonstick and minimize trauma during dressing changes. They also provide a barrier against external contaminants.
- Hydrocolloid dressings: Hydrocolloid dressings, such as Duoderm® and Comfeel®, are occlusive dressings that create a moist environment and promote autolytic debridement. They are suitable for low to moderately exuding wounds and adhere well to intact skin, providing a barrier against bacteria and other contaminants.
- Alginate dressings, such as Algisite® and Sorbsan®, are derived from seaweed and can absorb large amounts of exudate. They form a gel-like consistency when in contact with wound fluid, promoting a moist environment. Alginate dressings are typically used in heavily exuding wounds.
- Foam dressings, such as Allevyn® and Mepilex®, can be used for moderate to heavily exuding wounds. They are absorbent and provide a moist wound environment that supports healing. Foam dressings also offer cushioning and protect the wound from mechanical trauma.
- Transparent film dressings, such as Tegaderm™ and Opsite™, are thin, transparent sheets that adhere to the skin surrounding the wound. They provide a barrier against bacteria and other contaminants while allowing visualization of the wound. Transparent films are generally used for low-exuding wounds over another dressing. Direct contact with the wound is not recommended.

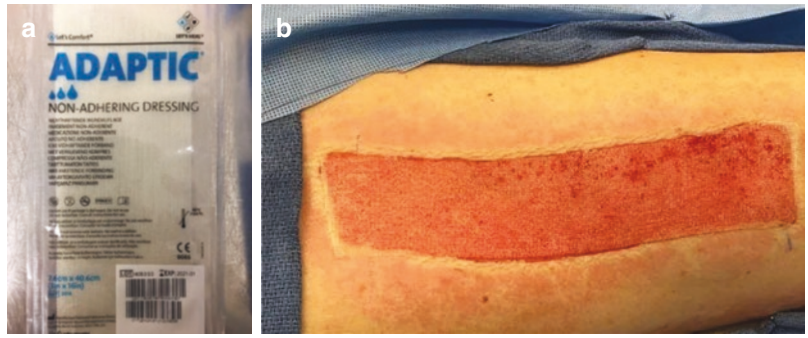

Fig. 7.2 STSG donor-site dressing with epinephrine-soaked ADAPTIC (**a**) that is trimmed to fit the STSG donor-site dimension (**b**)

A randomized controlled trial found no association between dressing type (hydrofiber, porcine xenograft, and polyurethane foam) and degree of hypertrophic scarring, although they demonstrated shorter healing times with hydrofiber and porcine xenograft dressings [9]. Another prospective trial compared Aquacel Ag hydrofiber with silver alginate and noted lower pain scores and a slightly quicker re-epithelization with silver alginate with no other statistically significant differences in outcomes [10]. Investigation of natural wound dressing, such as honey, aloe vera, and peppermint ointment as compared to petroleum jelly, also did not demonstrate any significant difference in the time of healing and overall outcomes. Other studies also compared various commercially available dressings; however, no definitive evidence-based conclusions can be drawn regarding the optimal dressing type [7]. One study reported the use of platelet-rich plasma gel and noted no significant impact on the rate of healing; however, significant improvement in pain scores was noted [11]. It is important to keep in mind that wound healing requires a suitable environment to be successful. Initial maintenance of adequate level of moisture allows for cell migration; however, as the wound re-epithelizes, the degree of moisture must be reduced to prevent the newly epithelized islands of skin from breakdown and the process restarting again.

There are different dressing recommendations for STSG donor site. The authors use ADAPTIC™ dressing (3M, Saint Paul, MN) after soaking it in epinephrine (Pfizer, New York City, NY) for 3–5 min. After harvesting the STSG, the wound is covered with epinephrine-soaked ADAPTIC (Fig. 7.2). Some surgeons prefer to cover the ADAPTIC with Tegaderm™ (Minnesota Mining and Manufacturing Company, 3M™, Saint Paul, MN) and ACE ® elastic bandage (3M, Saint Paul, MN). Typically, ADAPTIC peels off as the wound heals underneath it, and patients are instructed to trim it as indicated.

The editor utilizes a similar technique with a slight modification. A lidocaine with epinephrine-soaked ADAPTIC dressing is applied, excess fluid is dabbed off with gauze, and covered with Ioban™ (3M, Saint Paul, MN) with a wide margin. Then the leg is wrapped with ACE ® elastic bandage to prevent fluid accumulation under the dressing. If blood or exudate is accumulated in the immediate postoperative period, it can be aspirated with a large-caliber blunt needle, and dressing is left intact for 7 or more days and is changed prior to patient discharge from the hospital. Prior to discharge, Ioban and ADAPTIC are removed, the surgical site is gently rinsed with sterile normal saline and patted dry, and a single sheet of Xeroform™ is applied and covered by 4 × 4 gauze and secured with tape or *Kerlix*™. No occlusive dressing is recommended after 7 days as it can promote excessive exudate and secondary skin breakdown. The patient is then educated on trimming the edges of the dressing as it passively peels off from the areas of newly epithelized skin. This method was found to allow for uneventful low-maintenance healing with the ability to completely remove the Xeroform™ within 2–3 weeks (Fig. 7.3). The patient is then advised to apply a thin layer of

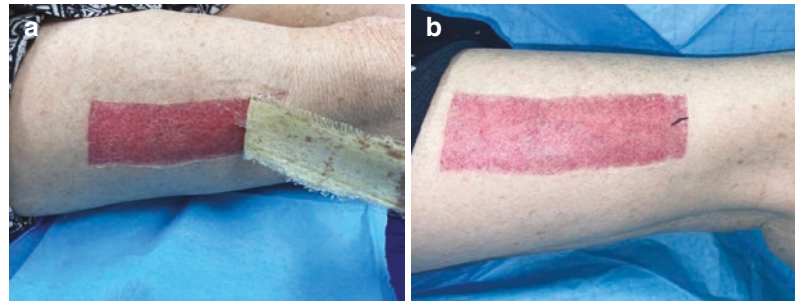

Fig. 7.3 (**a**) Right-thigh STSG donor site, 3 weeks post-op. (**b**) Right-thigh STSG donor site, 4 weeks post-op

topical antibiotic ointment or petroleum jelly to moisturize the site 2–3 times per day, and no other dressing is necessary unless the site is irritated by clothes.

Free Flap Donor-Site Dressing

In general, surgical site dressings for all donor-site incisions closed in the typical fashion are antibiotic-based ointments (i.e., Bacitracin, Xellia Pharmaceuticals, Copenhagen, Denmark), covered with 4 × 4 gauze and *Kerlix*™ gauze (Covidien, Dublin, Ireland).

The editor found that closing donor site in a layered fashion with 3-0 Vicryl® and 3-0 subcuticular Monocryl® suture, followed by Dermabond® and Telfa™ application, results in unproblematic healing and eliminates the need for suture removal at follow-up visits.

When the donor-site defect is reconstructed with STSG, it introduces the risk for complications, including delayed healing for greater than 6 weeks [12]. Multiple studies evaluating the role of vacuum-assisted closure (VAC) were carried out, and despite some reports of improved hand function and earlier mobilization, other studies failed to demonstrate any significant advantage to wound VAC use for fibula and radial forearm donor sites reconstructed with skin grafts [13–17]. Improved rate of skin graft take was observed by Straub et al. when platelet-rich fibrin was used as an interpositional membrane between the wound bed and the graft [2]. Additionally, use of dermal substitute matrices was also associated with reduced rates of healing complications and improved graft survival [18–20]. The most common method of dressing the grafted sites remains to be the application of a bolster dressing and a restrictive splint for both RFFF and FFF donor sites.

The authors' method includes STSG that is sutured in place with 3-0 chromic suture. Based on the surgeon preference, STSG can be left intact or meshed, or one can make small slits in harvested STSG with a scalpel (pie crusting) to increase covered surface area and prevent hematoma formation under STSG (Fig. 7.4).

Surgical site dressing then should provide uniform pressure over the STSG. The ideal dressing material should be non-adherent, semi-occlusive, and absorbent. The aim of the dressing is to immobilize, prevent shearing of skin graft, and prevent hematoma formation beneath skin graft. Tie-over bolster dressing is a common dressing choice over STSG. Tie-over bolster dressing should be kept up to 10–14 days. Alternatively, vacuum-assisted closure (VAC) can be used as short-term dressing over skin graft (Fig. 7.5). VAC should be kept for up to 10 days; after 10 days, skin graft dressing is 4 × 4 gauze, *Kerlix*™ gauze, and ACE ® elastic bandage.

The editor again has a similar technique with a few modifications. A bolster dressing is prepared by wrapping sterile 4 × 4 gauze or cotton balls in Xeroform™, which then is applied to the entire surface of the pie-crusted skin graft and secured to skin with 2-0 sutures in a crossover fashion. The leg is then wrapped in *Kerlix*™

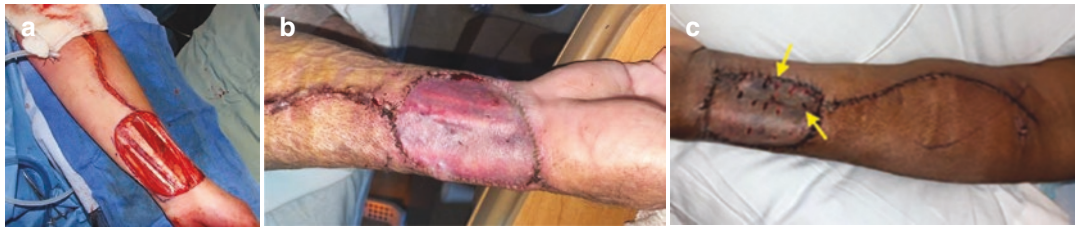

Fig. 7.4 Radial forearm free flap (RFFF) donor-site defect reconstruction can be achieved with STSG, dermal substitute, or local flap (**a**). STSG is the most common approach for RFFF donor-site defect reconstruction, STSG can be sutured in place and left intact [result in the best cosmetic outcome] (**b**) or meshed, or one would make small slits in harvested STSG with a scalpel (pie crusting, yellow arrows) to increase covered surface area and prevent hematoma formation under STSG (**c**)

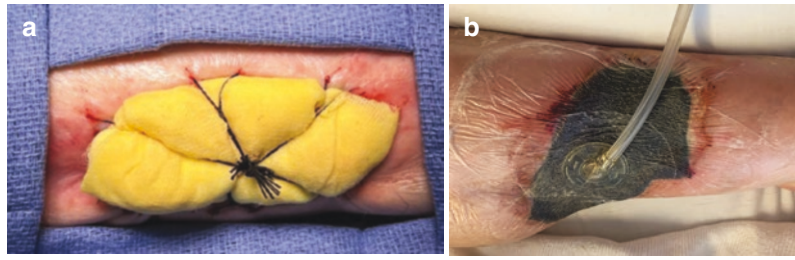

Fig. 7.5 Tie-over bolster dressing (**a**) is secured over STSG. Tie-over bolster dressing technique is by placing 3-0 silk sutures around the periphery of the skin graft, which are then tied over a bolster made up of xeroform gauze (DermaRite, North Bergen, NJ) and sterile cotton balls. The bolster dressing is left for 10–14 days. Alternatively, vacuum-assisted closure (VAC) can be used over STSG (**b**) for 10 days; after 10 days, skin graft dressing is 4 × 4 gauze, *Kerlix*™ gauze, and ACE ® elastic bandage

gauze and ACE ® elastic bandage. The lower extremity is placed into the CAM boot to provide immediate post-op comfort. The dressing is changed prior to patient discharge, which usually is between postoperative days 7 and 10. A small amount of saline may be required to moisten the bolster and allow for it to be removed without the risk of peeling off the skin graft. A study by David et al. noted a better skin graft uptake when the bolster dressing was removed 14 days post-op versus 5 days post-op [21]. After the bolster dressing is removed, a Xeroform™ dressing covered by 4 × 4 gauze is secured with *Kerlix*™ gauze and ACE ® elastic bandage. The patient is advised to change the dressing every 2–3 days until follow-up appointment. Adequate epithelization is usually noted 2–4 weeks post-op, and the patient is then advised to use a thin layer of antibiotic ointment and cover the site with simple 4 × 4 gauze to avoid irritation from clothes or accidental injury (Fig. 7.6).

Suction drain is required in most free flaps. For radial forearm free flap (RFFF), if the arm is decompressed, suction drain is not required. However, it is necessary when the arm is closed with local flap. Suction drain is sutured with 2-0 nylon. Drains are kept for 72 h or until the output is below 25 cc.

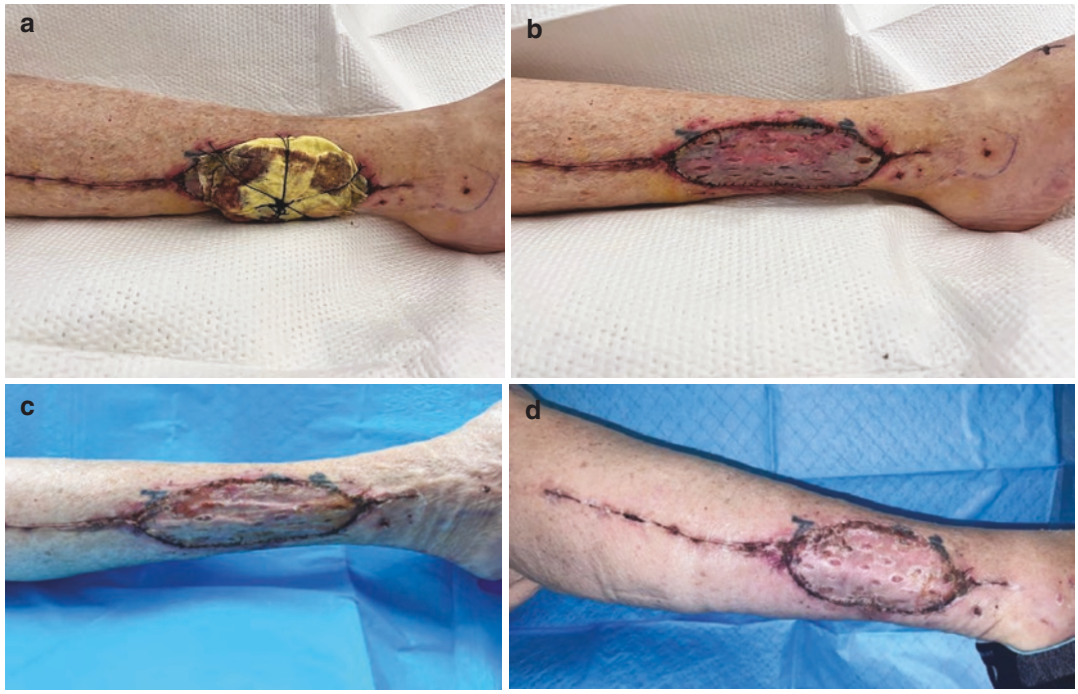

Fig. 7.6 (**a**) Bolster dressing prior to removal on post-op day 10. (**b**) Split-thickness skin graft appearance on post-op day 10. (**c**) Split-thickness skin graft appearance on post-op day 15. (**d**) Split-thickness skin graft appearance on post-op day 22

Radial Forearm Free Flap

In general, RFFF donor-site defect reconstruction can be achieved with STSG, dermal substitute, or local flap such as local skin flap (based on ulnar artery) or V–Y advancement flap. If the arm is decompressed, no drain is required. However, when donor-site defect is closed with a local flap such as local skin flap or V–Y advancement flap, suction drain is necessary, and the wound bandaged as before.

For optimum outcome, the wrist should be held in dorsiflexion position. This is achieved with a splint (Fig. 7.7). The splint will ensure [1] minimal contracture of underlying tendon, [2] it will provide uniform firm pressure overlying STSG, [3] it is held sufficiently rigidly to prevent movement of the wrist, and [4] when RFFF is closed with V–Y advancement flap, the splint is placed to avoid tension on the distal suture line. At 5–7 days, the wounds can be inspected, and the wrist extended gradually to a neutral position. The hand should be monitored for sign and symptoms of compartment syndrome.

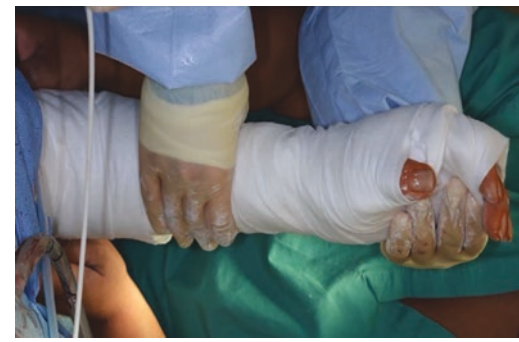

Fig. 7.7 Volar slab splint is used to hold the wrist in dorsiflexion position. The splint is kept for 5–7 days, or until complete healing of STSG

The splint is constructed from volar slab constructed from plaster of Paris. The splint is kept for 5–7 days, or until complete healing of STSG.

The editor found that the use of commercially available soft orthopedic volar splint allows for adequate surgical site stabilization, reduces the time in the operating room, and in editor's experience does not impact STSG healing. The splint is removed prior to the patient being discharged, with only ACE ® elastic bandage left to maintain stability of the surgical site.

Osteocutaneous Radial Forearm Free Flap

It is important to immobilize the arm to avoid radius fracture. The role of prophylactic plating of the radius has been established and is routinely recommended [22–24]. If no internal fixation was done, the arm should be placed in above-elbow plaster cast to prevent flexion, extension, supination, and pronation. The cast should be kept for 6 weeks. At 3 weeks, the arm should be X-rayed, and the cast is reduced to a below-elbow cast for a further 3-week period. Depending on donor-site defect reconstruction, the dressing is the same as for RFFF.

Osteocutaneous Free Fibula Flap

Osteocutaneous free fibula flap (OFFF) donor-site defect reconstruction can be achieved with STSG or dermal substitute or closed primarily (Fig. 7.8).

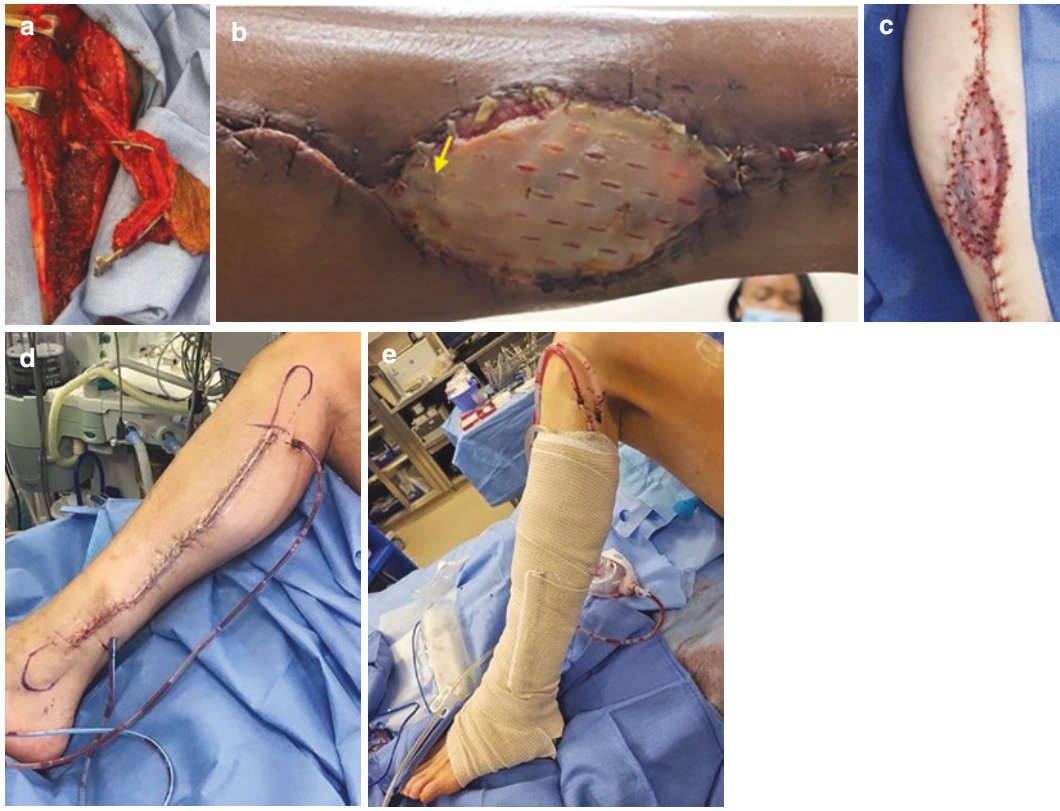

Fig. 7.8 Osteocutaneous free fibula flap (OFFF) (**a**) donor-site defect reconstruction can be achieved with FTSG, STSG, or dermal substitute or closed primarily. STSG is the most common approach for RFFF donor-site defect reconstruction; the STSG can be meshed, or one can create small slits in the harvested skin graft with scalpel (pie crusting, yellow arrow) to increase the surface area and allow blood drainage (**b**). OFFF donor-site defect that was reconstructed with ACell [dermal substitute] (**c**). OFFF donor-site defect that was closed primarily (**d**). OFFF donor-site dressing with 4 × 4 gauze, Kerlix™ gauze, and ACE ® elastic bandage (**e**)

When the width of OFFF donor-site defects is less than 6 cm, donor site can be closed primarily. The foot should be monitored for sign and symptoms of compartment syndrome, and the wound bandaged as mentioned before.

For optimum outcome, leg and foot should be immobilized for up to 2 weeks, or until STSG heals. This immobilization is achieved with a posterior splint or orthopedic walking boot.

OFFF donor-site defects can be reconstructed with dermal substitute with or without STSG. Examples of dermal substitute are Integra® (Integra LifeSciences, Plainsboro, NJ), AlloDerm™ (Regenerative Tissue Matrix™, LifeCell, Branchburg, NJ), and ACell (Integra LifeSciences, Plainsboro, NJ). The wound dressing consists of three layers: non-adherent Telfa (Medtronic, Dublin, Ireland), abdominal dressing (ABD, Medline Industries, Northfield, IL), and Kerlix™ Bandage Rolls secured with hypoallergic skin tape (Nexcare™ Sensitive *Skin Tape, 3M,* Saint Paul, MN). This dressing helps to maintain close approximation of UBM-S to the wound. Dressing changes occur every 2 days. Dressing should be continued until complete healing, which is defined as complete coverage of wound defect with skin.

The editor practices early mobilization with ambulation as tolerated starting on postoperative days 5–7 for fibula donor sites reconstructed with a skin graft. The patient is advised to abandon the CAM boot on discharge from the hospital unless it provides them with the comfort they require.

Osteomyocutaneous Scapula Free Flap

It is recommended to immobilize the shoulder in myocutaneous or osteomyocutaneous scapula free flaps with or without division of the accessory nerve. Shoulder should be immobilized with the arm in an adducted position for 2 or 3 weeks to avoid wound healing complication. A Velcro shoulder immobilizer can used. The immobilizer secures the forearm to the abdomen. It is important to avoid straps around the neck.

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8 Level of Care Required for Postoperative Free Tissue Transfer

Samuel J. Rubin, Ryan H. Sobel, and Heather A. Edwards

Introduction

Head and neck cancer is the sixth most common cancer worldwide and accounts for about 4% of all cancers in the United States [1]. In the year 2021, an estimated 66,630 people developed head and neck cancer [2]. Many of these patients received primary surgical management, which has led to fiscal strain on the healthcare system [3, 4]. Wissinger et al. conducted a review, including 77 studies, and determined that the estimated direct cost for the management of head and neck cancer patients was $3.64 billion in 2010, and the value of lost productivity for people with head and neck cancer in 2010 was $3.4 billion [5]. Kim et al. evaluated 11,403 patients with head and neck cancer who were followed for up to 5 years after primary treatment. It was determined that 94.7% of total costs can be attributed to inpatient care and 11.4% of costs can be attributed to reconstructive surgery [1]. Furthermore, free flap reconstruction and tracheostomy are significant determinants of charges and length of stay in head and neck surgery cases [6]. Gao and colleagues used a cost-effectiveness analysis to determine that free flap reconstruction was more costly than pedicled flap but was associated with improved quality of life, especially for early-stage cancers [7].

Free tissue transfer involves the anastomosis between donor and recipient vessels. The resulting blood flow to and from the free flap is dependent on the vascular pedicle and adequate blood supply through the arterial and venous anastomosis. Most microvascular surgeons would agree that the risk of flap compromise is highest within the first 72 h after surgery requiring close postoperative monitoring [8, 9]. Flap compromise can be categorized as arterial insufficiency, venous compromise, or hematoma [10]. Of these types of flap compromise, the most common cause is venous compromise [9, 11].

Although the success rate for free flap surgery has been reported as high as 95–98% in experienced hands [12–14], postoperative management for these patients is very costly. Patients receiving free flap reconstruction require close monitoring in the first 24–72 h after surgery. This includes frequent (often hourly) flap checks to be able to detect any arterial or venous compromise as early as possible to allow for expeditious cor-

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rective intervention. Close monitoring of vital signs, appropriate pain control, and nutritional assessments are also indicated.

Due to this need for close monitoring, these patients were historically monitored in intensive care units (ICUs) after surgery. However, in an era of value-based healthcare and cost savings, many microvascular programs now transfer free flap patients to specialty care units with nurses specifically trained in free flap care, rather than an ICU. This chapter reviews current practices and factors influencing postoperative disposition after head and neck free flap surgery; indications for ICU level of care based on surgeon surveys; and level of nursing care needed to manage free flaps on specialty head and neck units.

Indications for ICU Level of Care

There are multiple indications for postoperative admission after free flap surgery to the ICU (Table 8.1). Historically, patients receiving free flap surgery would stay intubated for 24 h or more after surgery to limit movement and protect the vascular pedicle [15]. However, recent studies have demonstrated the benefit of immediate extubation in the operating room (OR). Clemens et al. reviewed 75 patients who underwent a rapid awakening protocol (RAP) after surgery and were subsequently managed on a floor unit, compared to 605 patients who remained on mechanical ventilation and were cared for in the ICU. They demonstrated that overall complications were significantly higher in those patients in the mechanical ventilation cohort compared to the RAP cohort (61% vs. 31%, respectively; $p < 0.001$). Furthermore, overall length of hospital stay was significantly shorter in the RAP group compared to the mechanical ventilation group (5.96 ± 1.8 vs. 9.56 ± 7.5 days; $p < 0.001$). In another study, 50 patients remained intubated and sedated in the ICU for 24 h after free flap surgery, while the other cohort of 50 patients were transferred to the recovery room and extubated when they met extubation criteria. There was no significant difference in complication rates or flap compromise between these two groups. Similarly, Allak et al. conducted a study comparing immediate postoperative extubation in the OR compared to delayed extubation in the ICU and demonstrated that ICU stay was significantly shorter in the immediate extubation group, use of treatment for agitation and restraints was significantly greater in the ICU extubation group, and delayed extubation group had a significantly higher rate of pneumonia (PNA) (15% vs. 0% $p = 0.05$) [15]. Overall, these studies have shown significant benefit to immediate extubation compared with delayed intubation protocols [16]. While we recommend routine postoperative extubation in the operating room for flap patients, ongoing communication and collaboration are necessary between the surgical and anesthesiology teams to identify any exceptional circumstances in which patients would require ventilatory support. This should be limited to exceptional circumstances, such as when patients have significant medical complications resulting in cardiopulmonary compromise or neurologic deficits preventing extubation in the operating room, and should not be a routine part of free flap care.

Head and neck cancer patients commonly have significant histories of tobacco use and alcohol abuse that can adversely affect their baseline health and result in significant chronic cardiopulmonary sequelae. Additionally, prolonged dysphagia and nutritional dysfunction from tumor burden can lead to poor nutritional status, muscle wasting, and cachexia, all of which are factors predisposing to wound-healing deficiencies. Major medical comorbidities such as major cardiac complications or refeed-

Table 8.1 Indications for admission to ICU after free flap surgery

• Significant medical comorbidities (i.e., recent MI or stroke, cachexia, current alcohol abuse)
• Frequency of vascular/respiratory checks (i.e., hourly) that cannot be accommodated in another unit
• Pulmonary, cardiac, hemodynamic, or other major organ system failures
• Placement of new tracheostomy
• Ventilator support is required after surgery
• Lack of appropriately trained nurses on other units in the hospital

ing syndrome are a possible indication for ICU admission. Jones et al. demonstrated that postoperative medical complications, not microsurgical complications, negatively impact the morbidity, mortality, and true cost after microsurgical reconstruction [14]. In this study (n = 100), they demonstrated a flap success rate of 99%, with 6% of patients requiring return to the OR for re-exploration. 5% of patients experienced "life-threatening" major medical complications, and 37% of patients experienced "minor" medical complications primarily caused by pulmonary problems and alcohol withdrawal. Postsurgical medical complications increased the average hospital stay from 13.5 to 24 days. Additionally, 36% of true cost of microsurgical reconstruction was due to ICU cost and hospital room cost, and 24% was due to OR cost. Postsurgical complications resulted in a 70.7% increase in true cost, reflecting prolonged ICU stay. Patients with major medical comorbidities may benefit from close monitoring in an ICU setting. For example, those patients with pulmonary, cardiac, or other major organ system failures at the time of surgery may benefit from postoperative ICU admission due to the ability of having a critical care physician provide additional consultation for management of these complex patients and having the ability to provide closer nursing care. These medically complex patients often also require invasive cardiovascular monitoring including monitoring of arterial pressures with an arterial line or monitoring of central venous pressures, which can sometimes only be monitored in an ICU setting depending on individual hospital resources. However, some hospital systems may be able to care for these more critically ill patients on an intermediate care unit or head and neck specialty unit.

ICUs can be divided into two main groups: *high-intensity*, closed ICU, staffing models in which intensivists manage care for all patients, and *low-intensity*, open ICU, staffing models in which intensivists care for some or none of the ICU patients. Multiple studies have demonstrated the benefit of use of intensivists, including lower hospital mortality and reduced hospital length of stay [17]. However, Bhama et al. compared free flap patients who were either cared for in a closed ICU and those patients cared for in an open ICU and demonstrated no significant difference in ICU length of stay or incidence of medical or surgical complications [18]. In institutions employing a closed ICU, medical intensivist comfort with expected postoperative changes is critical. Management of postsurgical fluid shifts, flap monitoring, and early mobilization and nutritional requirements are essential, and a high level of surgeon involvement in the care of these patients remains critical. A thorough understanding of the resources and provider comfort levels within each institution is essential to obtain optimal outcomes in these complex patients.

Surgeon Surveys: Free Flap Management

Multiple surveys in both the head and neck cancer and the general plastic surgery microvascular literature have evaluated surgeon preference for postoperative management of free flap patients. One of the earlier surveys in this regard was published by Spiegel et al. in 2007, who surveyed all academic otolaryngology-head and neck surgery departments. The overall response rate was 41%, and the average number of free tissue transfers per year was 48.7. The self-reported success rate was 96.4% with an average of 6.88% rate of return to the operating room. Postoperatively, 88.9% of patients were immediately transferred to the ICU for an average of 2.44 days [12]. Another large 2019 study was based on a survey distributed to the Accreditation Council for Graduate Medical Education-accredited otolaryngology residency programs and the American Head and Neck Society fellowship sites. In this study, the average number of free flaps performed annually by each institution was 83. They reported that 75.2% of respondents routinely transferred patients to the ICU, 15.0% of respondents transferred patients to a step-down unit, and 8.1% of respondents transferred patients to the general floor. Average length of stay in the ICU was 2.4 days. The overall flap success rate

was 95.7%, and 6.8% required a return to the operating room [13].

Although there have been surveys evaluating postoperative management strategies for free flaps within the American Head and Neck Society, and Otolaryngology-Head and Neck Surgery residency programs within the United States, there are also surveys which have included general plastic surgeons performing microvascular surgery and multiple survey studies based in the United Kingdom. Haddock et al. distributed a survey to all plastic surgery and plastic surgery-based microsurgery directors in the United States regarding free flap management, which is not specific to head and neck reconstruction [19]. They received a 31% response rate to the survey and included a total of 3407 microvascular free flaps at 26 different centers per year. 78.2% of free flaps were initially sent to a highly monitored setting [recovery room (47.8%) and ICU (30.4%)]. The average length of stay in the ICU was 3.1 days, and 45% of responding centers attributed the need for postoperative ICU care to the lack of adequately trained nursing staff in alternative locations in the hospital. Furthermore, they estimated that ICU stay is associated with an increased cost of $2878–$3345 per day or an increased annual cost of $13.7–$15.9 million to the responding centers compared to specialty care units outside of an ICU setting. The authors noted that head and neck free flaps were more likely to stay in the ICU for a longer period of time compared to other types of free flaps.

Marsh et al. distributed a survey to members of the British Association of Oral-Maxillofacial Surgeons, which included a total of 57 units performing free flap surgery, and determined that 54.38% (n = 31) of surgeons sent patients to the ICU for at least the first postoperative night while 33.33% (n = 19) of patients recovered in high-dependency units, 7% recovered on a head and neck specialty unit, and 1.8% recovered on the general ward [20]. Furthermore, Murray et al. distributed a survey to the otolaryngologists, plastic surgeons, and oral-maxillofacial surgeons of the British Association of Head and Neck Oncologists. Within this survey study, oral-maxillofacial surgeons and plastic surgeons performed all microvascular reconstructive surgery, while otolaryngologists participated as the ablative surgeon. Oral-maxillofacial surgeons favored ICU for immediate postoperative care, while plastic surgeons favored high-dependency units (IMCU level of care) [21].

Comparison of ICU Versus Intermediate Care Unit/Specialty Head and Neck Units for Postoperative Monitoring

As the number of free flaps performed by many academic otolaryngology-head and neck departments has increased, there has been a shift from postoperative monitoring in the ICU to immediate postoperative management in a specialized head and neck unit or intermediate care unit (IMCU) level of care with specialized nursing (Table 8.2). Some initial studies looked at the management of complex head and neck cases, including multiple types of reconstruction, and not only focusing on patients receiving free flap surgery. This demonstrated the feasibility of head and neck surgery specialty units or caring for patients in the IMCU [22–25], rather than managing all these patients in the ICU. However, Cornejo et al. evaluated 179 free flaps in 170 patients (not all free flaps were used for a head and neck defect) and demonstrated a mean ICU length of stay of 5.8 ± 0.5 days. Thirty-seven flaps required reoperation, and 16 of these were for vascular compromise. The mean timing for vascular complications was 10.8 h versus 99.3 h for nonvascular compromise, and, therefore, 72 h of postoperative ICU monitoring was recommended [8].

Table 8.2 Requirements for specialty head and neck unit to monitor postoperative free flaps

• Adequate number of skilled nurses to be able to perform Q1 flap checks for 48–72 h
• 1:2 or 1:3 nurse-to-patient ratio
• Able to perform telemetry and monitor continuous pulse ox
• Nurses trained to perform flap checks including color, turgor, capillary refill, temperature, and Doppler signal

More recently, Patel et al. conducted a multicentered retrospective study including 9 academic medical centers and a total of 1085 free flaps. The majority of patients were initially cared for in the ICU (73%), while the remaining patients were cared for either in an IMCU (19%) or in general surgical ward (7%). Of the patients included in the study, a total of 96 (8.85%) required return to the operating room with 41 patients (4%) demonstrating total flap loss. There was no significant difference in flap outcomes based on postoperative care venue or frequency of resident flap checks [26]. Yu et al. conducted a study including 512 patients who underwent head and neck microvascular free flap reconstruction and were transferred to an IMCU with specializing nursing after surgery and determined that 3.5% of patients required subsequent transfer to the ICU, most commonly for respiratory distress, acute cardiac events, and severe infection. The most common complications noted in this population were agitation/delirium (10.7%) and pneumonia (10%). Heavy alcohol consumption and multiple comorbidities were significant predictors of ICU transfer, and the median timing for transfer from the IMCU to ICU was 5.5 days, and the majority of transfers occurred after 24 h. Additionally, patients that required transfer to the ICU were primarily for medical indications rather than surgical indications [27].

Multiple studies have compared outcomes in those patients undergoing free flap surgery that are transferred from the OR to a specialty head and neck unit/IMCU compared to a historical cohort of patients managed in the ICU. Arshad et al. compared 119 patients managed in the ICU postoperatively to 125 patients managed on a specialty head and neck unit. Patients that went to the ICU postoperatively had longer overall length of hospital stay (mean 10.28 vs. 9.89 days; $p = 0.008$) and incurred greater hospital costs. Furthermore, the ICU cohort had a significantly greater rate of pulmonary complications ($p = 0.002$). The patients managed in the ICU had an average length of ICU stay of 3.5 days [28]. Aponte-Ortiz et al. compared 82 free flap patients managed in the ICU after OR with 420 patients managed on the general surgical ward. In this study, surgeon and anesthesia team determined postoperative disposition based on overall clinical picture at the end of the case. Patients managed in the ICU had a 3.29-day increased length of hospital stay ($p < 0.0001$) and increased need for take-back surgery ($p = 0.02$). However, there was no significant difference in either early or late flap complications [29]. Panwar et al. compared flap outcomes in an ICU group ($n = 175$) and non-ICU/protocol group ($n = 72$) and demonstrated no difference in flap outcomes including flap survival rate or inpatient morbidity or mortality. ICU patients had a longer median overall hospital length of stay [8 days vs. 7 days ($p = 0.001$)], and median hospital charges and cost of care were significantly higher for those patients in the ICU cohort [charges = $109,367 vs. $86,195] [cost of care = $33,642 vs. $28,524] ($p < 0.0001$) [30].

Moreno et al. developed a clinical pathway for abbreviated postoperative hospital stay in patients receiving free tissue transfer to the head and neck. The patients transferred to a specialty head and neck unit after surgery, rather than the ICU, experienced significantly fewer medical complications (21.1% vs. 4.1%), overall hospital length of stay (10.5 days vs. 6.2 days), standardized total charges ($88,270 vs. $58661), and hospital costs ($41,365 vs. $22.680) compared to the ICU group. There were no observed differences in flap viability, surgical complications, reoperations, or readmissions [31]. Morse et al. conducted a similar study comparing outcomes between those patients transferred to the ICU after surgery and those patients on a free flap surgical pathway with transfer to a head and neck specialty unit; however, they compared a pre-pathway group to early pathway and late pathway groups. Adoption of the clinical pathway resulted in significant decrease in the median length of overall hospital stay (10 days to 7.5–7 days $p = 0.012$), 30-day readmission rates decreased from 16% in the pre-pathway groups to 0% and 3% in the early and late pathway groups, but the rates of medical and surgical complications in all three groups were equivalent [32].

Yalamanchi et al. conducted a study in which one group of patients recovered in a protocolized

non-ICU setting at an academic medical center while the other group recovered in the ICU at a community hospital. They demonstrated no significant difference in the total length of hospital stay between groups and no difference in terms of free flap survival, reoperation, readmission, or postoperative complications. However, patients in the ICU group had significantly higher overall costs ($47,315.44 vs. $38,853.50, $p < 0.0001$), including 239% higher for room and board ($p < 0.0001$) [33].

Although surveys continue to demonstrate that the majority of patients undergoing head and neck free flaps in the United States are initially cared for in an ICU, multiple studies have demonstrated that caring for most patients receiving free flap surgery for a head and neck defect in a non-ICU specialized head and neck unit is both safe and cost effective and often results in decreased length of stay. It is important to note that specialized head and neck units require that nursing staff is adequately trained to evaluate the flap and monitor these patients. Institutions therefore need to evaluate the cost:benefit ratio of providing training to non-ICU nursing staff and determine whether adequate care can be provided in a non-ICU setting. This may depend on flap volumes at the individual institution and the availability of a consistent nursing staff. Providing additional in-services and educational opportunities to nurses and mid-level providers, as well as bedside nursing education, can help to bridge the knowledge gap. Finally, patient education and clear information regarding the expected postoperative course and functional changes are essential in promoting patient independence and self-care.

Although Kovatch et al. demonstrated that 8.1% of surgeons that responded to the survey will recover patients in the general surgical ward [13], there is limited data regarding flap protocols for these units and comparison of outcomes between specialty head and neck units and general surgical IMCU or general surgical ward. In institutions where an adequate level of nursing care and monitoring is not available outside of the ICU, an ICU level of care may be provided for 48–72 h after surgery. However, it is important to emphasize early mobilization and patient participation in care in order to decrease the risk of medical complications, such as pneumonia, and minimize the possible increases in length of stay. We suggest early involvement of care coordination, physical therapy, and occupational therapy in the ICU setting. A consensus review article by Dort et al. from the Enhanced Recovery After Surgery Society recommended early mobilization, within 24 h after surgery, for patients receiving major head and neck surgery with free flap reconstruction [34]. Including physical therapy and occupational therapy early on in the hospitalization will help to facilitate early mobilization and discharge planning.

While the literature currently supports caring for the majority of patients who undergo head and neck free flap surgery in a specialized non-ICU unit, exceptions remain for patients who require an ICU level of care for other reasons such as major medical comorbidities, complications, or exceptional circumstances in which ventilatory support is required.

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Flap Monitoring

9

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Introduction

Development of microvascular free tissue transfer in the 1980s and 1990s offered dramatic improvements in both function and cosmesis for patients undergoing large resections, composite resections, and resection for recurrent disease. Large-scale studies since that time have found success rates for free tissue transfer in excess of 95% and have been associated with decreased rates of postoperative fistula, postoperative mandibular reconstruction plate exposure, improved rates of swallowing, and successful reconstruction regardless of age, gender, and history of prior radiation.

Pre-, peri-, and postoperative care of the free flap patient is among the most complicated and critical duties of head and neck reconstructive surgeons. The importance of early recognition of impending complications in a free flap is critical for flap success. This chapter focuses on postoperative flap monitoring methods and techniques.

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Timing and Methods

The health and quality of a free tissue transfer reconstruction can be monitored by a combination of methods: visual inspection, assessment of bleeding on prick, handheld or implantable vascular Doppler monitoring, assessment of turgor, measurement of capillary refill, and/or surface oximetry. Commonly used methods of free flap monitoring are outlined in Table 9.1.

The choice of monitoring technique often depends on a surgeon's comfort level with the technique and prior experience, as well as their practice setting. Clinical monitoring consists of assessing a free flap for color, temperature, capillary refill, and/or bleeding with pinprick or scratch. Clinical monitoring has long been the standard in free flap monitoring; it provides a quick and very cost-effective method to assess end-organ perfusion and has reported false-negative rates of 0.4% [1, 2]. While highly effective, clinical monitoring often requires assessment by a skilled member of the care team. This may be difficult in centers without dedicated trainees or nursing staff. As an intermittent monitoring technique, clinical monitoring requires a time commitment during the early

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Table 9.1 Free flap monitoring techniques

Method	Continuous vs. intermittent	Benefits	Drawbacks
Clinical monitoring	Intermittent	Direct and reliable assessment of end-organ perfusion Able to assess microcirculation	Skin paddle may not always be present or accessible Requires experienced monitor
Handheld Doppler monitoring	Intermittent	Ease of use	Potential for false results Venous monitoring more difficult
Color flow Doppler	Intermittent	Use with buried flaps	Trained radiologist needed for evaluation Limited availability
Implantable Doppler	Continuous	Ease of use Use with buried flaps	Learning curve for monitoring and use Cost
Near-infrared spectroscopy	Continuous	Ease of use Wi-Fi/remote capability	Cost

postoperative days. Finally, buried flaps can be monitored clinically by incorporating an external skin paddle and may allow for better detection of flap compromise [3, 4].

Handheld Doppler monitoring can be combined with clinical monitoring of free flaps to add additional information about vascular flow. For flaps with accessible skin paddles, a suture is typically placed at the site of a vascular perforator or above the main axial blood supply. Arterial flow can be assessed for triphasic quality and flow. Venous flow can also be assessed with handheld Doppler by experienced providers. Handheld Dopplers can also be used to monitor buried flaps with the same method: a mark or suture can be placed over the vascular pedicle, and the Doppler can then be placed to assess vascular flow. In both situations, Doppler quality and location should be confirmed in the operating room prior to transfer and demonstrated to members of the care team. It should be mentioned that monitoring of buried flaps with this method is technically challenging and can result in both false-positive and false-negative assessments if one were to inadvertently Doppler an area outside of where the vascular pedicle resides.

Color duplex ultrasound assessment has been utilized as a method to improve monitoring of buried free flaps. Unlike a handheld Doppler, color duplex ultrasound assessment allows for specific identification of the main vascular pedicle and an assessment of real-time flow or occlusion [5, 6]. Unfortunately, this technology may only be available at select centers and requires collaboration between experienced radiologists and microvascular surgeons to interpret results. An additional limitation is cost, which can range from $30,000 to 225,000 [5]. As such, color duplex ultrasound may have the best utility as a confirmatory test when other monitoring methods have failed.

Implantable Doppler monitoring was first described in 1988 and has since gained increasing use among microvascular surgeons [7]. In contrast to previously mentioned monitoring methods, implantable Dopplers have the ability to provide real-time information about vascular flow across both the arterial and venous anastomoses. Two versions currently exist: Cook-Swartz implantable Doppler devices and the Synovis flow coupler. Cook-Swartz Dopplers consist of a small piezoelectric monitor attached to a silicone cuff that can be attached to a vessel of choice. The Synovis flow coupler uses a similar Doppler device that is built into a standard venous coupler. Both devices have a small wire that attaches to a monitor box through the skin. Both devices have been found to have similar rates of false positives in the detection of flap compromise, as well as comparable rates of flap take-back and failure [8]. Implantable Dopplers have several benefits, including the ability for continuous monitoring, ease of use, and utility in buried flaps. Studies have found that rates of salvage are equal to or better than those with flaps undergoing clinical monitoring [9–12]. Despite

their success, controversy exists around the sensitivity of implantable Dopplers in detecting true flap failures. Initial studies found that arterial pulses can continue to be heard on an average of 220 min (3.6 h) after venous obstruction; however, venous obstruction resulted in an immediate loss of venous signal [7]. These findings suggest that venous monitoring is more sensitive for flap compromise. In contrast, a large meta-analysis of venous versus arterial implantable Doppler monitoring found that specificity for arterial monitoring was 95%, as compared to 87% for venous monitoring. However, these results were not statistically significant, and there was no significant difference in take-backs, salvage rate, or flap failure [13]. Pooled data from studies examining arterial versus venous implantable Doppler monitoring show sensitivities of venous monitoring to be 100%, but false-positive rates ranging from 0 to 33% [14]. The wide range of false-positive rates seen with venous Doppler monitoring suggests that surgeon experience with implantable Doppler use may play a role in its interpretation. Several authors have suggested that high false-negative rates of venous Doppler monitoring result from the learning curve that comes with implant placement. It is important to ensure a snug but not restrictive fit of the silicone cuff to prevent Doppler dislodgement and subsequent loss of signal. Wire connections should be kept slack within the neck to prevent displacement with patient position. Additionally, an adequate venous Doppler signal should be verified before leaving the operating room. Using these techniques, authors have found false-positive rates to be as low as 1–8% [15, 16]. The cost of implantable Doppler monitoring has been a criticism of its widespread use. On average, the one-time cost of a monitoring box is around $3500–5000, and each disposable probe costs about $400–500 [17]. A cost analysis of implantable Dopplers suggests that implantable monitoring costs can be offset by the reduction in flap failure: about 2–5 of every 100 patients [9, 18]. In a similar study, Moubayed and colleagues found that the cost of implantable Doppler monitoring may be justified for centers with a flap failure rate of 6% [19]. In rare cases, removal of the implantable Doppler wires may result in vascular pedicle disruption [20]. Finally, a drawback of implantable Doppler monitoring is that it assesses the main vascular flow. Microcirculation issues, discussed further below, may not be picked up with implantable Doppler monitoring alone and can only be clinically assessed.

Near-infrared spectroscopy (NIR) has emerged as a newer, real-time method of free flap monitoring. Near-infrared wavelengths are delivered via surface probe and used to determine the percentage of oxygen-bound hemoglobin within a volume of tissue (StO_2). NIR monitoring has long been used in breast reconstruction and has been found to detect flap compromise earlier than clinical monitoring and external Doppler monitoring [21–23]. Several NIR devices exist. The ViOptix near-infrared tissue oximeter (T.Ox Tissue Oximeter, ViOptix Inc., Fremont, CA) has been well studied for its application in free tissue monitoring. The device consists of a surface probe that attaches to an external monitor. Data is presented as real-time StO_2 and can be broadcast wirelessly to a smartphone device for remote monitoring. Prior studies have established StO_2 levels of 30% or below to predict flap failure, and a change of >20% over 1 h to be suspicious for flap compromise [24–26]. Surface probes are available for both cutaneous and mucosal surfaces and can be applied to externalized paddles of buried flaps. The utility of NIR monitoring in head and neck free tissue reconstruction has been explored [27]. In a large study of head and neck free tissue transfer patients, the optimal StO_2 cut-off for predicting flap success was found to be 68%, with a maximized sensitivity and specificity of 74.6% and 75%, respectively [28]. Cost becomes an issue with NIR, with the one-time cost of the monitor ranging from $19,500 to $30,000, and each disposable sensor costing $650–$12751 [17, 29–31]. As with other non-clinical methods of flap monitoring, a learning curve exists regarding probe application and use. The surface probe should be applied to a clean surface of a healthy skin. Ambient light has been known to affect StO_2 readings, a problem which can be remedied by covering the surface probe with a small foam or cloth. Probe dislodgement

can occur and can trigger a false-positive alarm on the monitoring system.

Other methods of flap monitoring exist though they are not as widely implemented as those discussed above. A concise overview of flap monitoring methods is shown in Table 9.1.

The timing of flap monitoring is provider and institution dependent, with most institutions implementing a closer period of monitoring during the initial postoperative period. In a survey of reconstructive practices among otolaryngology programs, Kovach et al. found that the majority of institutions (75.2%) performing head and neck free tissue reconstruction admit patients to the ICU for postoperative monitoring. Monitoring by residents and nursing staff is the norm, with hourly nursing flap checks performed in the initial postoperative period by over 75% of institutions [32]. Prior studies suggested that the majority of free flaps will demonstrate failure within the first 48 h after surgery [33]. However, recent data shows a smaller proportion of flap failures within the first 72 h after surgery, with the risk being highest up to 5 days after surgery. Salvage surgery after 5 days is associated with lower rates of success [34]. Given these data, monitoring during this time frame is essential to detect early flap compromise and to be able to perform salvage surgery. Once ischemia is detected, irreversible damage in microcirculation can occur in as little as 6 h [35]. Bone is more susceptible to ischemia with damage occurring in as little as 3 h [36]. Literature regarding the optimal timing from detection of flap compromise to salvage surgery is variable. Studies agree that early intervention for flap compromise results in optimal salvage outcomes. While time from detection to successful salvage has been reported to be as long as 16–24 h, optimal salvage rates are due to return to the operating room in as little as 1–2 h [37–39]. As such, signs of flap compromise are treated as a "surgical emergency" with immediate return to the operating room in cases requiring surgical salvage. Because of this, more intensive monitoring is favored during the early postoperative period. This practice has yielded salvage rates of 60–86% [40–42].

Indications for Implantable Doppler

Since its advent, implantable Doppler monitoring has gained popularity. Up to 40% of head and neck microvascular surgeons utilize implantable Doppler monitoring for more than 50% of their free flap cases [32]. Implantable Doppler monitoring has several advantages previously mentioned, including the ability for continuous monitoring and application in the monitoring of buried flaps. Prior studies have suggested that implantable monitoring in buried free flaps may lead to a higher false-positive rate as compared to traditional methods of handheld Doppler monitoring of an externalized skin paddle [43]. However, a large study looking at success rates in buried flaps showed that implantable Doppler use had comparable utility in flap monitoring to external skin paddle monitoring; additionally, the authors found that implantable Doppler use detected flap failure early and allowed for early salvage [44].

An understudied use of implantable Doppler monitoring is in a setting where a trained clinician is not readily available for flap assessment. The continuous nature of monitoring makes postoperative flap assessment easy for nursing teams and ancillary staff. As with other monitoring methods, educating the care team about true positives is essential. Theoretically, a "true positive" using implantable Dopplers will present as a complete loss of arterial and/or venous signal. Troubleshooting for technical issues, such as wire disconnection, should occur but should not take precedence over assuming that flap vascularity is compromised.

Causes of Flap Failure

Globally, rates of complete flap failure in head and neck reconstruction remain low at less than or around 5% [45–50]. While rare, much study has gone into causes of flap failure and methods of prevention. In general, causes of flap failure can be broken up into three categories: patient factors, external factors, and microvascular factors (Table 9.2).

Table 9.2 Factors contributing to free flap failure

Patient factors	External factors	Microvascular factors
– Comorbidities (diabetes, severe vascular disease) – Unrecognized coagulopathy – Prior radiation therapy – Malnutrition	Intraoperative: – Fluid management Postoperative: – Iatrogenic mechanical pedicle obstruction – Infection – Hematoma – Hypotension/hypoperfusion – Transfusion requirement	– Recipient vessel selection – Prolonged ischemia time – Pedicle geometry – Iatrogenic perforator or pedicle injury – Technical issues with vascular anastomosis – Vasospasm – Microcirculation problems

Patient Factors

By nature of their underlying disease, head and neck reconstructive patients often have comorbidities that can contribute to free flap compromise. A specific issue seen in this patient population is tobacco use, with over a quarter of patients reporting a history of recent smoking [51]. Active tobacco use can induce thrombocytosis, vasospasm, and hypoxia. While active smoking may lead to increased rates of postoperative complications and wound breakdown, large studies have not found a direct association between active tobacco use and flap outcomes [51, 52]. Head and neck cancer patients also often have a history of malnutrition due to their disease process. Studies have shown that low nutrition, as determined by preoperative prealbumin levels, can lead to a fourfold increase in flap failure [53]. Recently, sarcopenia as measured by skeletal muscle index (SMI) has been explored as a factor in reconstructive outcomes in head and neck cancer patients. Patients with sarcopenia have been found to have increased rates of postoperative complications including wound breakdown and fistula, both of which can contribute to late flap failure [54]. Preoperative nutrition optimization continues to be an area of active exploration. Current research suggests that a 5-day protocol of enhanced nutrition may help prevent wound issues seen in head and neck reconstructive patients [55]. Malnutrition may also play a role in coagulopathy, with up to 70% of head and neck cancer patients demonstrating abnormal coagulation profiles due to vitamin K deficiency [56]. The clinical significance on free flap outcomes remains unknown.

Known factors affecting hypercoagulability include a family history of factor V leiden, protein C deficiency, hyperhomocysteinemia, antiphospholipid antibody syndrome, prothrombin gene mutation, elevated factor VIII, anticardiolipin antibody syndrome, and essential thrombosis. A careful personal and family history can reveal patients who may require additional testing for these conditions. Success rates of 80% have been reported for appropriately identified and managed patients with these conditions undergoing free tissue transfer, though surgeons and hematologists must work closely to manage perioperative anticoagulation [57].

The impact of prior treatment has been explored as a factor in free flap outcomes. Preoperative radiation therapy can lead to disruptions in blood supply, vascular endothelial injury, and higher rates of calcification [58–60]. A meta-analysis of head and neck patients undergoing free tissue transfer after radiation therapy found an increased rate of flap loss when vessels were used from within the irradiated field. Radiation dose may play a role, with higher rates of flap loss in patients with >60 cGy of exposure to the neck [61].

Other patient factors including advanced age, obesity, alcoholism, ASA class, and hypertension have not been found to be related to success in head and neck free tissue transfer [62–66].

External Factors

Intraoperative

Much attention has been given to intraoperative factors and free flap outcomes. Intraoperative fluid administration has been implicated in free

flap failure due to excessive flap edema causing mechanical stress on the vascular pedicle. Edema may also increase suture line dehiscence and lead to wound breakdown [67]. Several studies have tried to determine the optimal amount of intraoperative fluid administration. Rates of fluid exceeding 5.4–6 mL/kg/h have been correlated with increased rates of flap loss [68, 69]. Haughey et al. similarly found that an overall fluid volume of 7 L was correlated with worse flap outcomes [67]. Goal-directed fluid management using flow-based hemodynamic monitoring has been advocated during reconstructive cases to minimize fluid administration and large fluid shifts. Studies show that this strategy can improve flap outcomes, reduce intraoperative fluid administration, and reduce duration of hospital stay [70–72].

Vasopressor use has long been debated as a cause of flap failure due to the potential for vascular spasm. Multiple studies have since shown the safety of intraoperative vasopressor administration across a range of free tissue reconstructions, including perforator flaps and bony reconstruction [73–79].

Postoperative

After surgery, close monitoring of free flap patients by an experienced care team is a key part of managing postoperative causes of flap failure. Proper education and sign-out about flap monitoring should be performed with members of the nursing team and any caregivers (trainees or faculty) involved in the patient's immediate care. While no studies have been conducted on the effect of external neck compression from pillows, neck ties, or otherwise, such implements should be avoided out of caution for inadvertent compression of the flap pedicle. The necessity of frequent resident/trainee flap checks has been questioned. Patel et al. found no differences in flap salvage or outcomes with decreased monitoring frequency by residents at academic centers performing free tissue transfer [80]. However, for low-volume centers and/or those without an experienced nursing team, frequent interactions between surgeons and the postoperative nursing team can help prevent adverse outcomes.

Postoperative hematoma development in the neck can compress the flap pedicle and limit both arterial supply and venous outflow. Hematoma development under a flap skin or muscle paddle can similarly compress perforator supply, or affect the microcirculation, and result in partial or complete flap loss. Though generally thought of as an early postoperative complication, patients on anticoagulants are susceptible to hematoma formation anytime during their stay.

Late external causes of flap failure include fistula and/or infection. The subtleties between the initial insult can be difficult to discern. In patients where a flap was used for a communicating mucosal defect, an infection should be assumed as due to a fistula until proven otherwise. Early studies show that localized infection can lead to pedicle thrombosis rates of 75%, with venous thrombosis being more common than arterial thrombosis [81, 82]. Regardless of the cause, surgical site infections in flap patients should be treated immediately with drainage, irrigation, and/or operative exploration. Management of a clean fistula is somewhat more controversial. Authors have advocated that a clean salivary fistula has no impact on microvascular outcomes if it is diverted with closed drainage, though operative management should still be considered for poorly controlled fistulas or those leading to infection [83].

Attention has been given to the impact of mean arterial pressure in the postoperative period to maintain free flap perfusion. Individual practices vary in terms of setting a perfusion pressure "goal"; however, outside of systemic causes of hypoperfusion, no study has found that low blood pressure alone contributes to flap failure [84]. A recent study explored the role of intraoperative mean arterial pressure (MAP) and found that patients with persistent MAP <60 had higher rates of flap failure (OR 1.22), though this finding could be related to the higher volume of intraoperative

fluids administered in these patients [85]. In the absence of systemic symptoms of hypoperfusion (low urine output, altered mental status, etc.), perfusion pressure goals do not appear to impact free flap outcomes. Similarly, postoperative transfusion requirement has been studied in relation to free flap loss. While a liberal transfusion protocol is associated with adverse postoperative outcomes, free flap survival has not been found to be affected [86, 87]. Postoperative antiplatelet agents are used by the majority of head and neck microvascular surgeons, with almost 50% preferring full-dose aspirin in the postoperative period [32]. Concerns about increased risk of bleeding and hematoma exist surrounding postoperative antiplatelet agents. Large retrospective studies and meta-analyses have found contradictory results with some suggesting an increased risk of bleeding and others finding no significant difference in either of these complications among patients receiving aspirin and/or low-molecular-weight heparin (LMWH) [88, 89]. In contrast, prospective studies have questioned the use of such agents solely for the prevention of flap compromise [90]. Most postsurgical head and neck free flap patients are both immobile and have advanced malignancy. Chemical prophylaxis for deep venous thrombosis (DVT) should be provided to these patients regardless of the reconstructive status. The addition of aspirin, at either 325 mg or 81 mg, is currently left to surgeon discretion, though it should be noted that no clear conclusion can be drawn about the efficacy or risk of postoperative aspirin use in this patient population.

Microvascular Factors

A variety of microvascular factors that could cause flap failure have been explored, including vessel selection, free flap type, number of venous anastomoses, ischemia time, anastomotic technique, and microcirculation problems [91–97]. Technical errors with flap design and raising, tissue handling, iatrogenic perforator or pedicle injury, vascular anastomosis, and/or geometry of the pedicle can result in flap compromise. Recipient vessel selection, including donor artery and vein and pedicle geometry, is important. Vessel kinking or poor geometry can result in thrombosis [91–93]. The use of interposition vein grafts has been shown to increase the risk of flap compromise due to venous failure [94, 95]. The internal jugular vein is thought to be a superior drainage vein compared to the external jugular vein due to its larger size, higher velocity of flow, stronger respiratory venous pump effort, and lower susceptibility to external compression [93]. The use of one versus two venous anastomosis (when possible) has been evaluated with some studies suggesting that two venous anastomoses may be superior, though this is not a universal practice [96].

Ischemia time, defined as the time from transection of the flap pedicle until the time of vascular reanastomosis, has been studied as a contributing factor to flap success. During ischemia time, the flap tissue is anoxic and undergoes cellular death. After reperfusion, there is some degree of ischemic reperfusion injury. This has been shown to be directly proportional to the duration of primary ischemia time [91, 92, 98–100]. In a large study of 690 flaps, ischemia time >60 min of duration was associated with a higher rate of partial and complete flap failure [98]. The type of tissue transplanted is also likely affected by ischemia time. Crawley et al. found that non-osteocutaneous free flaps were more prone to complete flap loss with prolonged ischemia time compared to osteocutaneous flaps [92]. It is thought that tissues with higher metabolic activity are more prone to ischemic reperfusion injury, so primarily muscle-based flaps are likely more prone to injury than primarily bone-based flaps [91].

Intraoperative vasospasm is a common cause of intraoperative vessel compromise. A number of pharmacologic agents to prevent or reduce vasospasm have been studied and used. Papaverine, verapamil, and lidocaine are the most commonly used agents [101, 102].

Recognizing Venous Versus Arterial Failure

A flap may lose perfusion due to compromise at the level of anastomosis, perforator, and/or microcirculation.

Arterial compromise almost always occurs early on postoperative day 0 or 1. The flap will be cold and very pale and will lack turgor. Impending signs of ischemia include a slight color change to the flap and/or change in the arterial Doppler signal. There will be no bleeding on pinprick (Fig. 9.1).

In the more common but still rare case of venous compromise, the flap color will become increasingly edematous and will progressively change color to a greyish/blue or even violet, and the neck drains will pick up as the flap will bleed from additional, dilated venous sources. There will be immediate, brisk, dark bleeding on pinprick (Fig. 9.2).

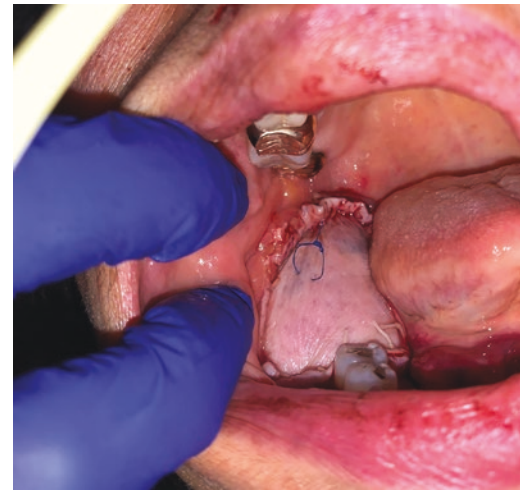

Fig. 9.1 Example of flap with concern for arterial compromise. The flap is pale and cold, with reduced capillary refill and no bleeding on pinprick

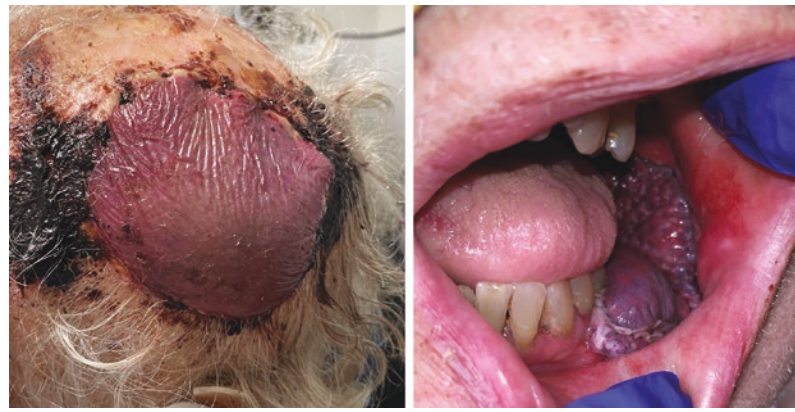

Fig. 9.2 Examples of flaps in the later stages of venous compromise. The flaps are violet and edematous. There is brisk, dark bleeding on pinprick

Early Bedside Interventions

The first step in managing flap compromise is early recognition and mobilization of appropriate resources. There should be a low threshold for return to the operating room for exploration. While waiting for the operating room to be ready, one can evaluate and attempt to correct factors that may be contributing to flap compromise. This includes addressing systemic factors such as hypovolemia or hypotension or mechanical factors such as head positioning or external compression, if present. If concerned for thrombosis causing free flap compromise, systemic anticoagulation in the form of heparin can be initiated.

Return to Operating Room

Prompt return to the operating room for direct exploration is imperative to maximize the chances of flap salvage. A failing flap that is most likely to be saved is one that has a correctable technical issue that is identified early and addressed in the operating room. The chances of saving a failing free flap after the first 48 h are low. Late thrombosis, defined as thrombosis occurring after the first 48 h, is nearly impossible to salvage. This is usually due to factors such as fistula development or infection, rather than a technical issue [39, 103, 104].

When returning to the operating room for exploration, attention should first be directed at the vascular pedicle. External causes can quickly be assessed and corrected, including hematoma causing compression, pedicle kinking, pedicle torsion, and poor pedicle geometry. After evaluation for these external factors, internal vessel factors should be considered. Both the artery and the vein should be closely inspected for thrombosis, flow, and vasospasm. Arterial flow can be assessed by feeling for pulsations in both the donor vessel and distal pedicle, or use an intraoperative Doppler to find a signal. The vein can be palpated and/or milked to feel for venous clot.

Identification of thrombosis should prompt one to take down the anastomosis and attempt to remove the thrombosis. Various techniques have been described. Copious heparinized saline can be flushed into the vessels. Manual thrombectomy including milking can be performed. The use of devices such as a Fogarty catheter to remove clot has also been described [105, 106]. Thrombolytic agents can be useful in both arterial and venous thrombosis situations. These agents include streptokinase, urokinase, or tissue plasminogen activator [105–107]. It is best to have forward flow in the recipient vessel in order for these agents to work. The venous anastomosis should be taken down prior to administration in order to avoid systemic administration. Tissue plasminogen activator (tPA) is the best studied agent. It binds to fibrin in a thrombus and converts the trapped plasminogen to plasmin, thereby inhibiting fibrinolysis. Use for flap salvage is off-label. An initial 2 mg dose of tPA should be loaded into a small TB syringe with a short 27-gauge needle and should be perfused through the flap through the arterial side. This may be repeated once, if needed [108].

Every attempt should then be made for reanastomosis. In certain cases, the initial donor artery and/or vein may not be appropriate and new donor vessels should be identified and selected, if possible.

Systemic antithrombotic therapy may be considered in cases of thrombosis once flow is reestablished. The use of systemic antithrombotic therapy does increase the risk of bleeding and hematoma formation, so the benefit of its use must be weighed with this risk.

When ischemia is noted without mechanical problems or thrombosis, vasospasm can be the cause. As mentioned previously, various agents to address vasospasm have been studied. These include papaverine, lidocaine, and verapamil. These can be applied topically and intra-arterially [101, 102].

Nonsurgical Interventions

In rare situations, return to the operating room is not possible or not indicated. This can be when initial surgical revision fails or there are micro-

circulation issues that cannot be addressed with pedicle revision.

Medicinal leeches may be used to alleviate venous congestion. Leeches produce an enzyme called hirudin, a powerful anticoagulant. Hirudin in the leech saliva acts locally at their bite site and continues its effects for 2–3 h locally after the leech is removed. When attached, the leech actively removes the blood, and then after removal of the leech, blood will continue to drain due to the local effects of hirudin. All patients undergoing leech therapy must be a fluoroquinolone antibiotic as many leeches carry a bacteria known as *Aeromonas hydrophila* in their saliva that can cause infections [109].

More recently, reports of the use of subcutaneous injection of recombinant tissue plasminogen activator rt-PA have suggested that this may successfully be used as a last attempt for salvage of thrombotic free flaps. Ilher et al. reported on three cases in which subcutaneous rt-PA was used to successfully salvage thrombosed radial forearm free flaps. In all cases, patients had already undergone attempted operative revisions and intravenous heparin injections. The flaps all had recurrent venous thrombosis 3–6 days after surgery. Two milligrams of rt-PA was injected subcutaneously at multiple sites into the compromised flap as the final attempt with successful thrombolysis with no or only partial soft tissue loss [110].

Conclusion

The development of microvascular free tissue transfer in head and neck surgery offered dramatic improvements in both function and cosmesis for patients undergoing large resections, composite resections, and resection for recurrent disease. Success rates for free tissue transfer in the head and neck are now in excess of 95%. Such a low failure rate makes it difficult to identify factors that contribute to these failures. As such, postoperative monitoring protocols remain heterogeneous with respect to method and frequency. With careful monitoring and early recognition of free flap compromise, free flap salvage is possible and high success rates can be maintained.

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Postoperative Delirium

10

Ashleigh Weyh and Anastasiya Quimby

Introduction

Delirium at its simplest can be thought of as an "acute brain dysfunction" in response to a pathophysiologic stressor. It is an acute cognitive disturbance, with associated fluctuating impairment in both attention and awareness. The DSM5 describes five criteria that are necessary to make a diagnosis of delirium [1]:

A. Disturbance in attention (i.e., reduced ability to direct, focus, sustain, and shift attention) and awareness (reduced orientation to the environment).
B. The disturbance develops over a short period of time (usually hours to a few days), represents a change from baseline attention and awareness, and tends to fluctuate in severity during the course of a day.
C. An additional disturbance in cognition (e.g., memory deficit, disorientation, language, visuospatial ability, or perception).
D. The disturbance in criteria A and C is not explained by another preexisting, established, or evolving neurocognitive disorder and does not occur in the context of a severely reduced level of arousal, such as coma.
E. There is evidence from the history, physical examination, or laboratory findings that the disturbance is a direct physiological consequence of another medical condition, substance intoxication (i.e., due to a drug of abuse or due to a medication), or exposure to a toxin, or is due to multiple etiologies.

Clinical presentation of delirium has been classified into three types: hyperactive delirium manifests with motor hyperactivity, agitation, restlessness, and possible aggression; hypoactive delirium demonstrates slowed motor and cognitive function in such a way that the patient may appear sedated and with mixed delirium that presents as a combination of hypo- and hyperactive states [2–4]. Hypoactive delirium is more common; however, it is less frequently recognized as the patient's hypoactivity may be attributed to postoperative pain and antianxiety medications [2]. Regardless of the type, key features are acute onset within 24–48 h after surgery, waxing and waning symptoms, transient duration, and improvement in symptoms with appro-

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priate treatment and/or identification and elimination of the etiologic factors [3–5]. This phenomenon has been given various terms such as "ICU delirium," "ICU psychosis," and "sundowning," all describing an acute mental status change with onset within days after surgery that alternates with baseline mental function through the day [3, 5]. Although many of these terms are used by physicians and imply waxing and waning mental state, they are not recognized by the Centers for Medicare & Medicaid Services (CMS) as the accepted diagnostic nomenclature. Acute delirium (AD) is the designated diagnostic term that is supported by CMS for purposes of billing and stratification of illness, as well as recommended by the American Psychiatric Association.

Overall incidence of delirium is reported to be 2.5–5% [6], while in head and neck oncologic populations, it can be as high as 36% [3]. Given the associated increase in morbidity, mortality, prolonged hospitalization, and healthcare cost [3–5, 7, 8], it is important for the head and neck surgeons to be familiar with risk factors, screening tools, diagnosis, and appropriate management of AD.

Risk Assessment

With accurate risk stratification, one can employ appropriate risk reduction measures to mitigate the onset and severity of AD. Risk factors can be broadly categorized into patient related and surgery related.

The most consistently identified patient risk factors in the current literature include male gender, age >70 years old, high frailty score, higher ASA score, end-stage renal failure, cerebrovascular disease, low albumin, alcohol, illicit drug, and tobacco abuse, with preexisting neuropsychiatric impairment being the strongest predictor of AD [4, 8–10]. Although age >70 years old is commonly cited, the 2010 National Institute for Health and Care Excellence identified age over 65 years as a risk factor. A study carried out by Kolk et al. focusing specifically on complex head and neck surgery found that in their AD group, average age was 68 years old [5]. Goldstein et al. noted no relationship between chronologic age and risk of post-op delirium; however, they saw correlation between poor performance of clock draw test, which is used to measure cognitive impairment, with increasing frailty score and risk of AD [7]. Even though these are minor differences in age groups, it may point greater relevance of frailty in the development of AD. Patients with malignancies are in a chronic inflammatory state that increases their frailty overall; thus, it may help explain the higher incidence of AD in head and neck patient population when compared to general population. Patients' baseline functional status, including sensory deficits, is important to evaluate. Patients who wear glasses or hearing aids should have them available postoperatively to prevent disorientation [11]. Higher ASA score, which implies more sever and/or greater number of comorbidities as well as medications, also implies greater difficulty with maintaining patients' homeostasis with surgical stresses, which in turn may lead to electrolyte, hormone, and fluid imbalances that may negatively impair brain function, leading to the development of AD. Preoperative presence of neurocognitive impairment not surprisingly was identified as the strongest predictor of postoperative AD [4]. Additionally, substances that impair neurocognitive function, such as illicit drugs and alcohol, as well as psychiatric disorders, such as depression and anxiety, are linked to higher incidence of AD [4, 9]. The extreme manifestation of AD that results from alcohol withdrawal is delirium tremens (DT) that will be discussed in more detail further in this chapter. Therefore, the three categories of patient-related risk factors, their age and frailty, comorbidities, and neurocognitive function, should be considered during assessment. A significant proportion of head and neck cancer patients are males of advanced age, with a history of alcoholism and tobacco use, thus already falling into high-risk category for AD.

Most cited surgical risk factors are major noncardiac surgery, prolonged surgery duration, blood loss and blood transfusion, flap reconstruction, tracheostomy, and postoperative intensive care unit (ICU) admission [8, 10, 12, 13]. The

type of surgery has been found to be associated with the risk of AD. Abdominal, pelvic, and major emergency surgeries and those requiring postoperative intensive care all confer increased risk [6, 14]. Complex head and neck microvascular reconstructive surgery falls into the category of major noncardiac surgery. Operative times can be considered prolonged, although there is no consensus in the literature what "prolonged" surgery is. This may explain the contradicting findings in studies that claim the presence or lack of association between surgery duration and risk of AD. One study identified surgery longer than 6 h as a risk factor [15]. Other studies identified surgery duration >10 h as a risk factor [8, 16], while a few studies demonstrated no increase in the risk of post-op delirium with surgery duration of about 9 h [5, 17, 18]. A study by Delyth et al. defined prolonged surgery as that longer than 5 h and thus concluded that there is association between surgery duration and AD [4]. Nonetheless, their data demonstrated average duration of surgery of 10 h in non-AD and 10.4 h in AD group, having no statistical significance between the groups [4]. Therefore, combining the available data, surgery duration of 9–10 h does not appear to significantly increase the incidence of AD, beyond the overall increase in risk that occurs when compared to short surgeries lasting <5 h.

Greater intraoperative blood loss and blood transfusions are more likely to occur with advanced-stage disease and more complex reconstructive choices. Data on blood loss and blood transfusion vary widely across studies, making it difficult to identify a threshold that would signify higher risk. Approximately 500 cc appears to be an average intraoperative blood loss observed in patient groups who underwent head and neck surgery and did not develop post-op delirium [8, 17–19]. Free flap reconstruction is cited as a risk factor for AD in general, and with regard to a choice of reconstruction, fibula free flap has been found to confer higher risk of development of AD [5, 8]. Presence of tracheostomy interferes with patients' ability to speak, which may not only contribute to the development of confusion, but also make the diagnosis of delirium more challenging to make, especially if it presents as hypoactive [4].

Inadequate postoperative pain control, addition of new drugs, polypharmacy, ICU admission, and flap checks have been linked to higher risk of AD [5, 8, 9]. Appropriate pain control is of utmost importance; however, heavy reliance on opioids may be detrimental as one study demonstrated that daily doses exceeding 90 mg of morphine resulted in 2.1 X risk of AD [20]. Anticholinergics, opioids, and benzodiazepines specifically have been cited as medications that significantly increase the risk of cognitive issues and precipitating AD [21]. Kolk et al. demonstrated that addition of even one new psychotropic medication postoperatively increased the risk of AD [5]. Siddiqi et al. noted that in non-ICU hospitalized patients, addition of three new medications conferred higher risk for the development of AD [5, 22]. Patients that are malnourished, kept immobile, experience sleep deprivation or altered sleep patterns, or experience emotional stress are all at heightened risk [23]. Free flap patients may require a period of immobilization; moreover, patient mobilization in ICU is at times challenging due to the nature of ICU units. Sleep cycle alterations also result from ICU stay as well as frequent flap checks immediately post-op.

Another well-known etiology of delirium in the elderly population is a UTI. Presence of indwelling urinary bladder catheters increases the risk of UTI and thus may precipitate AD as most patients will likely have a urinary catheter initially after surgery. Systemic organ failures, such as liver or kidney failure, can result in an acute brain dysfunction due to drug toxicity from impaired metabolism and clearance of drugs, even previously well-tolerated medications [24]. Although there are no specific labs to help predict AD, a recent study identified preoperative neutrophil-lymphocyte ratio (NLR) of >3.0 to be independently associated with postoperative AD [25].

Clinical Assessment and Diagnosis

The diagnosis of delirium may be challenging to make due to the fluctuating nature of the symptoms; therefore, various screening tools have been developed. Confusion Assessment Method (CAM), CAM-ICU, and Intensive Care Delirium Screening Checklist (ICDSC) are validated screening tools recommended by the American College of Critical Care Medicine (ACCM) and the Society of Critical Care Medicine (SCCM) [3, 26, 27]. Both methods utilize a series of questions and tasks to be completed by a patient. This allows for a degree of objectivity when cognition is in question. Nonetheless, the gold standard for the diagnosis of delirium remains a thorough clinical evaluation [28]. Any patient who is showing signs of cognitive impairment requires a formal mental status examination. This information is much more valuable if there is knowledge of the patients' baseline level of functioning. The following three findings are required for diagnosis per the DSM-5 criteria. First, *disturbance in attention and awareness* (i.e., reduced orientation and ability to direct, focus, and sustain attention) should be assessed. Next, the *disturbance must develop acutely* (hours to days) and will tend to *fluctuate* throughout the day. Finally, the patient needs to experience an *acute change in cognition*, affecting either memory, language, perception, or thinking. In addition to these three criteria, there must not be a preexisting neurocognitive disorder that can better explain these findings, and there must be evidence from the history and physical or laboratory findings that this mental disturbance is in fact caused by a medical condition, intoxication, withdrawal, or side effect [29]. If the patient meets the criteria established by DSM-5, search for a possible cause should be immediately initiated. Elimination of the precipitating factor or factors can help hasten the resolution and reduce the effects on morbidity, mortality, and long-term cognitive decline [28].

A comprehensive physical examination can be almost impossible in a delirious and uncooperative patient. Thus, a focused assessment of patients' general appearance, while evaluating for possible infection source, dehydration, with a thorough review of the vital signs should be performed. It is important to note that not all frail adults will manifest systemic infection with fever or noticeable change to the vital signs [30].

Next, it is also important to conduct a medication review and be on the lookout for well-known offenders such as opioids, benzodiazepines, and anticholinergics. Consulting guides like the American Geriatrics Society Beers Criteria are a good source to identify potentially inappropriate medications for older adults as well as those that contribute to central nervous system dysfunction [31].

Next, laboratory tests should be run to rule out common triggers. Serum electrolytes, creatinine, glucose, calcium, complete blood count, and urinalysis/culture are good initial tests. In the setting of head and neck cancer, drug levels and toxicology screens are usually unnecessary [32]. Blood gas or chest radiographs can be helpful in patients with suspected cardiopulmonary disease or early sepsis. In patients with a report of a slow decline over months, evaluation of thyroid function and B12 can also be helpful. Neuroimaging with head CT is not routinely indicated, or helpful, for these patients unless there is suspicion for stroke or meningitis, or the patient develops a new focal deficit [33].

A serious problem for many head and neck surgery patients is alcohol withdrawal, which can lead to a specific form of delirium called delirium tremens (DTs). DTs refers specifically to acute-onset delirium in a setting of alcohol withdrawal, but similar effects will occur with withdrawal from benzodiazepines/barbiturates. These substances are central nervous system depressants that increase the release of gamma-aminobutyric acid (GABA) resulting in brain's adaptation to excess neurotransmitter by reducing the activity of postsynaptic *N*-methyl-D-aspartate glutamate receptors [34]. An abrupt cessation of alcohol or other GABAergic substances in a patient no longer producing GABA can have deleterious effects on the body [35]. Alcohol withdrawal symptoms (AWSs) are relatively common, occurring in about 50% of people with alcohol use disorder [34]. Only about 1–5% of those patients deterio-

rate to a much more serious phenomenon of DTs, and those with a history of DTs are at greatest risk [34, 36]. AWS onset is within hours of alcohol cessation, while progression to DTs occurs over a couple of days, most commonly presenting on day 3 and may last for 1–8 days or longer [34, 36, 37]. AWSs present with hand tremors, insomnia, anxiety, tachycardia, tachypnea, hypertension, and hyperthermia. Whereas DTs signifies the presence of cognitive disturbance such as disturbances in attention, awareness, perception, memory, speech, and visuospatial ability, including hallucinations [34], DTs carries 1–4% mortality rate that occurs as a result of hyperthermia, seizures, and/or cardiac arrhythmias [34]. The Clinical Institute Withdrawal Assessment (CIWA) is an instrument used frequently in the United States to both assess and diagnose the severity of the withdrawal based on ten subjective factors: agitation, anxiety, auditory disturbances, clouding of sensorium, headache, nausea/vomiting, paroxysmal sweats, tactile disturbances, tremor, and visual disturbances [38]. Early detection of withdrawal symptoms and their management significantly reduce progression to DTs and associated mortality.

Management

As there are undisputed costs to patients and healthcare systems associated with AD and DTs, current management approach is aimed at risk factor modification, early detection, and appropriate management.

The American Society for Enhanced Recovery and Perioperative Quality Initiative released a consensus statement on postoperative delirium prevention [39]. Their recommendations include multidisciplinary approach that is comprised of three phases. In the preoperative phase, patients should be screened for the presence of high-risk factors and informed of any that exist, and any modifiable risk factors should be optimized. During intraoperative phase, minimizing high-risk medications and no delirium prophylaxis are recommended. In the postoperative phase, patients should be routinely screened for delirium, pain control must be optimized, high-risk medications should be minimized, and non-pharmacologic protocols should be employed [39].

Non-pharmacologic Interventions

As almost any medical condition can precipitate delirium in a susceptible patient, the first treatment for delirium is to identify and treat the underlying cause. Most commonly, this will be a fluid or electrolyte disturbance, infection, hypoglycemia, or organ failure. In the head and neck surgery population, alcoholism is quite common, so it is encouraged to supplement thiamine and B12, as it is inexpensive and virtually risk free. Mild confusion and agitation should first be approached with non-pharmacological interventions. The Yale Delirium Prevention Trial showed non-pharmacologic approach to be effective in decreasing the incidence of delirium from 15 to 9% in a medical unit [40]. Their protocol consisted of frequent patient orientation, early mobilization, medication review, sleep-wake cycle preservation, and management of sensory impairment and dehydration. Reducing ambient noise, keeping the patient on a routine throughout the day, and keeping windows open so the patient can be exposed to natural light during the day are all effective strategies to keep patients oriented [40, 41]. Additionally, frequent reassurance, touch, and verbal orientation, especially from known family members, can lessen disruptive behavior. Use of a sitter, or a dedicated professional to stay beside the patient to redirect behavior, is another effective option at some medical centers. Adequate pain control should be achieved with multimodal approach to avoid excessive use of opioids, as it is known to be one of the medications associated with precipitating AD. Some patients can become difficult despite these measures, trying to pull lines or getting out of bed; however, physical restraints should be reserved for last resort as they can further increase agitation and will result in prolonged immobility [42,

43]. Again, making the patient aware of their surroundings as possible is helpful, thus making sure that they all have glasses and hearing aids, and if necessary, tools to help communicate bedside are imperative. In patients with tracheostomies, supplies for writing should be present, and use of speaking valves as early as feasible and tracheostomy decannulation as quick as possible should be the goal.

Pharmacologic Intervention

Currently, there are no medications approved by the United States Food and Drug Administration for the management/treatment of delirium. However, multiple medications are used off-label to help manage the associated symptoms, especially when patients are threatening their own safety [28]. A pitfall of delirium management is that most medications given to treat associated agitation or psychosis can actually worsen the delirium by making the patient more confused and disoriented. Thus, there is a delicate balance between treating these symptoms and further worsening the overall disease process.

Antipsychotic medications are generally reserved for more severe agitation in a delirious patient. Low-dose haloperidol can be used on an as-needed basis. Newer atypical antipsychotics (quetiapine, risperidone, ziprasidone, olanzapine) have fewer side effects than haloperidol and similar efficacy. Atypical antipsychotics are also associated with less extrapyramidal side effects than haloperidol. Again, no studies to date have shown any long-term benefit from these medications in the management of delirium in regard to time in the intensive care unit or mortality [44]. These medications are only a viable short-term option to treat withdrawal symptoms, anxiety, or agitation, with less respiratory depression than benzodiazepines or pain medications.

Benzodiazepines have limited role for the treatment of delirium but are the drug of choice for delirium tremens, precipitated by sedative drug or alcohol withdrawal. *Thus, in cases of delirium not related to withdrawal, benzodiazepines should be strictly avoided* [41]. Dexmedetomidine is also frequently used in a critical care setting to manage anxiety, pain, and agitation while reducing sympathetic outflow. Its greatest benefit appears to be its ability to indirectly reduce the use of other delirium-inducing drugs [28]. Valproic acid is another treatment option, reserved for hyperactive delirium in the intensive care unit, and has shown benefits for patients also withdrawing from alcohol [28]. It is also important to recognize that the patient is in the correct hospital unit (floor vs. intensive care) based on the severity of their symptoms, level of nursing care, and necessary medical treatments for their delirium.

Delirium Tremens

Delirium tremens is a special case with well-defined, prophylaxis strategies. Generally, it is approached with long-acting benzodiazepines or barbiturates, set up with a daily taper. Another approach is to medicate the patient based on the CIWA score/patient symptoms, also known as a symptom-triggered regimen [35]. The risk of this approach is oversedating the patient, and also by not tapering the dose, the patient can experience withdrawal symptoms when the sedative medications are abruptly stopped. Haloperidol has some role, but has been largely superseded by benzodiazepines and is often reserved for one-time as-needed use. These patients also benefit greatly from normal measures such as frequent reorientation via keeping patients awake during the day in well-lit rooms and allowing them to sleep undisturbed at night. Well-lit rooms are often helpful because patients may experience hallucinations. Patients should also be treated prophylactically with thiamine and B12 as they may have underlying nutritional deficiencies associated with alcoholism. Remember that the goal of care in alcohol/sedative withdrawal is to *prevent* DTs.

Conclusion

Delirium is a common postoperative complication, even more so in the head and neck oncology and reconstruction population that carries high cost and morbidity and mortality. Head and neck microvascular patients fall into the category of high risk for AD due to numerous modifiable and non-modifiable risk factors. It is imperative for a head and neck surgeon to be well versed in the diagnosis and management of AD as it has direct impact on overall outcomes. Development of standardized protocols for the management of these patients that include screening for risk factors, optimization of predisposing factors, and minimization or elimination of precipitating factors is highly encouraged. Avoiding sedating medications after surgery and monitoring for delirium postoperatively should be performed routinely in head and neck surgery wards to prevent serious complications like admission to the intensive care unit, long-term cognitive dysfunction, prolonged hospitalization, or death.

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Prophylaxis

11

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Introduction

Microvascular free flap transfer has been widely recognized as the gold standard in head and neck reconstruction. Free flaps have provided surgeons with various available tissues, such as skin, muscle, and bone, for optimal restoration of form and function [1]. Since their first introduction in the 1970s, techniques of flap harvest and inset have been refined resulting in a reliably high overall success rate of 90–95% [2]. Despite its high success rate, postoperative complications do occur, resulting in a serious consequence [3]. Minor complications include wound dehiscence, infection, fistula, and donor-site problems, while major complications include flap failure, pneumonia, and cerebrovascular accidents [4]. Risk factors that have been associated with free flap failure include microvascular and wound-healing issues, prior history of radiation and chemotherapy, long-standing tobacco and/or alcohol use, and poor nutritional status [3]. Free flap failure can lead to prolonged hospital stays, increased costs, delays in rehabilitation, and delays to adjuvant treatment for cancer patients [5].

There are ongoing debates regarding preoperative, intraoperative, and postoperative prophylaxis of patients undergoing free flap reconstruction of the head and neck. In this chapter, we present current knowledge on prophylaxis against flap thrombosis, deep venous thrombosis (DVT), antibiotic, gastroesophageal reflux disease (GERD), nausea and vomiting, delirium tremens, and postoperative delirium.

Antiplatelet and Anticoagulation Agents for Flap Thrombosis Prophylaxis

During free tissue transfer, patients are at risk of hypercoagulability, venous stasis, and endothelial injury, collectively known as the Virchow's triad, increasing the risk of venous thrombosis formation at the pedicle anastomosis [6]. When thrombosis occurs, it is most often within the first 3 days of surgery, when vessel intimal damage is greatest [7]. As a result, antiplatelet and anticoagulation agents such as heparin, low-molecular-weight heparin (LMWH), aspirin, dextran, and prostaglandin E1 have been used during pre- and postoperative periods to reduce the risk of thrombus formation and improve perfusion to newly transferred tissue. A survey of reconstructive surgeons showed that 97% used anticoagulation agents during free tissue transfer [8]. Despite frequent use of these agents, there is limited evi-

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dence for a standardized postoperative regimen following free tissue reconstruction of the head and neck. Its use and surgeons' preference are largely based on anecdotal evidence, training, and prior use [9].

Heparin provides reduction in the risk of thrombosis without systemic side effects and is the most widely used antithrombotic agent [10]. Postoperative subcutaneous heparin has been shown to decrease the incidence of microvascular thrombosis [6]. A systematic review on postoperative anticoagulation after free flap reconstruction showed aspirin to have the lowest rate of thrombosis and free flap failure with an acceptable hematoma rate compared to other anticoagulation therapy [3]. However, inconsistent dosage and route of administration of aspirin make it difficult to draw meaningful conclusions at this time [3]. Dextran is another most frequently used antithrombotic agent. It is known to impair platelet function, prolong bleeding time, and destabilize fibrin polymerization [11]. The antithrombotic effect of dextran in studies on rabbits showed that the antithrombotic effect is more pronounced when vascular trauma is severe and prothrombotic factors are strongly activated [11]. Despite its potential benefits, a prospective randomized study of 100 free flaps of head and neck showed that dextran was not associated with an increased rate of flap survival and was found to increase the incidence of serious systemic complications including anaphylaxis, pulmonary and cerebral edema, and platelet dysfunction [31]. Recently, statins have been proposed as an anticoagulation adjunct due to their role in reducing inflammation, thrombogenicity, and improved vasodilation [12]. Given the prevalence of cardiovascular disease among head and neck cancer patients, it may be beneficial to start patients that have indications for statins [13]. Lastly, studies on combinations of anticoagulants compared to single-agent regimen found no significant differences in rate of complications, thrombosis, or flap failure [14, 15].

In addition to the use of antiplatelet and anticoagulation prophylaxis, special preoperative and intraoperative care should be considered to reduce the risk of thrombosis formation. Patients should be advised to stop smoking to reduce the risk of wound complications. Patients should also be advised to stop the use of prothrombotic medications such as tamoxifen and oral contraceptives prior to a surgery. Tamoxifen has been shown to increase the risk of free flap failure when taken in perioperative period, and its use should be held for at least 2 weeks prior to the surgery [16, 17].

During surgery, delicate tissue handling should be implemented to minimize the risk of thrombosis. Thrombosis formation during the surgery should be recognized and removed promptly. This will allow surgeons to analyze local factors that may be attributed to thrombus formation before revising anastomosis. Such local factors include vessel size mismatch, poor-quality recipient vessels, and compression/twisting of anastomosis or pedicle [5]. Additionally, topical vessel irrigation with heparinized saline has been shown to reduce thrombosis formation in an animal study [18]. However, this effect has not been replicated in human studies.

There is no clinical evidence to support the use of any anticoagulant or antiplatelet prophylaxis during the postoperative period [3]. Selected patients with a high risk of thrombosis formation may benefit from the prophylaxis, while some patients may have increased risk of bleeding from its use. As such, use of these agents should be approached individually. Further prospective, randomized control studies are warranted to develop a standardized anticoagulation protocol for head and neck free flap surgeries.

Special Considerations for Hypercoagulable Patients

Patients with hypercoagulability pose a unique challenge during free tissue transfer as flap failure may occur in the absence of inciting factors. Despite this challenge, Kotamarti et al. reported an overall success rate of 86.1% in hypercoagulable patients, which was attributed to the early initiation of therapeutic anticoagulation [19]. Routine testing of hypercoagulable disorder is currently not recommended as it is not cost effective and may fail to identify true etiologies of

hypercoagulability [20]. Thus, a detailed clinical history during the preoperative period is needed to identify patients at risk for hypercoagulability [21]. Hypercoagulable disorders include genetic conditions such as factor V Leiden, prothrombin mutation 20210, methylenetetrahydrofolate reductase (MTHFR) mutations, protein C deficiency, protein S deficiency, antithrombin III deficiency, and elevated factor VIII. Acquired thrombophilia includes antiphospholipid syndrome [19]. It is also important to note that thrombophilia may exist in 5–15% of the population and is often remained unnoticed until a complication arises during surgery [19].

Currently, there is insufficient data to establish the type, dosage, and duration of anticoagulation in hypercoagulable patients. A systematic review by Kotamarti et al. suggested that patients with known hypercoagulable disorders may benefit from proper evaluation by hematologists and preemptive use of additional anticoagulation to improve flap success [19]. Weight-based heparin nomogram (WBHN) has also been shown to reduce the risk of flap failure and may be continued several days into the postoperative period [19]. However, this must be weighed against increased risk of bleeding [19]. Therefore, a decision on the use of anticoagulation in hypercoagulable patients needs to be tailored to each individual patient.

Deep Venous Thrombosis Prophylaxis

Venous thromboembolism (VTE) encompasses a spectrum of diseases that range from asymptomatic deep vein thrombosis (DVT) to pulmonary embolism (PE) [22]. VTE is one of the most common complications with an incidence between 0.1 and 0.3% for DVT and 0.05 and 0.2% for PE [22]. Potential risk factors that are unique to patients undergoing free flap reconstruction include prolonged total operative time, physical manipulation of the vasculature, and extensive postoperative immobilization, especially of the donor extremity [23]. As such, thromboembolism prevention with mechanical prophylaxis and chemoprophylaxis is critical and weighed against the minimal risk of postoperative bleeding.

Mechanical prophylaxis such as pneumatic compression device (PCD) or venous foot pump (VFP) is started for all patients 30 min prior to surgery to help reduce venous pooling and is continued until postoperative ambulation [24]. To determine whether patients should receive chemoprophylaxis in addition to mechanical prophylaxis, validated tools such as Caprini or Rogers score can be used to stratify patient risk [22]. Preferred anticoagulation regime for microsurgery reconstruction of the head and neck includes subcutaneous unfractionated heparin 5000 U administered twice daily [22]. Additionally, for patients who are expected to have long periods of immobilization, a 10–14-day postoperative course of chemoprophylaxis can be considered [22]. For patients who have a history of VTE or high preoperative VTE, postoperative chemoprophylaxis can be extended for a total of 30 days [22]. As there is an increase in bleeding with anticoagulants, its use must be individualized based on the risk of VTE and the risk of bleeding [25]. Lastly, proper positioning and early ambulation should be initiated for all patients during postoperative period [22].

Antibiotic Prophylaxis

Surgical site infection (SSI) is a serious complication occurring in up to 80% of free flap patients and can lead to flap failure, resulting in oro- or pharyngocutaneous fistulae, prolonged hospitalization, and need for an additional surgery [26, 27]. Recommended antibiotic prophylaxis agents for clean-contaminated head and neck procedures include cefazolin or cefuroxime plus metronidazole, or ampicillin–sulbactam. Previous studies from the 1980s through the 2000s showed that (1) antibiotic prophylaxis reduced the risk of SSI [28–30], (2) prolonged prophylactic antibiotics do not result in reduced incidence of SSI [31–36], and (3) beta-lactam antibiotics are appropriate first-line agents [28, 29, 37]. As a result, current guidelines from the Centers for Disease Control (CDC), the Surgical Care

Improvement Project (SCIP), and the American Society of Health-System Pharmacists (ASHP) recommend against the administration of prophylactic antibiotic beyond 24 h [38, 39].

Microvascular free flap reconstruction presents a unique challenge with a higher infection risk compared to other clean-contaminated oncologic cases [30, 40–42] along with the detrimental effect of SSI on free flaps. The postulated reasonings for increased risk of SSI include increased contamination of the recipient site with salivary and respiratory secretions, higher American Society of Anesthesiologist (ASA) score of the patients, increased operative time, increased blood loss, and increased T stage that can increase surgical invasiveness and postoperative soft tissue dead space [43]. As a result, prophylactic antibiotics are started 1–2 h prior to surgery and often continued beyond 24 h at the surgeon's discretion [44, 45]. A recent systematic review and meta-analysis on antibiotic prophylaxis in microvascular free flap reconstruction suggest that patients undergoing free flap reconstruction of the head and neck should receive similar duration antibiotic prophylaxis (≤24 h) as other clean-contaminated head and neck cases, despite the increased risk factors for infection seen in this patient population [30]. The study also demonstrated that clindamycin monotherapy is associated with an increased risk of SSI, dehiscence/fistula, methicillin-resistant *Staphylococcus aureus* (MRSA), and distant infection compared to ampicillin–sulbactam [30]. Thus, antibiotics with broad-spectrum gram-negative coverage, such as cefuroxime, are recommended for patients with a true penicillin allergy when undergoing free tissue transfer in head and neck. Further studies are warranted to explore adequate duration of antibiotic prophylaxis in these high-infection-risk microvascular free flap reconstruction cases.

Gastroesophageal Reflux Prophylaxis

Gastroesophageal reflux (GER) is the retrograde flow of gastric contents to the pharynx and larynx [46]. High incidence of GER has been reported in patients undergoing laryngectomy with or without free flap reconstruction [47]. Although the exact pathogenesis is unknown, it has been postulated that laryngectomy leads to changes in pharyngeal plexus innervation and esophageal motility, increasing the risk for reflux [48]. It has been suggested that GER may also predispose pharyngocutaneous fistula formation after laryngectomy. Pharyngocutaneous fistula is a common yet devastating complication of total laryngectomy with incidence ranging from 3 to 65% [49]. Pharyngocutaneous fistula causes significant patient morbidity and is associated with increased hospital stay, reoperation, cost, delayed oral intake, speech rehabilitation, and further treatment such as radiotherapy [50]. GER is also recognized as a key contributor of complications with tracheoesophageal prosthesis during post-laryngectomy speech rehabilitation [51].

Few studies have explored the use of reflux prophylaxis in the perioperative laryngectomy setting. Seikaly et al. found that reflux prophylaxis using intravenous ranitidine and metoclopramide may help decrease the incidence of pharyngocutaneous fistulae [52]. Similarly, Stephenson et al. showed that perioperative enteral omeprazole was associated with a significant reduction in the incidence of pharyngocutaneous fistula [50]. Therefore, in the absence of contrary evidence, reflux prophylaxis is recommended for patients undergoing total laryngectomy with or without reconstruction [50].

Postoperative Nausea and Vomiting Prophylaxis

Postoperative nausea and vomiting (PONV) is an undesirable yet common complication following surgery. The reported overall incidence of PONV is approximately 30% after elective operations but can be as high as 80% for high-risk patients [53]. Patient-specific risk factors for PONV include young age (<40 years), female gender, nonsmoking status, and history of PONV or motion sickness [54]. Procedure-specific risk factors for PONV include use of specific anesthetic agents, perioperative opioid use, certain

operative sites, and long duration of surgery [55]. Early PONV occurs within 6 h after the surgery. Late PONV may occur between 6 and 24 h postoperatively and is associated with opioid use. PONV occurring after 24 h is termed delayed PONV, which can be related to opioid use and/or early mobilization after surgery [56]. Persistent vomiting can cause venous hypertension, tension on suture lines, and bleeding under skin flaps, which are particularly unwanted events after a microsurgical free flap reconstruction [53]. Thus, adequate management of the common, preventable, and treatable PONV is warranted.

Prophylactic antiemetic has become an important part of PONV management to reduce the symptoms of PONV. Studies have shown that patients are more satisfied with this prophylactic approach than with the treatment of symptoms when they occur in the postoperative period [57]. Currently recommended prophylactic antiemetics include 5-hydroxytryptamine (5-HT_3) receptor antagonists (ondansetron, dolasetron, granisetron, tropisetron, ramosetron, and palonosetron), neurokinin-1 (NK-1) receptor antagonists (aprepitant, casopitant, and rolapitant), corticosteroids (dexamethasone and methylprednisolone), butyrophenones (droperidol and haloperidol), antihistamines (dimenhydrinate and meclizine), and anticholinergics (transdermal scopolamine) [58]. Apfel et al. demonstrated that ondansetron 4 mg, droperidol 1.25 mg, and dexamethasone 4 mg were equally effective, with each independently reducing the risk of PONV by approximately 25% [59]. A combination of 5-HT_3 antagonists and corticosteroids has also shown to be efficacious [60]. Despite the use of established prophylactic antiemetic, 25–30% of patients have refractory PONV with persistent nausea and vomiting [61, 62].

In addition to prophylactic antiemetic, several strategies are recommended for reducing the risk for PONV: (1) adequate hydration, (2) propofol induction and maintenance, (3) minimization of perioperative opioids, (4) minimization of volatile anesthetics, (5) avoidance of nitrous oxide and reversal drugs, and (6) adequate intraoperative hydration [63].

Postoperative Delirium

Postoperative delirium (POD) is defined as a reversible cerebral disturbance characterized by fluctuating patterns of disorganized thinking, altered levels of consciousness, and varying degrees of inattention [64]. There are three forms of POD including hyperactive POD (agitation, aggressiveness, and hallucination), hypoactive POD (decreased attention, lethargy, and apathy), and mixed POD [65]. Symptoms of POD typically develop within the first 72 h after the surgery and can last for several days, with few cases persisting as cognitive dysfunction [65, 66]. During this time, patients may be kept intubated and sedated, with this being especially important in patients at risk of developing POD [66]. Without proper sedation, patients may become restless, potentially dislodging any tubes or drains, and risk disrupting new anastomoses [67].

Patients undergoing head and neck surgery are especially at risk of developing POD due to a high association with alcohol use disorder and malnutrition coupled with long operation hours [68]. The overall reported incidence of POD after a head and neck surgery ranges from 11 to 26% [66]. Risk factors associated with POD following a head and neck free flap reconstruction include increasing age, male sex, longer operative time, regional nodal metastases, alcohol use disorder, and active tobacco use. Notably, preoperative abstinence from alcohol was shown to be a negative risk factor for developing POD. POD results in extended hospital stay, higher costs, and increased mortality [69–71]. In addition, POD may also be a risk factor for flap loss and complication [72, 73]. Thus, early recognition of at-risk patients along with vigilant postoperative monitoring is needed to reduce the risk and severity of POD.

Delirium Tremens

Alcohol dependence and abuse are common among patients diagnosed with head and neck squamous cell carcinoma. A study has shown that

high-risk alcohol misusers are 15 times more likely to undergo free flap reconstruction for head and neck cancer [74]. Symptoms of alcohol withdrawal develop in up to 82% of patients who chronically abuse alcohol [75]. Withdrawal of alcohol consumption during the postoperative period can lead to delirium tremens, the most severe form of alcohol withdrawal. Delirium tremens presents as hallucination, seizures, and confusion in addition to autonomic hyperactivity such as tachycardia, diaphoresis, hyperthermia, and hypertension. The signs and symptoms of delirium tremens usually begin around 3 days after alcohol withdrawal and typically last for 2–3 days [76]. The mortality rate of delirium tremens is between 1 and 4% and usually results from hyperthermia, cardiac arrhythmia, complications of withdrawal seizures, or concomitant medical disorders [77, 78].

Benzodiazepine prophylaxis with lorazepam and diazepam has been shown to be effective in reducing the incidence of postoperative alcohol withdrawal that ultimately progresses to delirium tremens. The most frequently used benzodiazepines are lorazepam (Ativan) and diazepam (Valium) [73]. Lorazepam is metabolized by the liver into inactive metabolites and is preferred in patients with compromised liver function [73]. Longer acting diazepam may offer more gradual withdrawal and more effective seizure prevention [73]. Although prophylaxis with benzodiazepine reduces the incidence of alcohol withdrawal, it does not eliminate the symptoms [79]. Thus, early recognition and treatment are imperative to control symptoms and prevent progression to delirium tremens.

Conclusions

Microvascular free flap transfer requires a coordinated multidisciplinary approach to deliver careful preoperative, intraoperative, and postoperative management [25]. Although many institutions provide excellent care to patients undergoing free flap reconstruction, there is still significant variation in perioperative management. In this chapter, we presented current prophylaxis practice for prevention of flap thrombosis, venous thromboembolism, surgical site infections, gastroesophageal reflux, nausea and vomiting, delirium tremens, and postoperative delirium.

Heparin provides reduction in the risk of flap thrombosis without systemic side effects and is the most widely used antithrombotic agent postoperatively. Preferred DVT prophylaxis includes subcutaneous unfractionated heparin 5000 U administered twice daily, which can be prolonged to 10–14 days for patients who are expected to have long periods of immobilization. Recommended antibiotic prophylaxis agents for clean-contaminated head and neck procedures include cefazolin or cefuroxime plus metronidazole, or ampicillin–sulbactam, which can be used up to 24 h postoperatively. Reflux prophylaxis may help decrease the incidence of pharyngocutaneous fistulae in patients undergoing total laryngectomy with or without reconstruction. Several prophylactic antiemetic agents are available including 5-hydroxytryptamine (5-HT_3) receptor antagonists, neurokinin-1 (NK-1) receptor antagonists, corticosteroids, and antihistamines. Lastly, patients undergoing head and neck surgery are especially at risk of developing POD and delirium tremens. Thus, early recognition and intervention are imperative for these high-risk patients.

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Perioperative Nutrition in Head and Neck Free Flap Reconstruction

12

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Introduction

Nutritional optimization is a key but often overlooked aspect of the management of head and neck cancer (HNC) patients undergoing surgical resection and free flap reconstruction, both preoperatively and postoperatively. Due to a variety of physical factors, comorbidities, and metabolic perturbations associated with their disease process, HNC patients are at high risk for malnourishment prior to, during, and after treatment [1, 2]. While the prevalence varies with tumor site, stage, and assessment modality, overall >30% of HNC patients are malnourished prior to initiation of treatment [3]. As preoperative malnutrition has been associated with a variety of negative operative outcomes, the high rate of malnutrition in this patient population is both a challenge for head and neck surgeons and a target for improved interventions.

Assessing Malnutrition

While specific definitions of malnutrition vary, it is generally agreed upon that malnutrition encompasses deficiencies in a patient's intake of energy, protein, and/or essential nutrients [4, 5]. Within a clinical setting, there is expert consensus that malnutrition as a diagnosis should be grouped by etiology in order to reflect underlying inflammatory state given the effect of inflammation on nutritional requirements, with categories of "starvation-related malnutrition," "chronic disease-related malnutrition," and "acute disease or injury-related malnutrition," with HNC patients generally falling into the middle category reflecting a chronic state of mild-to-moderate inflammation existing concurrently with their nutritional compromise [6].

A variety of different metrics are used in practice to assess for malnutrition, each with their own strengths, limitations, and ideal use cases. These assessment modalities include clinical and anthropometric characteristics such as body mass index (BMI) and weight loss, biologic markers such as serum albumin level, and several validated composite scoring systems designed for holistic, multidisciplinary evaluation.

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Clinical Markers

Clinical characteristics such as BMI and weight loss are widely accepted as markers of malnutrition and are easily measured in a clinical setting. The WHO organization defines "underweight" as a BMI <18.5, a cutoff that has been widely adopted [7]. However, as obesity increases worldwide, there has been a push to raise BMI cutoffs in order to capture patients who may fall within clinically "normal" BMI but have significant disease-related weight loss. The European Society of Clinical Nutrition and Metabolism (ESPEN) consensus statement advocates for a screening cutoff of 20 for patients <70 years old and 22 for 70 years and older, as long as the patient also experienced weight loss [8].

Besides BMI, the other widely accepted screening modality is unintentional weight loss. Compared to BMI, which provides a static measurement at a point in time, unintentional weight loss provides a dynamic measurement of a patients nutritional status and has been found to have better sensitivity and specificity in identifying malnutrition in cancer patients compared to BMI [9]. While cutoffs differ somewhat between organizational guidelines, generally unintentional weight loss ≥5% within 1–3 months or ≥10% within 6 months qualifies a patient as being at risk for malnutrition [6, 8, 10].

From a research perspective, it is useful to have a common definition of malnutrition in order to allow for easier comparison between studies. Within the head and neck surgical literature, the most frequently used definition of malnutrition is unintentional weight loss ≥5–10% within 6 months along with a BMI <20 [10].

A variety of other clinical characteristics have been used as proxies for malnutrition. Fat free mass index (FFMI) is a composite height-weight metric similar to BMI; however, it only incorporates lean body mass rather than total body mass. As such, FFMI better reflects the loss of lean body mass seen in cancer-related malnutrition and is less affected by patient obesity [11, 12]. However, objective measurement of FFMI requires specialized equipment, making it less convenient than BMI. For malnutrition screening purposes, an FFMI of <15 for women and <17 for men has been suggested. Other metrics used include hand grip strength, arm and leg circumferential measurements, and skeletal muscle mass as calculated from imaging measurements [8, 13, 14]. However, these metrics also all require specialized training or equipment, making them more difficult to implement clinically compared to BMI or weight loss.

Biologic Markers

A variety of serum markers are sometimes used as proxies for malnutrition, most commonly serum albumin and prealbumin levels. The use of biomarkers to evaluate nutritional status is appealing, as they are objective, routinely obtained, and easily followed over time. Albumin and prealbumin levels in particular have also been correlated with a number of clinical outcomes of interest in HNC surgical patients including overall survival, disease-free survival, and wound infection [15–23]. Albumin, the most common protein in blood plasma, acts as a transport protein and regulates oncotic pressure. Prealbumin also acts as a transport protein and, though less well validated as a biomarker compared to albumin, is frequently used as its much shorter half-life (2–3 days vs. 20 days for albumin) means that it may better reflect acute changes in patient status [1]. Other biomarkers that have been used include transferrin, total serum protein, and composite markers such as prognostic nutritional index, which combines albumin and lymphocyte count [1, 10, 24].

The use of any of these biomarkers is controversial due to their activity as acute-phase reactants, meaning that perturbations in their levels may more accurately reflect systemic inflammatory status than nutrition. While systemic inflammation predisposes patients to malnutrition, albumin and prealbumin levels are not correlated to weight loss in noninflammatory etiologies of malnutrition. In the context of significant systemic inflammation, providing nutrition support will oftentimes not correct low albumin and prealbumin [25, 26]. As such, expert consensus

assigns limited relevance to biomarkers as indicators of malnutrition and cautions against their use as a primary screening or diagnostic modality for malnutrition [8, 13].

Composite Assessment

In addition to the individual clinical and biologic markers described previously, a number of validated instruments have been developed to provide a holistic assessment of nutritional status. The most commonly used of these assessments is the Patient Guided Subjective Global Assessment (PG-SGA). The PG-SGA was first developed in the 1990s as a scored, patient-reported extension of the Subjective Global Assessment—a physician-generated evaluation of patient nutritional status first published in 1987—and is comprised of two segments [27]. The first segment, known as the PG-SGA short form, is completed by the patient and assesses weight loss, food intake, activity level, and associated symptoms affecting eating [28]. The second segment, completed by a provider, further assesses relevant aspects of the patient's history and evaluates multiple physical characteristics including metabolic demand, muscle wasting, fat stores, and fluid balance [28]. At the end of the evaluation, patients are assigned to one of the three global assessment groups (well nourished, moderate/suspected malnutrition, severely malnourished), and the total score is used to triage patients to appropriate nutritional interventions.

Though not specifically developed for oncologic purposes, it is well validated in cancer patients and for evaluation of cancer cachexia and is frequently used in HNC both clinically and for research purposes [29–33]. PG-SGA scores are associated with a variety of clinical outcomes in oncologic patients including length of stay, postoperative complications, and overall survival [34, 35]. The PG-SGA is especially valuable in that it not only serves as a nutritional screening and assessment tool, but also triages patients and can be used to monitor the success of nutritional interventions [36]. While the physical components of the provider segments require time and some expertise to administer, the patient-completed PG-SGA short form alone has high sensitivity and specificity in detecting malnutrition compared to the complete PG-SGA and so can act as an easier screening tool [37–39].

A variety of other composite scoring systems have been validated for screening and assessing malnutrition. The Nutritional Risk Screening, 2002 (NRS 2002), was designed to identify who are malnourished or at nutritional risk and who would benefit from nutritional interventions [40]. Derived from a retrospective analysis of randomized control trials examining the effects of malnutrition and nutritional interventions, the NRS 2002 is a simple, provider-administered tool which generates a composite score based both on nutrition status as measured by BMI, weight loss, and food intake and on severity of underlying disease process. A score of 3 or greater out of 7 indicates that a patient is malnourished and that nutritional support should be started. The NRS 2002 has been well validated as a measure of malnutrition including in HNC, where it performs comparably to the PG-SGA while being quicker and simpler to perform [40–43]. Other scoring systems include the Malnutrition Universal Screening Tool (MUST), the Academy of Nutrition and Dietetics/American Society for Enteral Nutrition (AND/ASPEN) criteria, and the recently developed Global Leadership Initiative on Malnutrition (GLIM) criteria [13, 38, 43, 44]. While these systems vary somewhat in their specific assessments, they all evaluate multiple history and physical findings of malnutrition as well as underlying disease states.

Mechanisms of Malnutrition in Head and Neck Cancer

Rates of malnutrition and nutritional risk are very high in HNC patients, with greater than 30% of patients with significant weight loss at initiation of treatment, a number which is even higher in certain subgroups of patients including those with late-stage disease and tumors of the upper aerodigestive tract [3]. The reason for this is multifactorial, encompassing physical factors associ-

ated with HNC and its treatments, common characteristics of HNC patients, and systemic metabolic perturbations associated with malignancies referred to as cancer cachexia.

Physical Mechanisms

As suggested by the higher rates of malnutrition in patients with aerodigestive tract tumors compared to other head and neck locations, HNC can contribute to malnutrition via mechanical barriers to appropriate oral intake [1, 3, 45]. Patients with aerodigestive tract tumors experience varying levels of dysphagia, odynophagia, and trismus, all of which can contribute to the development of malnutrition via insufficient oral intake. This is further compounded in patients requiring salvage surgery, as prior radiotherapy, chemotherapy, or surgery can compromise oral intake via alteration of normal anatomy, fibrosis, xerostomia, dysgeusia, and loss of dentition among other mechanisms [45, 46].

Patient Characteristics

Several of the behavioral and demographic characteristics frequently seen in the HNC patient population also contribute to malnutrition. Alcohol and tobacco use are well established as major risk factors for the development of HNC, and rates of alcohol and tobacco use are high among HNC patients [47]. Heavy alcohol use is associated with malnutrition due to micronutrient deficiencies and lifestyle disruption, with high levels of malnutrition seen in patients undergoing treatment for alcohol abuse [48, 49]. Likewise, tobacco use is associated with decreased oral intake and lower body weight, potentially due to appetite-suppressing effects of nicotine [50]. Alcohol and tobacco use are also both associated with perturbations in taste, which may further contribute to decreased oral intake [51]. HNC cancer patients also tend to be older, with more than 50% of patients over the age of 60 [52]. These older patients are also at risk for sarcopenia, age-related loss of muscle mass that further contributes to the loss of lean muscle seen in malnutrition [53].

Cancer Cachexia

Per consensus guidelines, cachexia is defined as "a multifactorial syndrome characterized by ongoing loss of skeletal muscle (with or without loss of fat mass) that cannot be fully reversed by conventional nutritional support and leads to progressive functional impairment" [54]. It is frequently seen in cancer patients, occurring in over 80% of patients with advanced-stage disease [54–56]. While a detailed review of cachexia pathophysiology is beyond the scope of this chapter, cancer cachexia results from complex interactions between tumor and host cells via humoral factors leading to perturbations in metabolism and organ system function, resulting in the loss of skeletal muscle [56]. Factors contributing to muscle loss include decreased anabolism via reduction in anabolic hormone secretion and sensitivity and amino acid availability, as well as increased catabolism due to chronic proinflammatory stimulation and increased oxidative stress [2, 56, 57]. Cytokine-mediated disruption of the neuroendocrine axis also leads to perturbations in orexigenic and anorexigenic pathways, resulting in decreased appetite and oral intake, which further contributes to loss of muscle mass [1, 2, 57]. Recent evidence also implicates a variety of other organ systems in the pathogenesis of cancer cachexia, including conversion of white adipose tissue to brown adipose tissue, abnormalities in liver metabolism, and changes in gut microbiota [1]. Compared to the other factors contributing to malnutrition, cancer cachexia is particularly difficult to address, as it is only partially responsive to conventional nutritional support.

Effects of Malnutrition on Head and Neck Free Flap Reconstruction

Within the general surgical literature, preoperative malnutrition is well established as a negative surgical prognostic factor, having been associated with increased length of stay (LOS), delayed wound healing, and increased rate of complications among other undesirable outcomes [58, 59]. Though there are only a few studies examining the effects of malnutrition on head and neck free flap reconstruction specifically, the available evidence supports that it is likewise associated with poorer postoperative outcomes.

In the largest study to date, a retrospective review of 977 patients undergoing resection of HNC with free flap reconstruction, patients who were malnourished as measured by Nutrition-Related Index (a composite score of albumin level and body weight) had significantly higher 30-day mortality compared to matched controls, along with higher rates of pulmonary complications, bleeding, and venous thromboembolism [60]. Similarly, another large retrospective study found a significant association in multivariate analysis between preoperative albumin and overall survival in patients with upper aerodigestive tract squamous cell carcinoma undergoing resection and free flap reconstruction [23].

Looking at other postoperative outcomes after head and neck free flap reconstruction, separate retrospective studies found an increased rate of wound infections and increased rate of major postoperative complications in patients with low BMI and history of malnutrition, respectively [61, 62]. Likewise, in two retrospective studies which calculated the volume of skeletal muscle mass from CT imaging as a measure of malnutrition, decreased muscle mass at L3 was associated with a variety of postoperative complications including higher rates of wound infection, fistula, wound breakdown, and flap-specific complications [14, 63]. Finally, outside of head and neck reconstruction, a retrospective study of extremity free flap reconstruction found a significant association on multivariate analysis between malnutrition as measured by a composite score of albumin and lymphocyte count and rate of flap failure [24]. Some caution must be taken in interpreting these results as there is a lack of prospective studies, which limits preoperative nutrition assessment to regularly collected data such as BMI and albumin rather than more robust assessments such as PG-SGA. Nonetheless, based on existing data, there is a clear association between preoperative malnutrition and poor outcomes after head and neck free flap reconstruction.

Nutritional Interventions

Given the high prevalence of malnutrition in HNC patients and the negative surgical outcomes associated with preoperative malnutrition, there is a clear need for nutritional intervention in this patient population. However, implementing these interventions successfully—including nutrition screening and supplementation prior to hospitalization, in the immediate preoperative period, and postoperatively—requires a well-defined clinical pathway with close collaboration between an interdisciplinary team and institutional buy-in. A possible framework for addressing these challenges can be found in Enhanced Recovery After Surgery (ERAS) protocols.

ERAS Protocols

ERAS protocols are "patient-centered, evidence-based, multidisciplinary team-developed pathways for a surgical specialty and facility culture to reduce the patient's surgical stress response, optimize their physiologic function, and facilitate recovery" [64]. ERAS protocols were initially developed to improve patient recovery and outcomes after open GI surgery, where there is strong evidence that implementation reduces LOS and results in fewer major postoperative complications [65]. ERAS protocols have subsequently been developed for a variety of other surgical fields including head and neck surgery, for which consensus ERAS guidelines were published in 2017 [66–68]. ERAS protocols address

all aspects of the perioperative process including non-nutrition factors such as standardized multimodal anesthesia and intraoperative fluid management. However, a significant portion of the protocols focus on nutrition optimization—prehospital, preoperative, and postoperative—and as such serve as an evidence-based example for implementing nutritional support in head and neck free flap reconstruction [66].

ERAS in Head and Neck Surgery

In 2017, an international working group of head and neck surgeons, anesthesiologists, intensivists, and nutritionists published a consensus, evidence-based ERAS protocol specifically for head and neck surgery with free flap reconstruction [66]. Based on existing ERAS protocols, the group identified best practices for 17 areas of perioperative care, many of which are nutrition focused. These include comprehensive nutritional assessment with preoperative nutrition intervention as indicated, minimization of preoperative fasting with carbohydrate loading, and initiation of postoperative feeding within 24 h with oral diet if possible. In a subsequent systematic review of 2630 head and neck free flap patients, enrollment in ERAS protocols was associated with significant decreases in hospital LOS, readmissions, and wound complications [69]. While these improvements cannot be solely attributed to the nutrition interventions in the protocols, they nevertheless illustrate the potential of improved perioperative nutrition management in this patient population.

Prehospital Patient Assessment

The first step in successfully implementing nutrition interventions is identifying patients who are malnourished or at nutritional risk. As such, all patients being evaluated in clinic for possible head and neck surgery with free flap reconstruction should undergo nutritional screening as a routine part of their preoperative workup. Simple, patient- or nursing-performed screening tools such as the PG-SGA short form or NRS 2002 are well suited for this purpose and should be integrated into the workflow of a standard clinic appointment. Any patient identified as malnourished or at nutritional risk should then be referred to a clinical nutritionist for a comprehensive nutritional assessment. This assessment should include patient history, anthropometry, biochemistry, dietary intake, and a clinical examination of body composition [66]. Based on this evaluation, a personalized nutrition plan should be created, including patient-specific adaptations such as enteric access and feeding in patients unable to tolerate an oral diet. There is wide consensus for preoperative screening and assessment including National Comprehensive Cancer Network, Cancer Council Australia, and UK National Multidisciplinary Guidelines [70–72].

Prehospital Nutritional Support

Given the strong evidence for worse surgical outcomes, there is consensus agreement that HNC patients assessed to be malnourished should receive nutritional support prior to surgery [59, 66]. Within the general surgical literature, preoperative nutritional support has been associated with lower rates of postoperative complications and shorter LOS [73–75]. Unfortunately, there is a lack of prospective studies specific to head and neck surgery; however, in one small RCT, preoperative nutrition support in HNC patients was associated with improved preoperative quality of life scores [76]. Consensus surgical nutrition guidelines strongly recommend that severely malnourished patients receive support—with time ranging from 5–7 to 10–14 days—prior to major surgery, even if surgery has to be delayed [59, 77]. Particularly in the case of oncologic surgery, the benefits of optimal nutrition support must be weighed against potential negative outcomes associated with delaying definitive surgery. However, in general, there is at least some delay between when the decision to operate is made and when surgery occurs due to logistical and administrative realities, giving time for appropriate support in most cases as long as evaluation by clinical nutrition and initiation of treatment are performed promptly.

The appropriate form of nutritional support is determined with the clinical nutritionist based on their comprehensive assessment and the patient's individual needs. Whenever possible, sufficient nutrition is maintained with an oral diet with high caloric and protein content. Symptomatic barriers to nutrition such as pain or xerostomia can be addressed with topical or systemic medications. Diet consistency can be modified, and intake can be augmented with supplements such as nutritional shakes. However, if a patient is unable to maintain sufficient oral caloric intake even with support, enteral nutrition should be initiated.

Enteral and Parenteral Nutrition

Access for enteral nutrition can be established either with a nasogastric tube (NGT) or with a gastrostomy tube. Gastrostomy placement is accomplished either percutaneously under endoscopic (PEG) or radiologic (PRG) guidance or with an open surgical procedure if patient anatomy is not conducive to minimally invasive access. Though tumor seeding to the gastrostomy site following PEG placement has been reported, newer techniques utilizing direct transabdominal placement rather than the traditional method of advancing the tube transorally may minimize this possibility [78]. In HNC patients undergoing radiotherapy or chemoradiotherapy, a systematic review of RCTs found no difference in overall patient satisfaction or complications between NGT and PEG [79]. However, in practice, NGTs are generally used when enteral nutrition is required for less than 4 weeks, while gastrostomy tubes are used for longer term feeding, as NGTs are more cumbersome and easier to dislodge [1, 10, 80].

A number of standard tube feed formulas are commercially available, as are a variety of specialty feeds such as low glycemic index feeds for diabetic patients and free amino acid feeds for patients with impaired GI function [1]. Depending on a patient's ability to tolerate PO, enteral feeding can be used as a supplement to oral feeding or as a sole source of nutrition. Type and volume of feeding are determined based on the results of the comprehensive nutritional assessment by clinical nutrition.

In the rare instances where an HNC patient cannot receive enteral nutrition, such as when enteral access cannot be established or with comorbid intestinal failure, parenteral nutrition can be provided preoperatively. In malnourished general surgical patients, preoperative parenteral nutrition is associated with improved postsurgical outcomes including decreased complications and LOS [58]. However, compared to enteral nutrition, parenteral nutrition is more expensive, is more complicated to administer, and may be associated with higher rates of infectious complications [81]. As such, parenteral nutrition should only be utilized when oral or enteral nutrition is not possible.

Immunonutrition

One of the defining features of cancer cachexia is the inability to fully reverse it with conventional nutritional support [54]. This is due to the metabolic, inflammatory, and immune perturbations associated with cancer cachexia, with patients exhibiting a chronic systemic inflammatory state with a shift from anabolism to catabolism [56]. As such, significant research has gone into the development of oral and enteral diets supplemented with specific nutrients thought to have a beneficial immune- and inflammation-modulating effects, known as immunonutrition or immune-modulating diets [82].

A variety of nutrients have been utilized in these dietary formulas based on their known physiologic roles, the most widely used of which are glutamine, arginine, omega-3 fatty acids, and ribonucleotides [81, 82]. Arginine is an amino acid involved in wound healing and immune function via its role in numerous synthetic and metabolic pathways including nitric oxide metabolism, collagen production, and normal T-cell, B-cell, and macrophage activity [83, 84]. Arginine is considered a conditionally essential amino acid, in that in can be synthesized de novo by the body, but can be depleted in times of metabolic stress or rapid tissue turnover as seen in cancer cachexia [82, 84]. Glutamine—another conditionally essential amino acid for which demand increases during catabolic disease states—serves as oxidative

fuel for immune cells and rapidly replicating cells such as GI mucosal cells and is involved in gluconeogenesis [85, 86]. Omega-3 fatty acids, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), competitively inhibit the production of proinflammatory arachidonic acid and decrease the expression of proinflammatory cytokines and adhesion molecules [87]. Ribonucleotides, as the constituent elements of DNA and RNA, are required for essentially all cellular processes and, like arginine and glutamine, require exogenous supplementation during times of metabolic stress [86]. A number of commercial immunonutrition formulas are available, containing varying combinations and concentrations of these elements.

The use of perioperative immunonutrition in general surgery is well established, with a number of systematic reviews of RCTs showing a decreased rate of postoperative complications and LOS [81, 88, 89]. Use of immunonutrition is also cost effective [90]. As such, multiple consensus guidelines strongly recommend perioperative immunonutrition in patients undergoing major cancer surgery [81, 91, 92]. However, there is no consensus on the ideal timing of immunonutrition, or if preoperative immunonutrition alone is more effective than standard nutritional supplementation [81, 93].

The use of immunonutrition in head and neck surgery is less well studied. A 2018 systematic review of 19 head and neck-specific RCTs examining the efficacy of perioperative immunonutrition found a significant decrease in the rate of postoperative fistula but no decrease in wound infections or LOS [94]. Most included studies were small, at high risk of bias, or both. Conversely, in a recent prospective study of HNC patients undergoing salvage surgery after radiotherapy—a group at increased risk for poor wound healing—use of preoperative immunonutrition was associated with decreased postoperative complications and LOS [95]. Large, well-designed studies are necessary to further elucidate the efficacy of immunonutrition in head and neck surgery as well as answer the questions regarding ideal timing, formulation, and use in certain patient subgroups.

Preoperative Nutrition

Avoidance of Preoperative Fasting

Traditionally, patients are instructed to fast starting at midnight before major surgeries due to concerns for aspiration during induction of anesthesia, meaning that they may go without nutrition or even fluids for eight or more hours prior to surgery even without taking into account any delays or changes in surgical scheduling. However, this is not supported by current evidence. In a meta-analysis of RCTs, a shortened fluid fast that allows clear fluids up to 2 h before surgery was not associated with increased aspiration, regurgitation, or morbidity [96]. This is reflected in the newest best practice guidelines from both US and international anesthesia societies, which allow for clear liquids up to 2 h before surgery and light meals up to 6 h before surgery [97, 98].

Conversely, fasting for even a short period of time prior to surgery is associated with undesirable physiologic changes. Fasting induces a catabolic state. This further contributes to metabolic stress and increases postoperative insulin resistance, making glycemic control more difficult [99, 100]. Postoperative hyperglycemia in HNC patients undergoing free flap reconstruction has been associated with higher rates of surgical site infection [101]. Preoperative fasting is also associated with increased inflammation, decreased immune functioning, and increased patient discomfort and anxiety [102–105]. Because of this, there is strong expert consensus that preoperative fasting should be limited as much as possible including in head and neck surgery [66, 81, 91].

Carbohydrate Loading

Given the deleterious effects of preoperative fasting, ERAS protocols advocate for carbohydrate loading in patients prior to surgery with a carbohydrate-rich drink [65, 81]. While exact protocols vary, patients are commonly given 800 mL of a 12.5% carbohydrate drink at midnight prior to surgery and another 400 mL 2 h before surgery [59, 65]. A variety of commercial formulations are available to patients over the counter. In several systematic reviews of RCTs,

use of preoperative carbohydrate loading was associated with increased insulin sensitivity and improved postoperative discomfort [106–108]. Effect on LOS is equivocal, with the most recent review finding a small decrease in LOS compared to fasting but not to water or placebo [108]. No difference was seen in postoperative complications, and notably, no aspiration events were seen in any of the included studies. Other individual RCTs have associated carbohydrate loading with improved preoperative comfort, decreased postoperative inflammation, enhanced immune function, and better retention of muscle strength both 1 week and 1 month after surgery [102–105, 109]. The overall quality of existing trials is low, and there is a lack of head and neck surgery-specific trials. Nevertheless, the ERAS head and neck protocol offers the option for preoperative carbohydrate loading given the low cost, minimal associated risks, and well-established benefit to patient comfort, if nothing else [66, 81].

More recent studies have also examined the efficacy of adding whey protein to preoperative carbohydrate drinks, theorizing that it may further decrease inflammation and improve postoperative recovery [110–112]. In an RCT of HNC patients undergoing surgery, the addition of whey protein to standard preoperative carbohydrate loading was associated with decreased postoperative complications and no instances of aspiration [113]. However, given the small size of the trial, more evidence is needed to make informed recommendations regarding preoperative whey protein use.

Postoperative Nutrition

Postoperative Feeding

Optimal nutritional management of HNC patients undergoing free flap reconstruction does not end at the time of surgery, but rather continues through the postoperative period. A major topic of investigation within the surgical nutrition literature has been the appropriate timing for resuming feeding after surgery. Though there is a lack of head and neck-specific studies, multiple systematic reviews of RCTs from the GI surgery literature found that resumption of feeding—either enteral or oral—within 24 h of surgery resulted in shorter LOS and potentially a decrease in postoperative infections and other complications [114, 115]. Early feeding was also not associated with any increased morbidity. As such, there is wide consensus among surgical nutrition guidelines and ERAS protocols—including for head and neck surgery—that feeding should be resumed within 24 h of surgery [65, 66, 81, 91].

Early Oral Feeding

As discussed above, there is clear evidence that early feeding in general is beneficial to postoperative recovery. In line with the principle that oral feeding is always the preferred route of nutrition when feasible, there is also evidence that early oral feeding specifically may convey additional benefits compared to early enteral or parenteral nutrition. In a systematic review of trials comparing early oral feeding to traditionally timed feeding ± early enteral or parenteral nutrition in 2112 patients undergoing upper GI surgery including esophagectomy, early feeding was associated with a decreased LOS [116]. No increase was seen in mortality or in postoperative complications including anastomotic leak.

However, early postoperative oral feeding in HNC patients is more controversial. Per the ERAS head and neck protocol, after free flap reconstruction, "oral diet is the first choice for all patients tolerating it" [66]. Yet, there are a number of reasons why these patients may not be able to tolerate oral feeding in the early postoperative period. Fundamental changes in upper aerodigestive tract anatomy resulting from surgery and reconstruction may render patients unable to safely tolerate an oral diet. Patients who will be able to tolerate an oral diet in the long term may nevertheless be unsafe for an oral diet in the early postoperative period due to swelling and a need to learn compensatory swallowing techniques. Finally, there has traditionally been a concern that early oral feeding may compromise the surgical site, leading to flap dehiscence, poor wound healing, or fistula formation.

Early oral feeding has been best studied after total laryngectomy. In a systematic review of 14

studies (4 RCTs, 10 cohorts, 1886 total patients) comparing the rate of fistula formation in patients started on oral feeding on or before postoperative day (POD) 5 versus after POD 5, no increased rate of pharyngocutaneous fistula formation was seen in the early feeding group [117]. The early feeding group also had a decreased LOS in the two studies which used it as an outcome measure. There was also no increased fistula rate with early feeding in a subgroup analysis of studies in which >40% of patients were undergoing salvage surgery, an important finding for clinical practice given an increasing percentage of salvage surgeries due to increasing rates of primary treatment with nonsurgical therapies [118, 119]. However, another systematic review published around the same time found an increased risk of fistula with early feeding, though no increase was seen when only including RCTs [120].

Among other head and neck subsites, a number of studies have examined early feeding after oral cavity free flap reconstruction [121–124]. In the largest study, 400 patients (212 with previous radiotherapy or chemoradiotherapy) were either given nothing per mouth until POD 5 or evaluated for oral fluids ± soft diet on POD 1 [124]. In the early feeding group, 46% were able to tolerate oral fluids and 30% were able to tolerate a soft diet on POD 1, which increased to 94% and 84% by POD 3. In line with prior studies, there was no increase in fistulas, flap dehiscence, or other complications in the early feeding group, while LOS was significantly reduced [121, 122, 124].

Overall, while available evidence supports that early feeding after total laryngectomy or oral cavity free flap reconstruction is likely safe and may reduce LOS, there is a lack of large, randomized trials. As such, appropriate caution should be taken in implementing early feeding, with patients assessed on an individual basis. A team-based approach with collaboration between surgeon, dietician, and speech language pathologist should be used to determine the optimal timing for restarting oral intake [66].

Comprehensive Nutrition Management Pathway

Successfully implementing comprehensive nutrition management for HNC patients undergoing free flap reconstruction requires a multidisciplinary team and institutional support. The following section outlines the key steps of a head and neck free flap nutrition pathway based on the current evidence and best practice guidelines previously discussed in this chapter, and how these steps fit into clinical practice.

All patients should undergo nutrition screening at their initial visit with their head and neck surgeon, and those found to be malnourished or at risk for malnutrition should be referred to clinical nutrition for comprehensive assessment and initiation of appropriate nutritional support. It is critical that referred patients are seen by a nutritionist in a timely manner in order to give sufficient time for support without delaying surgery. Patients can also be referred to IR or GI at this time for PEG placement if it is anticipated that they will require more than a month of enteral nutrition. In the immediate preoperative period, patients should be allowed to have clear liquids by mouth until 2 h preoperatively, with a carbohydrate drink given 6 h and 2 h preoperatively. Implementation of these preoperative interventions must be done in close collaboration with anesthesia in order to ensure that they are implemented safely and do not result in cases being delayed. Postoperatively, feeding should be resumed within 24 h of surgery, either orally or via enteral access. Early oral feeding can be considered in patients who underwent total laryngectomy or oral cavity resection; however, the decision on optimal timing and need for supplementary tube feeds should be made in collaboration with clinical nutrition and speech language pathology. Diet supplementation with immune-modulating nutrients can also be considered throughout the perioperative period, particularly in patients at high risk for poor wound healing.

Conclusion

HNC patients are at high, multifactorial risk for preoperative malnutrition due to the nature of their disease process. Malnourishment, in turn, is associated with a variety of negative outcomes following head and neck surgery with free flap reconstruction including higher rates of major complications and increased 30-day mortality. As such, it is critical that malnutrition be identified and interventions initiated prior to surgery, and that nutrition monitoring and appropriate nutritional support are continued throughout the entire perioperative period. ERAS protocols, which have been increasingly adopted across surgical fields, provide a multidisciplinary, evidence-based framework for the implementation of comprehensive perioperative nutritional management. Larger prospective, randomized trials are necessary to better assess the effectiveness and safety of nutrition interventions in HNC patients undergoing free flap reconstruction, particularly regarding immunonutrition and early oral feeding.

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Pain Management

13

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Introduction

Head and neck cancers (HNCs) are a significant public health problem, with over 350,000 new cases diagnosed yearly and 150,000 deaths annually worldwide [1]. The disease process and morbidities of treatment have a profound effect on the quality of life. In addition to cosmetic changes and functional challenges, patients frequently suffer from acute and chronic pain. This chapter discusses pain management strategies for patients undergoing complex head and neck microvascular reconstructive surgery.

Physicians strive to minimize psychological and physiologic stresses associated with surgery and pain. Furthermore, we seek to mitigate side effects and associated risks with opioid prescriptions. Adequate perioperative pain management is integral to patient care and outcomes. Each of the biological, psychological, and social dimensions of the pain experience should be considered and explored to provide optimal perioperative pain management [2]. Ensuring adequate analgesia is crucial for patient comfort and enhances early ambulation, minimizes deconditioning, decreases length of stay, mitigates cardiac and pulmonary complications (i.e., reduces the risk of venous thromboembolism), improves recovery, reduces the likelihood of developing chronic pain, and reduces healthcare cost [3]. Providing adequate analgesia may be challenging as mainstay treatments like opioids have significant side effects and addiction potential. The use of multimodal analgesia has been studied in patients undergoing major head and neck surgeries and should be used as part of routine pain management. Multimodal techniques aim to reduce total opioid consumption and their associated side effects. Various pharmacologic and nonpharmacologic options for analgesia are discussed in this chapter.

Factors Associated with Pain

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage. The head and neck are richly innervated with many anatomical structures confined in a small space contributing to high sensitivity to pain [4]. Pain associated with head and neck reconstruction has characteristics of nociceptive and neuropathic pain types. Nociceptive pain is caused by tissue injury, whereas neuropathic pain

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is from nerve injury. Although seemingly similar, their descriptions and treatments may be unique.

Factors that correlate with the severity of postoperative pain include preoperative opioid use, increased body mass index, anxiety, depression, extensivity of surgery, and duration of surgical operation. Depression and anxiety are associated with increased perception of pain severity, whereas prolonged duration of acute pain leads to increased mood dysregulation [5]. In certain cases, consulting a psychiatrist preoperatively can aid in utilizing psychodynamic, behavioral, and pharmacologic modes of treatment [6]. Physicians should recognize that an individual's perception, expression, and reaction to pain are influenced by genetic, developmental, familial, psychological, social, and cultural variables. Each of these factors of the pain model can profoundly affect the experience of pain in each patient to varying degrees. Understanding these factors helps physicians individualize their approach to pain management within the framework of the biopsychosocial model. Physicians can identify and potentially intervene on these patient factors. With the help of case managers and social workers, clinical pathways can be developed to address sociocultural variables. Other independent factors that affect postoperative interpretation of pain include attention to pain and understanding, control, and expectation of pain. Data supports a correlation between higher cerebral function and perception of pain [7]. As personalized medicine grows, we may be able to offer patients more effective medications based on their underlying genetic factors.

Pain management considerations for patients undergoing head and neck free flap surgeries begin before the operation occurs. Physicians should set reasonable expectations for the degree of pain patients generally experience after free flap surgery. The initial postoperative period is the most painful, and pain normally reduces in subsequent days to weeks. Extended resection, flap coverage, nerve lesions, inflammation, and high-dose opioid administration can lead to hyperalgesia and, at worst, chronic postoperative pain [8]. Causes of inadequate postoperative analgesia include lack of reasonable pain expectations, complications, medication tolerance and side effects, and poor pain assessment [9]. Counseling should focus on minimizing opioid use, including instructions on how to safely taper off. The tapering process can take days to weeks or months, depending on the patient and his/her opioid use patterns. Follow-ups should be scheduled to screen for opioid dependence, guide tapering, and assess for persistent pain. Clinical pathways developed at the departmental or institutional level provide patients and physicians with appropriate preoperative planning and counseling centered around what to expect on the day of surgery and the postoperative course thereafter.

Opioids

Most opioids are synthetic derivatives of morphine, which was first isolated from poppy plants in 1804 and is still used. Opioids play a vital role in analgesia as they are considered the treatment of choice for moderate-to-severe pain and recommended for patients who are unresponsive to other types of analgesic medications [10, 11]. Opioids vary based on their receptor affinity and agonist qualities. Opioids are classified as pure agonists, agonists-antagonists, or partial agonists. For acute postoperative analgesia, pure opioid agonists are most frequently chosen, whereas partial agonists and antagonists are utilized in the treatment of chronic pain and/or substance use disorders. Opioids are chosen and dosed based on their pharmacokinetics and pharmacodynamics within the context of each patient's history. Opioid use is associated with side effects, including postoperative nausea and vomiting, constipation, sedation, hypotension, and respiratory depression. These side effects, if present, create barriers to patients' postoperative recovery.

Chronic opioid use is a global health problem, and surgery is often the point of initial exposure for many chronic opioid users [12]. A retrospective study showed a considerable prevalence of chronic postoperative opioid use in patients who have undergone major resection with free flap reconstruction for head and neck cancers, with

52% of opioid-naïve patients continuing to use opioids at 3 months and 41% at 12 months postoperatively. In chronic opioid users, 82% continued opioid use at 3 months and 77% at 12 months postoperatively [13]. Preoperative opioid use, prior tobacco use, and advanced pathologic T-stage were identifiable risk factors for chronic opioid use in patients undergoing free flap reconstructive surgeries. Patient age may also factor into pain experience. One study showed that continued opioid use was common in younger patients (under 60 years of age), whereas older patients had fewer opioid refills [14]. Growing evidence supports an association between opioid use in the acute postoperative period and subsequent development of chronic opioid use [12, 15–17]. State prescription monitoring programs can be used to verify medication history to screen for patients at risk for potential use disorder.

Opioids can be rotated or converted based on their equianalgesic dose (Table 13.1); however, the side effect profiles are the same at equianalgesic doses. If patients are on opioids for a long term, they are at risk for withdrawal if abruptly discontinued. Withdrawal, while unpleasant, is not life-threatening. For patients who suffer from chronic pain or use opioids at baseline as outpatients, physicians should attempt to mitigate these patients' baseline pain. Perioperatively, patients should continue their basal analgesic medications. Some physicians may attempt to decrease baseline opioid use or encourage involvement in therapy or behavioral modifications to decrease patients' pain prior to surgery. For patients on chronic opioid maintenance therapy (i.e., buprenorphine or methadone), physicians may consider consulting addiction specialists to participate in a multidisciplinary care team to assist with any necessary dose adjustments. Maintenance medications should be continued perioperatively, including buprenorphine-naloxone and methadone. Other medications, such as naltrexone, should be held. The timing and perioperative planning must be coordinated with an anesthesiologist or perioperative physician in advance of surgery [18]. Patients with concomitant psychological pathologies, including poorly controlled major depressive disorder, may meet indications to consult psychiatry to reduce postoperative complications like worsening of preexisting psychiatric disorders. Multidisciplinary hospital pathways may be created to decrease a patient's preoperative opioid use by 10–30% prior to their surgical admission, if able.

Table 13.1 Equianalgesic opioid dosages. When converting between opioids, the physician must decrease the dose offered (by 25–50%) to account for **cross-tolerance** or differences in opioid binding affinities. Failing to account for cross-tolerance puts a patient at risk of adverse events, such as respiratory depression. mg = milligram

	Intravenous	Oral
Morphine	10 mg	30 mg
Oxycodone	–	20 mg
Hydromorphone	1.5 mg	7.5 mg
Fentanyl	0.15 mg	–

If complex HNC patients must be NPO postoperatively or must use a gastric tube, analgesic medication administration should be altered. If patients who are on chronic or long-acting oral opioid therapies are limited to using a gastric tube or parenteral administration postoperatively, their long-acting medications need to be converted into a regimen that would provide appropriate, equianalgesic basal analgesia either enterally, intravenously, or transdermally. Long-acting opioids, such as MS Contin® or OxyContin®, cannot be crushed for administration into a gastric tube. Consider consultation with the acute pain service or pharmacists for guidance. Parenteral opioids can be used postoperatively, although currently there are no long-acting parenteral formulations available for use. However, when patients are able to tolerate an oral regimen, parenteral opioids should be converted to an oral (or per gastric tube) regimen as swiftly as possible as oral medications provide longer lasting analgesia.

Providing patients with **patient-controlled analgesia (PCA)** is safer than ordering nurse-administered intravenous opioid boluses. A PCA regimen consists of an infusion pump delivering a programmed dose of medication in response to the patient pushing a demand button. There are inherent safety facets when using a PCA, including that only the patient is to push the demand

Table 13.2 Standard intravenous PCA starting settings for opioid-naïve patients [19]. Generally, continuous infusions are limited to pediatric patients or complex opioid-tolerant patients. If considering starting a continuous infusion, it is prudent to seek expertise from pain service physicians. mg = milligram; mcg = microgram

	Morphine	Hydromorphone	Fentanyl
Demand dose	1 mg	0.2 mg	10 mcg
Lockout	Every 6 ***or*** 10 min	Every 6 ***or*** 10 min	Every 6 min
Continuous infusion	0	0	0
1 h limit	10 mg ***or*** 6 mg	2 mg ***or*** 1.2 mg	100 mcg

button, and if the patient becomes sleepy, he/she will not be able to activate his/her demand. Consequently, PCAs decrease the risk of inadvertent overdose. Furthermore, providing patients with an independent way to administer analgesics as needed can be helpful for patients' sense of control, eliminating administrative delays, and better approximating patients' variable analgesic needs. Common PCA settings are listed in Table 13.2. PCAs can help physicians understand a patient's opioid consumption over 24 h, and this data can help guide appropriate as-needed (PRN) opioid dosing. Some patients, however, such as those who are confused or delirious, may not be able to use a PCA effectively, and alternatives should be implemented.

Multimodal Analgesia

Multimodal analgesia is designed to reduce or eliminate opioid use [20]. Rather than relying solely on opioids, other analgesic modalities should be offered if and when appropriate. The mechanisms and pathways of pain signaling play a role in pharmacologic targets. As part of optimal perioperative care in head and neck reconstructive surgeries, effective pain management is an important goal of the **Enhanced Recovery After Surgery** (ERAS) protocol and includes multimodal analgesia [21]. Multimodal analgesia is the concurrent use of more than one modality of pain control to achieve effective analgesia, with opioids reserved for severe refractory pain [20]. An understanding of the physiologic basis of pain allows physicians to appropriately choose pharmacologic agents to target pain.

Pain occurs when mechanical energy of noxious stimuli is converted into electrical energy, which is propagated by ascending sensory neurons. Local anesthetics target these first-order sensory neurons. The synthesis of local inflammatory mediators, such as prostaglandins, can be inhibited by cyclooxygenase (COX) inhibitors. The initial sensory transmission from first-order afferent nociceptive fibers synapses in the dorsal horn of the central nervous system (CNS) using neurotransmitters, including substance P, prostaglandins, adenosine, and glutamate. From the dorsal horn, the second-order neurons of the spinothalamic tract decussate and ascend the spinal cord to reach the thalamus. The trigeminothalamic tract supplies the head and face. Signals reaching the thalamus are processed by the ventral posterior nucleus (VPN) and transmitted to the cerebral cortex via the posterior limb of the internal capsule. This ascending pathway initiates conscious realization of pain. At the cerebral cortical level, pain is a subjective experience that varies in perception. A concomitant descending efferent pain pathway, originating within the hypothalamus, modulates the sensation of pain. This endogenous "pain-inhibiting" system is the target of some analgesic therapies, including opioids. Stimulation of the periaqueductal gray within the midbrain activates enkephalin-releasing neurons that descend to the raphe nucleus in the brain stem. Serotonergic neurons from the raphe synapse with inhibitory interneurons within the substantia gelatinosa, resulting in the release of enkephalin and dynorphin. Descending noradrenergic fibers from the locus coeruleus of the brain stem modulate ascending pain signals. This explains some of the physiologic hyperadrenergic manifestations of pain such as hypertension and tachycardia. These manifestations may be detrimental in microvascular surgeries intraoperatively and postopera-

tively. Many of the analgesic agents target receptors of the ascending and/or descending pain pathway; thus, understanding the neurophysiologic basis of pain transmission and perception can help physicians provide superior analgesia.

Multimodal analgesia is successful because it targets different pain signaling molecules or directly affects receptors involved in the pain pathway. It is best clinical practice to use a multimodal approach to manage patients' pain during their hospital course [22]. A multimodal approach can be implemented preoperatively, intraoperatively, and postoperatively. Preoperatively treating patients with analgesic medications to reduce postoperative pain is known as preemptive analgesia and has become part of multimodal pain pathways that have been applied to many types of surgeries, including head and neck cancer surgery [23]. Preoperatively, patients can be administered oral or intravenous medications. Preemptive analgesia has been shown to delay time to the first analgesic request and reduce total analgesic use [24]. Timing of administration has not been shown to make a significant difference in effect, thus giving preemptive analgesics immediately before surgery is acceptable. The most frequently used preemptive analgesics are acetaminophen and gabapentin [22]. Multimodal analgesia reduces opioid use intraoperatively and in the postanesthesia care unit (PACU) when patients are administered preoperative oral celecoxib, gabapentin, and/or tramadol [25]. A large systematic review study showed that gabapentinoids were the most commonly used non-opioid (72.9%) followed by nonsteroidal anti-inflammatory drugs (NSAIDs) (44.6%), acetaminophen (44.3%), corticosteroids (25.1%), ketamine (7.2%), and nerve block (3.4%) [22]. The use of multimodal analgesia is associated with significant reductions in opioid use and concomitantly decreases opioid-related adverse events (ORAEs) [26]. Patients who receive multimodal analgesia have lower pain scores in the postoperative period (POD 0–6) compared to opioid-only counterparts [20]. Of the multimodal analgesic regimens studied, none have demonstrated increased incidence of postoperative hematomas or flap failure, even with the use of NSAIDs [27]. Topical applications, such as topical capsaicin, lidocaine, or diclofenac, may be beneficial for patients. These medications are well tolerated but should be limited in certain patient populations.

Lidocaine and ketamine infusions are viable options but depend on the expertise of intraoperative anesthesiologists or postoperative acute pain specialists and require investment from hospital systems to ensure safe and effective applications [8]. A multidisciplinary, dynamic approach to pain management for patients undergoing free flap surgery must be tailored to each patient. When possible, multimodal analgesic approaches should be implemented to decrease the risk of opioid dependence and ORAEs, provide better perioperative analgesia, and enhance recovery after surgery.

Acetaminophen

Most multimodal analgesic approaches include the use of acetaminophen. Acetaminophen, also known as paracetamol, was first synthesized in 1877 and is widely used over the counter as an antipyretic and analgesic. Acetaminophen is inexpensive and has minimal side effects when used in appropriate doses. Acetaminophen has two mechanisms of analgesic action. First, prostaglandin synthesis is inhibited through cyclooxygenase-1 (COX-1) and, mainly, COX-2. Second, the active paracetamol metabolite is formed in the CNS and acts as a weak agonist of cannabinoid receptors CB1 and CB2 [28]. In addition to its role in preemptive analgesia, acetaminophen has been proven to provide effective analgesia in the postoperative phase of care [29]. Onset of action of oral acetaminophen can take up to 1 h, whereas intravenous acetaminophen provides analgesic effect within 5–10 min and peak analgesia within 1 h. Studies have demonstrated that intravenous acetaminophen may play a role in reducing the total narcotic requirement in the first 8 h after surgical resection of head and neck cancer surgery and contributes to alleviation of postoperative pain, decreased length of stay, and

potentially decreased cost to the patient and hospital overall [30]. Current recommendations suggest a maximum of 3–4 g administered in a 24-h period. In patients with hepatic dysfunction, a maximum of 2 g should be administered in a 24-h period. Acetaminophen is known to be hepatotoxic; thus, caution should be used in patients with liver pathology. Otherwise, acetaminophen is well tolerated with minimal side effects and low addictive potential, making it essential to the multimodal analgesic approach.

Nonsteroidal Anti-inflammatory Drugs (NSAIDs)

An important component of multimodal analgesia is NSAIDs. Medications such as celecoxib, ibuprofen, and naproxen are within this class of drugs, most of which are widely used and easily accessible over the counter. Most conventional NSAIDs are nonselective competitive inhibitors of COX-1 and COX-2 and work by inhibiting the conversion of arachidonic acid to prostaglandins and thromboxane. Prostaglandins play a role in initiating the inflammatory response, local vasodilation, and sensitization to pain and hyperalgesia. Thromboxane induces vasoconstriction and platelet aggregation. Although celecoxib, unlike COX-1 inhibitors, has been shown to have minimal inhibitory effects on platelet aggregation, there have been case reports of associated surgical bleeding [21]. While these medications are generally well tolerated, their manufacturers report considerable risk including gastric ulceration/bleeding, renal failure, and increased risk of serious (and potentially fatal) adverse cardiovascular thrombotic events, including myocardial infarction and stroke. Risk may occur early during treatment and may increase with duration of use. The use of NSAIDs should be avoided in patients with creatinine clearance (CrCl) less than 30 and/or on hemodialysis as NSAIDs may increase the risk of acute kidney injury and renal failure. It is recommended to use the lowest effective dose for the shortest duration of time, consistent with individual patient goals, to reduce the risk of adverse effects. Selective COX-2 inhibitors (i.e., celecoxib) were thought to be associated with increased risk of thrombosis by promoting an imbalance of prostacyclin and thromboxane; however, studies have demonstrated that the use of celecoxib does not have deleterious effects on free tissue transfer survival or healing [31]. The American Head and Neck Society showed that the use of celecoxib after head and neck free flap reconstructive surgery provides effective analgesia and reduces oral, intravenous, and total opioid consumption perioperatively without increasing surgical flap-related complications [32]. NSAIDs are an effective adjuvant and should be considered as part of a multimodal analgesic regimen.

Gabapentinoids

Recent studies have shown that gabapentinoids do not have clinically significant analgesic effects. Their use is not routinely recommended in the perioperative setting by the American Society of Anesthesiologists [33]. Despite these recommendations, some clinical pathways include gabapentin as part of their multimodal analgesic pathway. Though gabapentin is not routinely used for the management of postoperative pain, evidence supports use of gabapentin to improve pain control and significantly decrease opioid use in the acute postoperative setting in head and neck free flap surgery [26]. In reconstruction surgeries involving the tongue, studies have shown that administration of a single preoperative dose of gabapentin improves analgesia while decreasing opioid requirements (measured in morphine equivalents), sedation scales, and antiemetic usage without additional side effects or surgical complications [34].

Gabapentin, which acts on voltage-gated calcium channels, was initially marketed as an anticonvulsant and is currently used for neuropathic pain. Contrary to its name, it has no GABAergic action. Gabapentinoids exert their mechanism of action by reducing the activation of excitatory calcium channels and decreasing neuronal signaling within the pain signaling pathway. Gabapentinoids have the potential to be misused,

especially in patients with a history of substance use disorder [35]. Currently, no intravenous formulations of gabapentinoids exist, limiting its use to patients with enteral access. Gabapentinoids undergo minimal metabolism; however, patients with concomitant renal dysfunction need cautious dosing as drug elimination is altered significantly with decreased creatinine clearance. If taken for an extended period of time, gabapentin needs to be tapered off rather than abruptly discontinued to avoid symptoms of withdrawal and possible seizures. For similar reasons, patients taking gabapentin chronically should continue their home dose throughout the perioperative period.

Ketamine

Ketamine at higher doses induces a trancelike, dissociated state that provides analgesia, amnesia, and sedation [36]. Ketamine preserves spontaneous respirations, airway reflexes, and cardioacceleratory effects including increased blood pressure and heart rate [36]. These unique properties of ketamine may be favorable in selected patient populations but detrimental in others. At lower subanesthetic dosing, such as 2–5 μg/kg/min, ketamine is an effective adjuvant analgesic and reduces opioid consumption, pain level, nausea, and vomiting [37]. Ketamine mitigates hyperalgesia associated with opioids and is beneficial for surgical patients when severe postoperative pain is expected or for opioid-tolerant patients [37]. Ketamine is contraindicated in patients with severe cardiovascular disease including uncontrolled hypertension and unstable angina, poorly controlled psychosis, and severe liver disease and used with caution for patients with elevated intracranial or intraocular pressures [37]. Ketamine exerts its effects as a N-methyl-D-aspartate (NMDA) receptor antagonist, and its metabolite, norketamine, also has analgesic properties [38]. Within the spinal cord, NMDA receptor antagonism produces analgesia by preventing central sensitization in dorsal horn neurons [39]. Ketamine has a similar chemical structure and NMDA receptor activity as phencyclidine, and ketamine has misuse potential [40]. However, there is no data to suggest that a short course of ketamine while in a hospitalized setting increases the risk of misuse.

Lidocaine

Lidocaine is a local anesthetic with a wide range of clinical applications. Local anesthetics provide analgesia to the location in which they are applied. For example, viscous lidocaine may be applied over areas of discomfort, such as sutures that may anchor nasogastric tubes. Topical lidocaine is formulated in different concentrations, most commonly 2% and 4%. Lidocaine formulations include ointments, jelly, and sprays, all of which can be used to provide local anesthetic effects. Lidocaine is commonly used to infiltrate subcutaneous tissue and reduce incisional pain. Importantly, because of its wide availability and rapid effects, topical lidocaine can be used to prevent and treat vasospasm, which has an adverse effect on the survival of free tissue transfers [41]. Prolonged vasoconstriction decreases blood flow to the flap and promotes thrombosis at the anastomotic sites. Intravenous lidocaine, which has been incorporated into some ERAS pathways, effectively mitigates postoperative pain with relief persisting for 48 h after infusion ceases [42]. The mechanism for mitigating acute perioperative pain is unclear but may be related to a priming blockade of granulocytes, which could limit the exaggerated release of cytokines and reactive oxygen species [43]. The use of intravenous lidocaine infusions for postoperative pain can be implemented upon consultation with an acute pain expert. Risks associated with intravenous infusions are mainly related to local anesthetic systemic toxicity; an overdose may affect the central nervous system (presenting as drowsiness, confusion, euphoria, double vision, seizures), cardiovascular system (presenting as hypotension, bradycardia, arrhythmias, cardiac arrest), respiratory system (presenting as tachypnea, apnea), or hematologic system (causing methemoglobinemia) [8]. One of the first signs of acute toxicity is tinnitus, which cannot be

assessed in a patient under general anesthesia. However, the doses for adjuvant analgesia are safe and result in plasma concentrations (5 μg/mL) far below toxic levels [42]. Weight-based lidocaine regimens in studies have shown that 1.33–3 mg/kg/h achieved adequate plasma concentrations of 2–5 μg/mL [42]. Caution should be taken when prescribing lidocaine infusions in patients with cardiac dysfunction or hepatic dysfunction, which may impair lidocaine metabolism. The toxic dose of lidocaine is 5 mg/kg or lidocaine with epinephrine is 7 mg/kg.

Regional Anesthesia Techniques

In some cases, perioperative peripheral nerve blockade can be performed, depending on anatomical surgical considerations and expertise in the field of regional anesthesiology. Peripheral nerve blocks can be used in combination with general anesthesia as an adjuvant part of multimodal analgesia. Regional anesthetic techniques provide visceral and/or somatic analgesia or dermatomal distribution of analgesia, depending on which nerve(s) or fascial planes are selected for the block. Knowledge of anatomy and sensory innervation is crucial when considering which nerve blocks to perform.

Donor skin graft sites tend to cause patients a significant amount of postoperative pain, and regional anesthesia techniques including single-shot peripheral nerve blocks or peripheral nerve catheter placement can be performed to anesthetize these donor sites. For example, patients who undergo harvesting of donor skin from the lateral thigh can receive ultrasound-guided **lateral femoral cutaneous nerve** (LFCN) blocks to provide simple and safe analgesia. Similarly, for free fibular flap donor sites, combined **femoral** and **common peroneal nerve blocks/catheters** are an effective method of postoperative analgesia, reducing opioid use and improving patient satisfaction [44]. Contrary to single-shot peripheral nerve blocks, peripheral nerve catheters allow for continuous infusion of local anesthetic.

Peripheral nerve catheter utilization is a safe and effective form of analgesia for lower extremity free flap surgery and significantly reduces opioid use and ORAEs and may have an added benefit of shorter length of stay [45]. Perioperative pain causes an increased sympathetic tone leading to peripheral vasospasm. All local anesthetics have vasodilatory properties, which may negate the vasospasms associated with pain. The use of regional anesthetic techniques can mitigate the sympathetic outflow associated with pain and is safe for microvascular surgeries as they have not been shown to compromise microsurgical outcomes [45]. These analgesic techniques are limited by surgeon and anesthesiologist skill and collaboration. Local anesthetics are well tolerated and used as an excellent part of a multimodal analgesic approach. Nerve catheters, however, should be used with caution in some patients, including those susceptible to bleeding, due to the rare risk of developing hematomas caused by catheter insertion or removal that could cause nerve compartment compression [46]. In addition, caution should be taken in patients with systemic disease or infection as these conditions alter serum pH and affect anesthetic absorption kinetics [46].

Though not widely utilized, facial nerve blocks in the head and neck have been used for analgesia in patients undergoing different types of major head and neck surgeries [47]. These techniques are individualized depending on anatomical factors of the surgical reconstruction as certain peripheral target nerves may be involved in the surgical resection. The sphenopalatine ganglion block (SPG), also known as pterygopalatine ganglion block, has been utilized for chronic pain [47]. The SPG contains motor, autonomic, and sensory fibers that innervate the hard palate, soft palate, tonsils, nasal, and pharyngeal mucosa. The SPG block can be performed in an awake or anesthetized patient using a transnasal or transoral approach. A transoral approach is more difficult technically. The SPG block is effective in the treatment of acute migraine headaches; however, clinical data is sparse regarding its utility in major reconstructive surgery [47].

Indications for Pain Management Service Consultation

Most acute pain services are either anesthesiologist-based or given by mid-level provider with physician supervision. The goals of an acute pain service include coordinating care with other physicians, nurses, pharmacists, and therapists in an attempt to minimize patient discomfort and treatment complications [48]. Some institutions limit using certain analgesics, such as ketamine infusions, and require consultation with an acute pain specialist. Regular pain assessments and documentation of pain scores are an important component of assessing and minimizing pain as frequent assessments increase the likelihood that patients' pain remains below an acceptable, predetermined threshold [9]. One of the most important elements of an acute pain service is cooperation among all involved healthcare professionals to develop protocols and achieve evolving goals for postsurgical mobilization and discharge. The benefits of an acute pain service have been demonstrated in a number of studies and show that patients report overall improvement in postoperative pain scores, patient satisfaction, and sleep pattern after interfacing with an acute pain service [48]. Acute pain service consultations are helpful for patients requiring complex pain management to achieve adequate analgesia. For example, these experts help manage PCA pumps, and lidocaine and ketamine infusions, and place regional nerve blocks and catheters. If physicians find themselves using high doses of opioids, consulting an acute pain service may be appropriate. Some patient populations are likely to have inadequate analgesia including patients with substance use disorder and those who are on chronic opioid antagonist treatment. Chronic opioid antagonist treatment upregulates opioid receptors and produces functional supersensitivity [49]. Forming a perioperative plan that incorporates preoperative planning, intraoperative dosing strategies, and postoperative follow-up can prevent delays in discharge and facilitate swift recovery.

Other Analgesic Modalities

Understanding the opportunities within one's practice system, such as exploring the structure of pet therapy, music therapy, or virtual reality, can improve patients' perceptions of pain. There is ongoing research into new non-opioid analgesics and other ways to mitigate pain.

Psychological interventions including strategies targeted toward reducing stress, anxiety, negative emotions, and depression using education, therapy, behavioral modifications, and relaxation techniques are emerging approaches toward improving patients' pain perioperatively [50]. Virtual reality is an emerging modality that effectively reduces pain as an adjuvant therapy in hospitalized patients [51] and may also reduce chronic pain [50]. Further research needs to assess the extent to which one needs to be immersed and present in a virtual environment in order to reduce pain, and the dosage necessary to maintain pain reductions in chronic pain over time [51]. Physicians should consider immersive virtual reality therapies as an adjunct to standard multimodal analgesia to help reduce acute pain and potentially for chronic pain conditions [51]. Another modality of nonpharmacological analgesia is acupuncture. Used in traditional Chinese medicine for centuries, acupuncture has been shown to offer immediate analgesic effects [52]. Though these skills and techniques are limited to those trained in acupuncture, it has shown clinical significance as an alternative for analgesic medication or as a reasonable method for pain treatment [52]. In addition, some practitioners assert that acupuncture may cause significant reduction in xerostomia after neck dissection surgeries; however, higher quality studies are needed. Music therapy is another modality providers can use with the goals of reducing a patient's stress, increasing comfort, and promoting relaxation. Music therapy is readily available, low risk, and inexpensive and does not require intense training of staff. The positive psychological impact of music can improve patients' perception of pain perioperatively [53]. In summary, nonpharmacologic therapies as an adjuvant to

standard pain management strategies should be used when possible as they improve a patient's experience of pain.

Conclusion

Patients undergoing head and neck cancer surgeries and reconstructions benefit from a biopsychosocial approach to their pain management. This approach includes assessing patients' expectations, goals, and limitations. Institutional-level clinical pathways can be developed to standardized pain regimens including multimodal analgesia, facilitate consultant participation, and streamline the use of alternative pain management therapies. Standardizing pain management regimens can improve efficiency; however, it is important to individualize interventions for each patient and tailor treatment to their specific needs. Comprehensive management of pain goes beyond medication or opioid management, and non-medication interventions are beneficial.

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Mental Health

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A cancer diagnosis can take a toll on a patient's mental health and well-being. However, contrary to popular belief, not all cancer patients will struggle with mental health issues, and experiencing debilitating anxiety or depression is not the norm. Head and neck cancer patients represent a unique subset of cancer patients with regard to mental health issues; patients may present with comorbid diagnoses of substance use disorders, which can complicate the course of cancer treatment and negatively affect outcomes. Additionally, the changes in function and appearance that occur during head and neck cancer treatment can lead to new or worsening anxiety and depression. In this chapter, we aim to explore the background of mental health problems in head and neck cancer patients, identify risk factors, and review interventions that can be performed by the patient's treating physicians.

Pre- and Postoperative Anxiety and Depression Risk Factors

Patients with head and neck cancers (HNCs) may present with preexisting anxiety, depression, or other comorbid mental health issues. These issues may also emerge at the time of diagnosis, treatment, or transitions into survivorship. If untreated, psychological distress can lead to diminished health outcomes, heightened symptom burden, increased length of hospitalization, reduced ability to care for oneself, reduced compliance with treatment, increased treatment complications, and elevated mortality [1–6].

Suicidal ideation is common among all cancer patients, including HNC patients. Although still rare, the risk of completed suicide is two times higher among those with a cancer diagnosis than in the general population (Missono et al., 2008) [7]. Completed suicide is even more likely among those with an HNC than another type of cancer [8], with risk factors among this specific population identified as male sex, substance use, chronic pain, mood disorder diagnoses, and rural residence [9, 10].

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The likelihood of comorbid mental health concerns is greater if the patient has a history of substance use, including alcohol or tobacco [11, 12]. Those who currently smoke are at increased risk for co-occurring mental health concerns such as depression or anxiety [13]. Conversely, those with a mental health disorder smoke at 2–4 times the rate of the general population [14]. This is important, as tobacco and alcohol use increases the risk for head/neck cancers and may continue following cancer treatment, presenting additional complications and poorer outcomes [15–18].

Preoperative factors that may increase the risk of depression and anxiety posttreatment are having advanced-stage cancer, living alone, receiving chemotherapy, pretreatment depression or anxiety, and being male [1, 5, 19]. Furthermore, distress from changes to functioning and appearance as a result of treatment and surgery is common among patients with HNC, and this may increase their risk for mood disturbance. Significant declines in quality of life can occur with tracheostomy, chronic pain, changes to the vital mechanics of eating and speech, and facial disfigurement, among other postsurgical complications. These changes can also cause social isolation or withdrawal, which can remove the patient from their typical support networks and can potentiate mental health problems. The American Society of Clinical Oncology (ASCO) recommends that all HNC patients in survivorship with disfigurement or disability after treatment be referred to a behavioral health provider for preemptive evaluation [20].

Several recent studies have examined the opportunity for posttraumatic growth, or positive personal changes as a result of cancer, among head and neck cancer patients; while the overall presence of posttraumatic growth was low, these studies identified several correlates of positive psychological change following the threat of HNC including good social functioning, younger age, and early stage (I or II) at diagnosis [21, 22]. Additionally, referrals to palliative care can be important during the treatment for HNC patients, as a palliative care visit can reduce the risk of suicidal acts in this population [9].

Patient Evaluation and Symptom Recognition

Patients presenting with signs of psychiatric distress should be more formally evaluated through the use of brief, self-report questionnaires that are now part of well-accepted guidelines, including those written by the National Comprehensive Cancer Network, the ASCO, and the American College of Surgeons Commission on Cancer [23–25]. Two of the most common and well-validated screening measures are the nine-item Patient Health Questionnaire (PhQ-9; [26]) and the seven-item Generalized Anxiety Disorder (GAD-7) questionnaire [27]. Even briefer validated versions of these instruments are available for use, including the PhQ-4, which contains two items from each scale (Kroenke, Spitzer, Williams, & Löwe, 2009). The 14-item Hospital Anxiety and Depression Scale [28] has also been used for decades and validated with many populations and has demonstrated good sensitivity, specificity, and positive predictive value among patients with HNCs [29]. The Brief Symptom Inventory is also a recognized tool for assessing anxiety and depressive symptoms among cancer patients [30, 31]. A more thorough review of assessment tools for cancer-related distress and suggested cutoff scores can be found elsewhere (e.g., [24]). One or several of these screening questionnaires should be incorporated into the initial patient evaluation and help identify at-risk patients who may benefit from further evaluation and treatment by a mental health professional.

Although the presentation of anxiety and depression can vary greatly based on age, culture, ethnicity, sex, context, and other factors, informal, observational assessment and self-reported history are important when considering if a patient is experiencing symptoms of depression or anxiety. Common observable symptoms of anxiety include muscle tension, irritability, fidgeting, and restlessness [32]. Common observable symptoms of depression might include psychomotor retardation, weight or appetite changes, blunted or depressed effect, and verbal comments that suggest hopelessness about the future. These

Table 14.1 Organic causes of depressive/anxiety symptoms in HNC patients

Metabolic	Endocrine	Medications	Other
Anemia	Hypothyroidism	Steroid use	Sleep disturbance
B12/folate deficiency	Hyperthyroidism		Treatment-related pain
Hypercalcemia			Low nutrition

patients may also report reduced pleasure or engagement in activities or hobbies they used to enjoy [32]. Asking patients plainly about their mood is important, as patients may not readily offer this information. Additionally, symptoms such as weight loss, low appetite, and fatigue can be treatment related and due to low nutrition, mucositis, hypothyroidism, or other organic causes. Initial workup should include baseline blood chemistry, measurement of TSH, and discussion of nutritional intake (Table 14.1). After organic causes have been evaluated, a careful discussion between the physician, patient, and patient's friends/family if able can help reveal underlying psychological issues. Patients of concern should be referred to mental health and supportive care providers for further assessment of psychiatric symptoms and psychosocial needs. Statements of hopelessness, a desire for hastened death, and thoughts of suicide are of particular concern and often require evaluation by a trained clinician to ensure patient safety.

Management

Engagement with supportive care is integral to reducing distress and mental health symptomology as well as preserving QOL. The mental health and psychosocial needs of patients with HNC change over time requiring varying intensities and types of psychosocial intervention along the care trajectory. Psychiatrists, psychologists, social workers, psychiatric nurses, music and art therapists, and chaplains may all be helpful in addressing anxiety and depressive symptoms among those with an HNC diagnosis. Early after diagnosis or prior to starting treatment, supportive interventions such as interdisciplinary counseling or psychological evaluation can help patients prepare for treatment, identify coping mechanisms, and address unhealthy behaviors (including substance use) that may negatively impact treatment outcomes. During primary cancer treatment, interventions are helpful in reducing distress associated with unpleasant side effects. In particular, anxiety and panic during radiotherapy are common among patients with HNC given the restriction imposed by thermoplastic masks [33]. Medication and relaxation techniques are routinely employed to reduce this "mask anxiety," yet efficacy of these interventions for this type of anxiety is understudied [34]. After treatment, HNC patient experiences many of the same issues as other cancer types including prominent fear of recurrence, difficulty returning to "normal," and changes to sense of self. There are also evidence-based end-of-life interventions, including meaning-centered psychotherapy, dignity therapy, and cognitive behavioral therapy (CBT), to reduce existential distress or psychiatric symptoms among all cancer patients with late-stage illness.

Management of anxiety and depression in patients with head and neck cancer can require multimodal interventions, including medication management. The first line of pharmacological treatment of anxiety and depression is antidepressants (SSRIs), which is the same as for general population. In choosing an antidepressant, providers should consider favorable side effect profile, easy dosing (once daily), and availability in pill and liquid form (to use through nasogastric tube, etc.). Pharmacological treatment can be safely initiated by the surgeon, oncologist, or primary care doctor. Studies have shown that prophylactic treatment with the antidepressant (citalopram, escitalopram) may decrease the incidence of depression during treatment for head and neck cancer and improve quality of life and psychological well-being [35, 36, 37]. Use of benzodiazepines for the treatment of anxiety generally should be avoided, especially in patients with a history of alcohol use. Head and neck can-

cer patients often have pain related to surgery, disease process, or other therapies. Pain can compound the symptoms of anxiety and depression that patients experience; likewise, psychological factors (e.g., pain catastrophizing) can exacerbate the experience of pain and worsen functioning [38, 39]. For patients in chronic pain due to treatment, referral to a pain management team can help with symptom control. Alternative therapies, including acupuncture, have been shown to reduce pain in HNC patients and can also be considered [40].

In addition to specialized psychiatric care, supportive, complementary therapies may also be helpful. Occupational and legal guidance, for example, may be helpful among HNC survivors, given that special arrangements for meal breaks and communication assistance in the workplace may be required following functioning changes after surgery. Furthermore, sexual health education or couples counseling may help with reduced intimacy and social avoidance following postoperative changes to appearance and mouth or throat operation.

Management of substance use within head and neck cancers can entail brief interventions within the HNC clinical setting or more intensive referrals for substance use disorder treatment outside the clinic. Substance use concerns, including tobacco use, can also be treated directly through conversations with patients that aim to elicit patient's own motivations for change. Individual psychotherapy focused on patients' motivations for change can result in improvement of substance use disorder outcomes. Evidence-based approaches such as motivational interviewing (MI) involve brief interventions from healthcare providers to foster behavior change among patients, contribute to significant and sustained change, and are considered a gold standard treatment for substance use disorders [41]. MI for substance use entails a nonconfrontational, collaborative approach to eliciting a patient's own motivations for change (rather than the provider's motivations for the patient); this approach is described in detail elsewhere [42, 43]. Following brief motivational interviewing within the clinic, patients can be referred to mental health or substance use disorder treatment specialists to further assess patient needs and connect them with services in the community.

Many referral options exist for maladaptive substance use and substance use disorder treatment, including multiple intensities of treatment (e.g., inpatient, residential, partial hospitalization), providers (addiction psychiatrists, psychologists, substance use counselors), and adjunctive treatments (e.g., medication-assisted treatment, self-help groups). The American Society of Addiction Medicine outlines patient placement criteria for determining the appropriate intensity or level of care for patients with substance use concerns [44].

Optimization of Patient Outcomes via Mental Health Treatment

Mental health treatment for anxiety, depression, and other mental health concerns among cancer patients leads to a number of beneficial outcomes including improved cancer treatment adherence, improved quality of life, and reduced symptom burden, among other things. A recent systematic review of psychological interventions among HNC patients displayed a promising impact of these interventions, particularly CBT and psychoeducation, on health-related quality of life, depression, and anxiety [45]. Literature consistently demonstrates the benefits of psychological and psychiatric treatment for those with substance use disorders. For head and neck cancer survivors with a history of tobacco use disorder, a combination of medications such as varenicline antidepressants, along with psychotherapy, can lead to significant reductions in tobacco use.

Evaluation of mental health issues in HNC patients should be done using the abovementioned questionnaires at their initial appointment and at intervals during their treatment. Providers should ensure that organic causes of depressive symptoms are evaluated. For patients who screen positive for anxiety or depression, providers should feel comfortable starting medication prior to referral if necessary. All patients who screen positive for mental health problems and/or sub-

stance abuse prior to or during treatment should be evaluated by a multidisciplinary team, optimally including psychiatrists, therapists, substance abuse counselors, and pain management specialists. Careful follow-up is required for patients who express self-harm or suicidal ideation; these patients should be referred expeditiously and may require hospitalization.

In conclusion, the management of mental health in HNC requires a team approach. HNC patients require follow-up for the duration of their treatment and through the survivorship period for the development of mental health concerns. Oncologists are critical as the "first line" in assessing patients, providing appropriate referrals to subspecialists, and implementing medical therapy where appropriate. A multidisciplinary therapy team is instrumental in optimizing the care of these complex patients.

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Physical and Occupational Therapy

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Introduction

Microvascular free tissue reconstruction has become integral to the surgical care of patients with locoregionally advanced head and neck cancer. Care and attention dedicated to preserving the viability of the reconstruction in the postoperative setting remain at the forefront of surgeons' and patients' minds. Historically, mobilization was routinely delayed due to concerns for disrupting the microvascular anastomoses, and patients would often be sedated and ventilated in the intensive care unit (ICU) for several days after surgery [1, 2]. In the past decade, evidence has emerged that early mobilization may reduce postoperative complications, ICU length of stay, and hospital length of stay [3].

While there is no universal protocol for perioperative and postoperative management for complex head and neck reconstruction, evidence-based recommendations have been described to minimize postoperative morbidity [4]. These consensus-based Enhanced Recovery After Surgery (ERAS) recommendations following complex head and neck surgery represent an effort to standardize perioperative and postoperative care; however, only 3 of the 17 recommendations address postoperative mobilization and physical therapy. Some postoperative complications following head and neck cancer resection and reconstruction can be avoided with early mobilization. Additionally, physical and occupational therapy in the immediate postsurgical period can help to restore function early. These benefits of early mobilization must be weighed against the importance of preventing injury or compromise to the reconstructive tissue.

Rehabilitation and physiotherapy after major head and neck surgery and reconstruction include not only management of the surgical sites but also prevention and management of any surgery-related loss of function. Postoperative inpatient physiotherapy addresses the following:

- Respiratory concerns including control of secretions around surgical sites, decreasing

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ventilator time, ensuring proper tracheostomy management or prompt extubation, and managing respiratory distress if present
- Cardiovascular complications, such as dependent edema and prevention of deep vein thrombosis
- Musculoskeletal complications and functional limitations, such as muscle stiffness or scarring, joint pain and dysfunction, and weakness in the head and neck region

Head and neck oncologic surgery can be particularly challenging due to the vital neurovascular structures present, which are at times intimately involved with the tumor. Obtaining adequate margins when critical vasculature, sensory and motor nerves, globes, and the skull base are adjacent to the tumor results in complex multifaceted defects that require a challenging reconstruction.

The loss of any vital structure of the head and neck, whether planned in the resection or unforeseen based on tumor growth, results in complex and often extended rehabilitation to restore lost function. Herein, we review different types of head and neck resections in the context of affected structures and rehabilitation needs, address immediate postoperative recovery from major free tissue reconstructive surgery to the head and neck, and describe multidisciplinary evidence-based techniques of physical and occupational therapy in these patients.

Oncologic Defects of the Head and Neck

Head and neck resections involving osseous structures result in defects that without adequate reconstruction would compromise facial contour and projection, mastication, sensory and motor nerve function, and can potentially result in difficulty breathing.

Composite Defects

Composite defects are those consisting of more than one tissue type including osseous and soft tissue structures. These defects can be large, require complex reconstruction, and result in temporary, and at times permanent, loss of function that requires extensive and prolonged rehabilitation.

Oral cavity tumors that involve or are located near osseous structures such as the maxilla or mandible may result in sensory loss in the distribution of the second and third divisions of the trigeminal nerve (cranial nerve V), respectively. Temporomandibular joint (TMJ) dysfunction is largely dependent on the extent and type of resection, e.g., a segmental resection of the mandible not involving the joint itself carries concern for articular head dislocation [5]. For oncologic resections that involve the temporomandibular joint (TMJ), consideration must be given to recreating the TMJ with a new articular head, commonly fashioned from the osseous free tissue being utilized for reconstruction, in order to minimize the severity of TMJ dysfunction postoperatively. While it is critical to evaluate TMJ function via occlusion and maxillomandibular relationship intraoperatively to ensure the correct position of the native condyle or neo-condyle in the articular fossa, postoperative manipulation of the jaw or muscle pull may cause disarticulation and deviation. There can be postoperative limitations in jaw range of motion due to inflammation, pain, surgical resection of the condyle and/or coronoid, and resection of the pterygoid muscles. Trismus, defined as tonic contraction of the muscles of mastication resulting in mouth opening of less than 35 mm [6], can affect patients preoperatively due to tumor involvement of the TMJ or the pterygoid muscles, and patients have reported symptoms of surgery-related trismus as early as the day of discharge following surgery [7]. Postoperative (chemo)radiation further increases the risk of trismus as a result of treatment-related fibrosis [8]. To prevent trismus, mouth-opening and jaw range-of-motion exercises are recommended. Optimal timing of initiation of jaw range-of-motion exercises remains unclear; however, it is recommended to begin as soon as 2 weeks after surgery [9], with some evidence supporting starting as soon as 1–2 days after surgery [10].

Soft Tissue Defects

Oral Cavity Defects

Defects consisting of soft tissue structures alone may result in the sacrifice of neurovascular structures with resultant loss of function related to the structures that have been removed. In the case of oral tongue malignancy necessitating partial, hemi-, subtotal, or total glossectomy, speech and swallow function may be impaired, with larger resections resulting in more significant impairment of these critical daily functions [11]. Oncologic resection may require removing both intrinsic and extrinsic tongue musculature. Lip and buccal cancer necessitating resection of muscles of mastication, muscles of oral competence, and sensory nerve fibers can result in difficulty swallowing some or all consistencies of food and liquids due to impaired movement of a food bolus within the oral cavity. Speech and language pathologists and dietary/nutrition teams should be involved in the immediate postoperative care of these patients depending on the type of reconstructive surgery performed.

Oropharyngeal Defects

Speech and swallow are commonly affected after oropharyngeal resection and reconstruction [12]. Resection of oropharyngeal structures such as the superior pharyngeal constrictors, palatopharyngeus, stylopharyngeus muscle, base of tongue musculature, and motor and sensory nerve fibers of the glossopharyngeal nerve can result in dysmotility and impairment of initiation of deglutition. Resections of the lateral pharyngeal wall and peritonsillar regions place the carotid artery, the internal jugular vein, and the vagus nerve at risk. Reconstruction of this region must provide adequate coverage to prevent exposure of these critical structures, especially if patients are to receive postoperative radiation or have been irradiated prior to surgery. Removing part of the soft palate may result in velopharyngeal insufficiency, hyper-nasal speech, and dysphagia. Reconstruction of this area should focus on separating the oropharynx and nasopharynx, restoring swallow function and nasal breathing, and optimizing speech. Postoperative rehabilitation with speech and language pathologists is imperative.

Laryngeal Defects

In oncologic surgery of the larynx, the degree of swallow and speech dysfunction depends on the extent of the resection. Partial, supraglottic, or supracricoid laryngectomy results in temporary dysphagia and voice changes, though as the remainder of the preserved laryngeal structures adjust and compensate, swallow and speech improve with rehabilitation after several weeks [13]. More extensive laryngeal surgery such as total laryngectomy or laryngopharyngectomy renders patients aphonic in the immediate postoperative period. Options for voice rehabilitation include tracheoesophageal puncture (TEP), electrolarynx, and esophageal speech. Generally, after 1 week of strict NPO for non-radiated patients and 2 weeks for previously head and neck irradiated patients, swallow therapy is initiated under the care of a speech and swallow therapist. Swallow therapy can continue for several weeks to several months depending on patients' progress and preexisting swallow function. Patients undergoing salvage laryngectomy following (chemo)radiation may have persistent dysphagia following surgery due to radiation-induced fibrosis of the pharyngeal musculature and esophageal stenosis that may require esophageal dilation.

Neck Dissection and Neurovascular Dysfunction

Neck dissection is often performed concurrently with resection of the primary tumor, either as a therapeutic or as an elective procedure. The residual deficits following neck dissection depend on the levels of the neck that are treated and the vital structures removed at the time. In the past century, morbidity following neck dissection has decreased as the number of non-lymphatic structures removed has decreased. Radical neck dissection, first described by Crile in 1906, involved removing all lymphatic and non-lymphatic structures of the neck from the mandible to the clavicle with the exception of the carotid artery,

lingual nerve, hypoglossal nerve, phrenic nerve, and brachial plexus. Lymphatic and non-lymphatic structures including the sternocleidomastoid muscle, spinal accessory nerve, internal jugular vein, omohyoid, and submandibular gland were removed. Removal of the spinal accessory nerve and resultant paralysis of the trapezius contributed to painful dysfunction of the shoulder and upper extremity as described by Ewing and Hayes in 1952 [14]. Patients reported cosmetic deformity, difficulty abducting the upper extremity above shoulder level, and discomfort. Over time, surgical technique evolved as evidence demonstrated similar oncologic outcomes and survival when lymphatic only structures were removed and non-lymphatic structures were spared.

Modified radical neck dissection was described by Suarez in 1963 [15]. This surgery spared the sternocleidomastoid muscle, internal jugular vein, and where possible the spinal accessory nerve, while removing all lymphatic structures of the neck. Surgical technique further evolved, and now selective neck dissections, which is the removal of lymph nodes immediately draining the primary tumor site, are commonly performed. Selective neck dissections have the lowest morbidity of the different types of neck dissection; however, some patients continue to experience shoulder and upper extremity disfunction [16]. Spinal accessory nerve dysfunction resulting from neck dissection can be due to resection of the nerve itself for oncologic purposes, though it can also occur when the nerve is preserved, likely due to neuropraxia. Symptoms of shoulder complaints and dysfunction occur in 18–77% of patients undergoing nerve-sparing modified radical neck dissections and in 29–39% of patients undergoing selective neck dissection [17, 18]. Evaluation of the spinal accessory nerve pre- and postoperatively includes assessing for ipsilateral shoulder and neck pain, abduction of the upper extremity above the horizontal plane, and head rotation to the contralateral side. These maneuvers assess the strength of both the trapezius and the sternocleidomastoid muscles. Asking patients to elevate their shoulder is commonly done; however, the levator scapulae muscle assists in this function, so this is not a specific test for spinal accessory nerve function. Electromyography testing can be performed to evaluate the extent of spinal accessory weakness if there is a decrease in range of motion postoperatively. Further clinical evaluation by physical exam 2–3 weeks after surgery, assessing for bilateral active upper extremity abduction, shoulder girdle inspection, evaluation for signs of trapezius atrophy, altered position of the scapula, and "shoulder drop" indicate spinal accessory nerve dysfunction. The presence of two of three physical signs suggests nerve dysfunction. A single symptom may be the result of postoperative pain and immobilization. Some patients experience symptoms that cannot be attributed solely to trapezius weakness, such as restriction of internal and external shoulder rotation, forward shoulder flexion, and pain when lying on the involved side, and it is thought that this may be a result of adhesive capsulitis (AC) of the glenohumeral joint [19]. Minimizing postoperative immobilization will reduce the chances of chronic shoulder joint dysfunction and AC. While the optimum timing of initiation of physical therapy has not been well described, it is recommended that patient education and prevention of disuse fibrosis with the assistance of a physical therapist be implemented in the "immediate" postoperative period following neck dissection surgery [16, 20].

Neck dissections that require ligation of the internal jugular vein place the vagus nerve at risk for injury. Injury to the vagus nerve will clinically manifest as vocal fold paralysis, dysphonia, likely dysphagia, and possible aspiration. Marginal mandibular nerve injury may also occur during neck dissection, which is clinically evident as weakness in depression of the ipsilateral lower lip. The hypoglossal nerve is similarly at risk during a neck dissection at levels 1B and 2A, as it passes inferior and medial to the digastric muscle. Injury would result in ipsilateral weakened tongue movement, with tongue deviation toward the side of injury. If the carotid sheath is manipulated during the operation, the cervical sympathetic chain may be injured and manifest as oculosympathetic palsy, or Bernard-Horner's syndrome, a constellation of ipsilateral symp-

toms that includes ptosis, miosis, and anhidrosis of portions of the face. The phrenic nerve is occasionally encountered during neck dissections if there are adherent lymph nodes to the floor of the neck or at the skull base. Injury to the phrenic nerve occurs in approximately 8% of radical neck dissections and results in elevation of the ipsilateral diaphragm. Clinically, this may manifest as an increased incidence of atelectasis in the postoperative course [21].

After undergoing neck dissections, patients may experience pain and a decreased range of motion of the neck. There is often a clinically evident reduction in active cervical extension, flexion, and shoulder abduction [22]. To reduce postoperative neck pain and prevent overstretching the trapezius, it is recommended to use a pillow or arm rest to support the shoulder and upper arm while seated [23]. A prior history of neck radiation increases the risk for and severity of these side effects. Radiation causes muscle fibrosis, which contributes to decreased range of motion. Postoperative pain and edema, together with radiation-induced fibrosis, can lead to significant reduction of range of motion, if physiotherapy is not initiated to regain muscle function [24].

Neck dissections that involve the central compartment place the recurrent laryngeal nerve (RLN) at risk for injury. The RLN is also at risk during thyroid surgery, and sacrifice of the RLN results in vocal cord paralysis and decreased sensation within the larynx below the level of the vocal cords [25].

Lymphedema may also occur following neck dissections and is typically more pronounced following bilateral neck dissections, compared to unilateral neck dissection. When this does occur, manual drainage and compression with multilayered bandages are recommended [23], as will be discussed in detail below.

Patients who have received prior curative-intent radiation to the neck and who have undergone dissection of the carotid sheath during surgery are at increased risk of a carotid blowout approximately 10 days to 3 months after surgery [26]. Ideally, range-of-motion exercises after neck surgery begin around 2 weeks postoperatively. This must be weighed against the risk of carotid artery blowout with patients previously irradiated to the neck. Fistula formation and delayed wound healing in the head and neck may delay initiation of physical therapy since these factors increase patients' risk of carotid blowout [26].

Donor-Site Morbidity

Free flap selection depends on the defect being reconstructed. In general, resected osseous structures are replaced by osseous free tissue, and soft tissue structures are replaced with soft tissue free tissue. There are many factors to consider when determining which type of free flap is appropriate, such as previous injuries or surgeries that may have disrupted the blood supply to a potential free flap harvest site, comorbidities such as peripheral vascular disease and hematologic disorders, and patients' cardiopulmonary status. Harvest of different types of free flaps carries risks related to the donor site, and postoperative physical therapy should be targeted to address any functional sequelae that may arise after surgery.

Upper Extremity

Upper extremity free flaps are extremely effective in oral cavity reconstruction. Both the radial forearm free flap and the lateral arm free flap are slim and pliable, with the RFFF possessing a longer pedicle that can be easily anastomosed to vessels in the neck.

Lateral Arm Free Flap

Song et al. [27] introduced the lateral arm free flap, which is a soft tissue free flap without an osseous component. Scar visibility is the most common morbidity and patient complaint about the lateral arm donor site. Impaired elbow mobility is associated with the highest patient dissatisfaction. It is recommended that intensive postoperative mobilization is initiated. Paresthesia of the arm has been reported

but does not seem to affect patient satisfaction [28].

Radial Forearm Free Flap

Radial forearm free flap can be either a fasciocutaneous free flap, often used for intraoral reconstruction, or less commonly an osteocutaneous flap, commonly used for maxillary defects and short-segment mandibular reconstructions. Prior to the introduction of prophylactic radial bone plating, fracture of the forearm was the most common morbidity associated with this flap [29].

Arganbright's study [30] of radial forearm free flaps using split-thickness skin graft (STSG) found that tendon exposure is the most common donor-site morbidity, followed by sensory neuropathy, infection. Radial fracture was the least common. To improve the success of a STSG, it is recommended to keep the forearm in a splint for 5–7 days postoperatively [31] protected with soft dressing and continue full arm mobilization after the splint is removed, until the wound is healed [32].

Lower Extremity

Use of the lower extremity in head and neck microvascular reconstruction has expanded due to the versatility of the multiple free flaps available. Physiotherapeutic considerations are notable due to frequent use of the lower extremity in daily living and the necessity to return to near-baseline function. Most commonly used are the fibula free flap (FFF), the anterolateral thigh free flap (ALT), and the medial sural artery free flap (MSAP).

Fibula Free Flap

The FFF is a workhorse of head and neck reconstruction. It can be harvested as an osteocutaneous, osteomyocutaneous, or osseous flap and can be incorporated into a variety of mandibular and maxillary defects with accompanying soft tissue defects. However, use of the FFF is not without donor-site morbidity. Early donor-site morbidity includes delayed wound healing, wound infection, partial or total skin graft loss if used, and wound dehiscence. These sequelae occur in 1–17.4% of patients according to a systematic review of donor-site morbidity following fibula free flap surgery [33]. Late donor-site morbidity includes chronic pain typically around the ankle joint, ankle instability, gait abnormality, decreased a range of motion, claw toe deformity, and sensory deficits in 3.9–11.5% of patients [33]. The fibula bears between 6.4% and 10% of body weight with the ankle joint in neutral position and varies with flexion, eversion, and loading [34], though it has been theorized "that the fibula is merely a strut that maintains the ankle configuration and does not actively participate in weight-bearing" [35].

Lower extremity immobilization follows fibula free flap harvest with either a controlled ankle movement (CAM) boot, posterior plaster splint, or leg cast. The choice of methodology of immobilization is primarily institution and surgeon dependent. Regardless of the means of immobilization, it is important to maintain the ankle in gentle dorsiflexion and the toes visible when placing the dressing to the donor limb. The toes remain visible to monitor the donor limb for vascular compromise—a rare yet feared complication of FFF harvest.

Generally, the limb remains elevated for 24 h after surgery. Initiation of ambulation varies across institutions, with some surgeons advocating for early mobilization on postoperative day 1 or 2 [36] according to a review of 157 patients in which the authors found no association between incidence of donor-site complications and timing of ambulation. Other authors have described waiting until postoperative day 5 if a skin graft is present [37]. Weight-bearing status is not well described in the postoperative period. In a review of 100 patients undergoing FFF, Babovic et al. described ambulating on postoperative day 2, without the mention of weight-bearing status [37]. Others have described non-weight-bearing walking with crutches and physical therapy on postoperative day 3. Weight-bearing is increased gradually at the end of 6 weeks; however, crutches were encouraged for 6 months. It is important to

note however that in the patients described, the fibula was used to reconstruct the femoral head; therefore, the restrictive weight-bearing status may have had more to do with the recipient site than the donor site [37]. In head and neck reconstruction, it is generally accepted that toe-touch weight-bearing can be initiated on postoperative day 3, after an initial period of non-weight-bearing, progressing to full weight-bearing around postoperative day 7, under the direction and care of a physiotherapist [38]. The leg is to remain elevated when not ambulating, including when sitting in a chair. Removal of the splint or cast varies as well by institution—remaining in place for 3 to 7 days, depending on the presence of a split-thickness skin graft. Use of the CAM boot with ambulation can be offered to patients for comfort, and duration of use ranges from 2 to 6 weeks depending on institutional preference.

Anterolateral Thigh Flap

Since the thigh-based perforator flap was first described by Song et al. in 1984 [39], it has become a reliable and widely used flap in soft tissue reconstruction of the head and neck. Depending on the defect and reconstruction goals, the anterolateral thigh flap (ALT) can be harvested as a fasciocutaneous flap or as a musculocutaneous flap harvested with a portion of the vastus lateralis. Morbidity following ALT harvest, while low, can impact hospital length of stay, postoperative function, and patients' quality of life (QOL). A systemic review and pooled analysis of donor-site morbidity after thigh flaps describe a 0.9% hematoma rate requiring evacuation, 2% seroma rate, and 3.8% rate of wound dehiscence. Leg contour deformity was described and was increased when vastus lateralis was also harvested [40]. Postoperative pain was reported in 2.6% of pooled cases. Subjective and objective musculoskeletal dysfunction was reported. While a reduction of isokinetic contraction force in 20–26% of patients was reported in half of the studies reporting on musculoskeletal dysfunction, no difference was reported in the other half of the objective studies, and a pooled analysis found no significant decrease in contractile force. In a mixed-methods study analyzing prospective and retrospective data on sensory and motor deficits following ALT harvest, researchers found that 82% of patient reported numbness, and the size of the free flap was associated with 2-point discrimination scores. At 1 year after surgery, there was no difference between isometric quadriceps contraction in the ipsilateral (surgical) thigh compared to the contralateral thigh. Intramuscular dissection did not appear to have an impact on motor function nor did the flap size [41].

Wound dehiscence may prolong hospital stay for patients whose ALT donor sites are primarily closed. Harvest of large flaps increases the likelihood of dehiscence. A recent study investigating the impact of incisional negative-pressure therapy (INPT) found that in patients where an incisional negative-pressure system was applied, there was a lower incidence of dehiscence and skin necrosis compared to a control group. There were also fewer overall complications in the INPT group (7.14%) compared to the control group (37%), and in a multivariant analysis, INPT was associated with reduced donor-site complications, notably in patients with thigh defects >8 cm [42].

Posterior Tibial Flap

The free posterior tibial flap is a soft tissue flap that has been increasingly used to reconstruct soft tissue head and neck defects [43]. Overall morbidity from harvesting the posterior tibial artery is low, with reports of 87.5% of patients having no complaints after surgery. In a study of 64 consecutive patients undergoing a posterior tibial flap for oral cavity defects, no patients reported difficulty walking on ground level; however, weakness and/or fatigue was reported in 10.9% of patients going up and down stairs. No participants reported cold intolerance. Ankle movement was not affected postoperatively, before and after exercise, nor was the ankle-brachial index [43].

Torso

There are several frequently used free flaps harvested from the torso. The scapula, latissimus dorsi, rectus abdominis, and deep circumflex iliac artery flap are among the most commonly used torso flap.

Scapula Free Flap

The scapula flap is a versatile flap that can be harvested as an osseous, osseocutaneous, or mega-flap if the latissimus dorsi muscle is also harvested; however, it is typically not the first choice for osteocutaneous reconstruction due to the need to reposition the patient for harvest and difficulty of simultaneous flap harvest and ablation surgery [44]. Postoperatively, it is recommended that the arm of the donor site be placed in a sling for 3–6 weeks. Some surgeons recommend immobilization period of 2 weeks prior to initiating protected passive range of motion at the start of the 6th week, begin active range of motion, and at the 12th week begin strengthening the shoulder [45]. Others begin physical therapy on postoperative day 7 with gentle passive movements that continues after discharge for at least 3 months [46]. Donor-site morbidity after scapula harvest includes objective (Constant-Murley score) and subjective (the Disability of the Arm, Shoulder, and Hand (DASH) test) decreased range of motion of the upper extremity in many patients, specifically decreased abduction, that improves with time and does not appear to interfere with the activities of daily living. Seroma and wound dehiscence tend to occur when larger skin paddles are harvested [46].

Latissimus Dorsi Free Flap

The latissimus dorsi can be used as a myocutaneous or muscle-only flap. Morbidity following latissimus dorsi free flap harvest includes numbness and difficulties with strenuous activities such as reaching over the head, vacuuming, and cleaning windows. Difficulty with leisure-time activities such as tennis and golf has also been reported [47], and there is some evidence to support that shoulder joint function may also be affected [48]. While these impairments may be acceptable to some patients, they are not negligible and postoperative physical therapy can help to minimize the level of impairment.

Rectus Abdominus Free Flap

The rectus abdominis flap can also be harvested as a myocutaneous flap or muscle-only free flap. Because a portion of muscle is harvested, the most worrisome complication is and abdominal hernia [49]. To reduce stress on the abdominal wall postoperatively, the head of the bed should be elevated to a 45-degree angle and the patient may lie in a fetal position on the uninvolved side, should be advised to avoid Valsalva maneuvers, and should cough with a pillow up against the chest. The patient should be taught to use log-rolling techniques to avoid disrupting abdominal sutures while moving around in bed. Abdominal strengthening exercises usually begin several weeks postoperatively, with lifting and sit-ups beginning at 6 weeks after surgery [50].

Deep Circumflex Iliac Artery Free Flap

The deep circumflex iliac artery free flap can be harvested either as an osteocutaneous or an osteomusculocutaneous free flap. Approximately one-quarter of patients report sensory deficits, which is generally the most common sequela reported. Other donor-site morbidity includes gait abnormalities, chronic pain, and hernia formation. Aggressive postoperative physical therapy is thought to reduce potential gait disturbance [51].

Postoperative Physical and Occupation Physical Therapy

Timing of initiation of physical therapy tends to be surgeon and institution dependent. Head and neck surgeons historically have been conservative in postoperative mobilization—citing concern for integrity of the microvascular anastomoses. Injury to the vascular anastomosis within the neck after reconstruction is of great concern to head and neck surgeons in the immediate postoperative period. Historically, patients were sedated and immobilized for 2–3 days postoperatively, although there has been a notable shift in recent literature advocating for early mobilization, as soon as within the first 24 hours following surgery [4]. Early initiation of mobili-

zation has been associated with decreased length of ICU stay, fewer days on a ventilator, and shorter hospital stay [52]. However, any physical manipulation of the neck or abrupt turning of the head may jeapordize the microvascular anastomosis and, thus, place the reconstruction at risk of compromies. It is therefore recommended for the head and neck microvascular team to specifically indicate to physical therapy, occupational therapy, and all healthcare providers involved in the care of patients to avoid any movements that may compromise the reconstruction.

Pulmonary physical therapy should also be initiated as early as possible after head and neck oncologic surgery to avoid undue pulmonary complications. Many patients undergoing major head and neck surgery require placement of a tracheostomy tube, and adequate pulmonary physical therapy, attentive nursing care, and use of surgical pathways contribute to fewer pulmonary complications postoperatively [1, 4].

The treatment of patients that have undergone medical and/or surgical treatment for head and neck cancer can be challenging for the patient, their family, and the medical team including rehabilitation specialists. Not all rehabilitation specialists are comfortable working with this patient population due to the complexity of these patients and their surgeries. There can be significant physical impairment, as well as social and emotional issues related to difficulty speaking and eating, as well as changes to patients' physical appearance. Being mindful and attentive to multiple surgical sites simulateously while rehabiltating patients adds to the complexity.

The rehabilitation specialist has numerous issues to address including swelling, lymphedema, soft tissue fibrosis, posture, breathing pattern changes, strength, function, and aerobic activity. Seventy-five percent of head and neck cancer patients will develop lymphedema [53]. A close relationship with the care team must be emphasized, including speech language pathology for swallowing and trach care if needed. Consultation with the surgical team for appropriate progression and protection of surgical sites and graft/flap sites is also critical. Involving the Radiation and Medical Oncology teams regarding postoperative adjuvant treatment is an important part of patient care.

A global view of the patient is needed, and standardized protocols may not universally apply to all patients. It is recommended that treatment is based on individual patient needs and ongoing reassessment. Many of these issues will be discussed below.

The Lymphatic System

The lymphatic system is a one-way return system for fluid to the heart, originating in one-cell-layer-thick lymphatic capillaries, intimately intertwined with venules and arterioles in the capillary beds in the interstitial space. The function of the lymphatics at this level is to remove microorganisms, cellular debris, and fat, thereby preventing their return to the heart.

Onboarding of fluid to the lymphatic capillaries is impacted by differences in hydrostatic and oncotic pressure of vessels in the capillary beds, as well as body movement that can open and close the lymphatic capillaries via the presence of the anchoring filaments. The vessels of the lymphatic system get progressively larger proximally, acquiring valves to prevent backflow, as well as smooth muscle (lymphangion) to propel fluid. Fluid is directed to the lymph nodes (which have arterial and venous supply) for filtering before progressing more proximally before return to the heart via the subclavian veins.

It is estimated that there are 600–700 lymph nodes in the body with higher concentrations in the head and neck region, as well as inguinal area and abdomen.

The lymphatic system operating without impairment will transport 2–3 L of fluid per day. It is a low-volume, low-pressure system and is easily impacted by disruption of the pathways due to surgery, scar tissue or fibrosis, and reduced body movement.

Other components of the lymphatic system (that are not the focus of rehabilitation) include the bone marrow, thymus, spleen, tonsils, and Peyer's patches. An important function of the

lymphatic system is the production of T and B lymphocytes for the body's immune response.

Lymphedema

Lymphedema is an abnormal accumulation of protein-rich fluid in the interstitium, which if untreated can cause chronic inflammation and reactive fibrosis in the affected soft tissue. A retrospective study found that 75% of head and neck cancer patients had secondary lymphedema more than 3 months after treatment [53]. Lymphedema severity is associated with substantial symptom burden, functional impairment, and reduced QOL [54].

Secondary lymphedema is lymphedema caused by disruption of the normal lymphatic pathways due to surgery, scar tissue, and/or radiation fibrosis. External lymphedema involves the external structures of the face, neck, submandibular, and submental regions. Although not readily visible, internal lymphedema can affect the tongue, epiglottis, and airway producing potential issues with respiration, mastication, swallowing and speech, and neck tightness [55].

Evidence describing other anatomic sites [56] indicates that early identification of lymphedema followed by early initiation of therapy may result in regression of swelling and prevention of late sequela issues such as fibrosis and limited function. If lymphedema of the head and neck is not recognized and treated early, head and neck soft tissue may become fibrotic and contracted, which can limit motion and impair function. Patients will greatly benefit if lymphatic assessment and management are part of their comprehensive treatment plan.

Fluid-level control in the body is a delicate balance between systems, including the lymphatic system. Local factors can be impact transport capacity or lymphatic load.

Impairment or damage to the efferent lymphatic pathways will cause reduction in fluid from the periphery as it attempts to return to the heart via the venous system. This is classified as reduced transport capacity and can cause buildup even with normal lymphatic load.

Increase in lymphatic load also has the potential to increase local swelling even in the presence of normal transport capacity. Lymphatic load can be increased by factors such as infection, and as the result of surgery, radiation and chemotherapy.

A patient that has combined impairment of transport capacity and lymphatic load presents a significant challenge to long-term management.

Identifying and Documenting Lymphedema

After nearly all surgical interventions, it is normal and expected to have postoperative edema that resolves after several weeks, or longer if the patient has a history of head and neck radiation. Swelling that develops, persists, or worsens should illicit a referral to a lymphedema rehabilitation specialist for assessment and management. For patients that have had radiation without surgery, lymphedema onset is typically delayed. Family members are often the first to notice late-onset swelling and should be educated to bring it to the attention of the care team.

Preoperative evaluation with a physical therapist allows for collection of baseline measurements of the head and neck as well as the ability to provide appropriate education to the patient and family. Clinical assessment can include numerous methods, each with its own benefit.

Observation: Signs of lymphedema can be seen with visual observation. The patient may present with fullness or edema that was not present prior to surgery or treatment. Additionally, facial asymmetry, alterations in postural alignment, limited range of motion, and changes to breathing patterns are also signs of lymphedema that be observed.

Palpation: Skillful palpation will identify differences in tissue turgor, reduction in scar tissue mobility, pain with palpation, and pitting (Table 15.1). There are numerous scales for documenting pitting. There is little consensus on the use and validity of the measurements.

The one we use is adapted from the Guelph Hospital Congestive Heart Failure pathway (Table 15.1).

Table 15.1 Pitting edema scale

Pitting edema	Description
1(+)	2 mm or less, slight pitting, no visible distortion, disappears rapidly
2(+)	2–4 mm, somewhat deeper pit, no readably detectable distortion, disappears in 10–15 s
3(+)	4–6 mm, pit is noticeably deeper, lasts for >1 min, dependent extremity looks fuller and swollen
4(+)	6–8 mm, pit very deep, lasts as long as 2–5 min, dependent extremity is grossly distorted

Table 15.2 Staging of lymphedema

Stage 1	The edema dissipates during the day and becomes worse at night because of the lack of gravity
Stage 2	The edema no longer dissipates during the day with evidence of pitting, and some area of induration, with no tissue changes
Stage 3	The edema does not dissipate, greater induration and little pitting, tissue change irreversible

Adapted from The Guelph Hospital Congestive Heart Failure pathway, used in the textbook of Lymphedema Management [57].

Staging of lymphedema allows for clear communication and documentation between members of the care team for patients (Table 15.2).

Lymphedema staging for the head and neck [57, 58]

Tape measure: Identifying a standardized way of measuring and documenting external head and neck lymphedema has been difficult. The tape measure has been found to be the most cost-effective and efficient way of providing reproducible and standardized measurements. The following measurements are those employed often, and the clinician should make effort to measure with the patient in the same position each time. If possible, measurements should be taken at or close to the same time of day, and this information should be documented for the care team. All effort for consistency in the tension of the tape should also be made. In a clinic where measurements might be taken by more than one practitioner, it is worth the time to compare notes regarding tape tension.

Measurements can be taken at the following areas, among others, as described in the ALOHA trial [58] and in Table 15.3 (Fig. 15.1):

1. Lower neck circumference: lowest neck circumference superior to the angle of the neck and shoulder
2. Upper neck circumference: highest neck circumference inferior to mandible
3. Length from ear to ear: earlobe-face junction on one side to the earlobe and face junction on the other, intersecting a point 8 cm inferior to the lower lip edge
4. Length from lip to lower neck circumference: midline, inferior lower lip edge to lower neck circumference

MoistureMeterD: MoistureMeterD is a unique water-specific instrument for the measurement of water content of biological tissues. It measures the dielectric constant of the skin and subcutaneous tissues noninvasively and locally in a few seconds. The tissue dielectric constant (TDC) is directly proportional to the amount of water in the tissue, however it only reaches a depth of 5 mm. These products are relatively new to the market, and the cost to purchase may make it not practical for most clinics [58, 59].

Digital photography: Digital photography is an effective method for evaluating and documenting changes in external lymphedema over time. As with tape measurements, consistency in patient positioning, distance from the camera, and lighting are important to allow for accurate comparisons to be made with sequential photographs. Photographs entered into the electronic medical record (EMR) allow all members of the care team to see progress or identify exacerbation. Patients can develop lymphedema insidiously, which may only be appreciated by looking at sequential photographs. In addition, patients may not appreciate progress until observing it themselves in photographs. Digital photography when combined with other aspects of assessment can be an important component of a comprehensive assessment battery for external head and neck lymphedema.

Table 15.3 Pretreatment evaluation of head and neck patients. *AROM* active range of motion

Range of motion (degrees)	Goniometer or CROM—circle one	
Neck flexion AROM (degrees)		
Neck extension AROM (degrees)		
Right neck rotation AROM (degrees)		
Left neck rotation AROM (degrees)		
Right neck lateral flexion AROM (degrees)		
Left neck lateral flexion AROM (degrees)		
Quadrant/Spurling's test	L =	R=
Shoulder active flexion	L =	R=
Shoulder active abduction	L =	R=
Shoulder active internal rotation	L =	R=
Shoulder active external rotation	L =	R=
Shoulder passive external rotation	L =	R=
Mandibular opening	(mm)	
Strength testing		
Shoulder flexion	L =	R=
Shoulder abduction	L =	R=
Left elevation (upper trapezius)		
Right elevation (upper trapezius)		
Left adduction (mid trapezius)		
Right adduction (mid trapezius)		
Neck flexion-neutral		
Left neck flexion (sternocleidomastoid)		
Right neck flexion (sternocleidomastoid)		
Neck extension		
Swelling measurements (Fig. 15.1)		
Tragus to tragus		
Tragus to medial eye		
Tragus to lateral corner of nose flare		
Tragus to lateral corner of mouth		
Tragus to mid chin		
Lower neck		
Mid-neck circumference		
Upper neck circumference		
Vertical circumference		
Posture assessment		
Other:		
Plan or intervention based on examination		

MRI and CT scans: MRI and CT scans are able to provide accurate measurements of swelling; however, they are cost prohibitive for routine assessment of lymphedema and are not part of the scope of practice for rehabilitation professionals.

Treatment of Lymphedema

There are benefits to the development of protocols for treatment of lymphedema; however, it is highly recommended that each treatment plan be individualized based on a comprehensive evaluation of the patient, rather than based on strict adherence to a protocol. Because each patient will have a different combination of medical and surgical treatments, as well as different comorbidities and prior limitations, each patient should have a specific treatment plan based on his or her needs. In addition to manual lymph drainage, the patient may benefit from interventions such as soft tissue mobilization, use of elastic tape, as

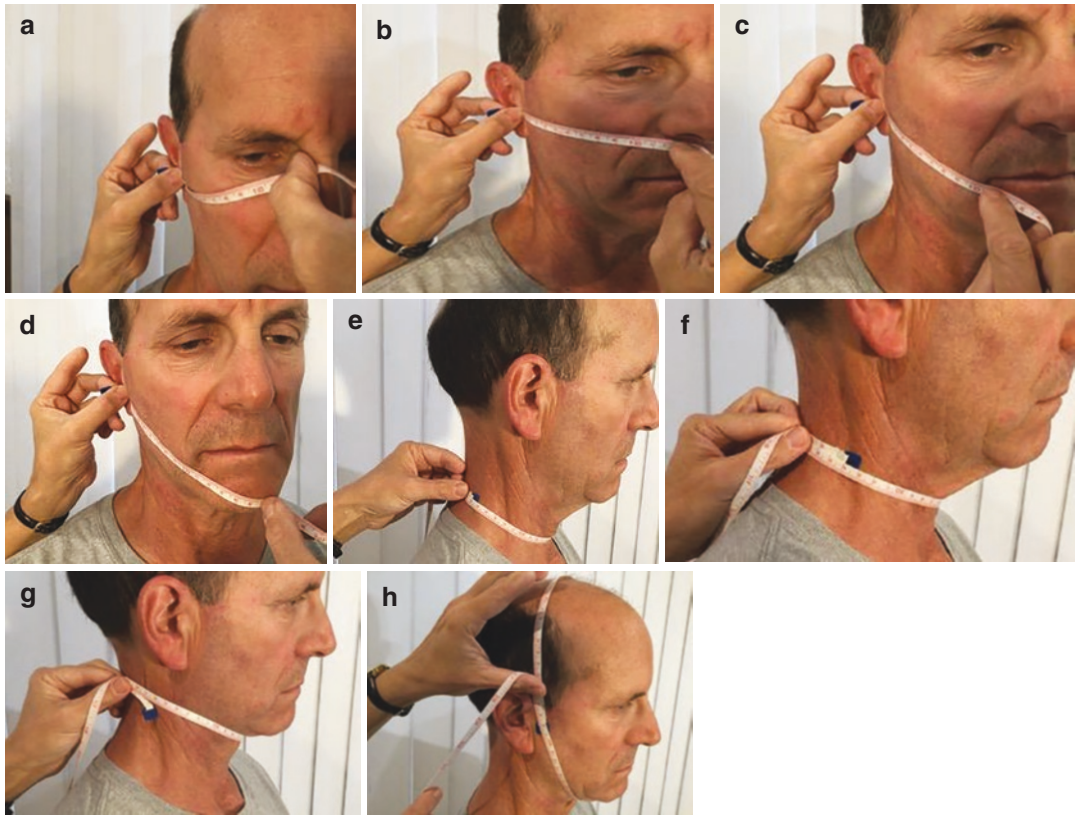

Fig. 15.1 Tape measurements of the head and neck as part of the pretreatment and posttreatment physical therapy comprehensive evaluation. Tragus to medial canthus (**a**), tragus to lateral nasal ala (**b**), tragus to oral commissure (**c**), tragus to mentum (**d**), lower neck circumference (**e**), mid-neck circumference (**f**), upper neck circumference (**g**), and vertical head circumference (**h**)

well as compression products and other modalities. All treatment should be based on the patient-specific treatment plan [60].

Manual Lymph Drainage

Usage of manual lymph drainage (MLD) began in the 1930s based on the work of Dr. Emil Vodder. MLD consists of light manual strokes in specific areas to promote lymphatic flow and remove lymphedema from the congested area and promote reabsorption of the protein-rich fluid. It has been found that patients undergoing MLD demonstrated fluid reduction of up to 60% and reported improvement in symptoms related to lymphedema [61]. There are collateral or alternate lymphatic pathways that the lymphedema therapist can use to redirect fluid around the involved or impaired area, away from the area of fluid congestion and guiding it to healthy functioning lymphatic pathways.

Normally, treatment progresses from proximal structures, moving distally into the involved area and then reversing the sequence. The techniques use light pressure and specific directions for best results. For example, MLD can be used on axillary nodes to direct flow from the cervical region to the axillary nodes.

There are numerous "schools of thought" on specific techniques and methods; however, the general concepts and principles are the same as described in the guidelines above. Therapists trained in lymphedema management have signifi-

cant training in specific techniques and should be integral members of a comprehensive rehabilitation program.

The patient or a caregiver can be instructed on simple MLD techniques to perform at home to help with carryover between sessions in the clinic.

Several contraindications and precautions exist for performing MLD, such as avoiding MLD on patients with active non-treated cancer (unless it is provided in a palliative setting to provide pain relief), avoiding the cervical region if the patient has a history of carotid plaques, and avoiding intraoral MLD in the presence of mucositis or other intraoral infections.

Soft Tissue Mobilization

There are multiple names for soft tissue mobilization, such as myofascial release, soft tissue work, and manual therapy. Despite the difference in names, the goal is to improve soft tissue mobility in order to increase local range of motion (ROM), improve function, reduce pain, promote lymphatic flow, and help healing. All techniques should be based on the individual patient's needs. Caution is needed to avoid areas undergoing or that have recently undergone radiation, as cutaneous side effects from radiation can be painful.

Timing of techniques is important and will be related to the patient's stage of healing and patient reaction to hands-on techniques.

Soft tissue mobilization can be divided into direct and indirect techniques. Direct techniques work into the restriction or limitation. Indirect techniques work into a position of ease or away from the restriction. Early in healing or recovery (approximately the first 5–15 days), the patient may tolerate and benefit from indirect techniques for help with issues related to pain and swelling and may increase motion and function. This can be combined with other interventions described herein. Later in the healing stage, the patient may tolerate and benefit from a more direct technique working directly into the restriction to mobilize the involved soft tissue. LymphaTouch, described below, is a direct technique, while elastic tape can be used in both indirect and direct ways.

Elastic Tape

Elastic tape, such as Kinesiotape, "K-Tape," and Rock Tape can be used to stimulate lymphatic drainage as well as provide musculoskeletal support, reduce pain, and improve scar tissue mobility. Research has demonstrated improvement of lymphatic flow rate of 24–37% when elastic tape and ROM were combined [62]. Tape can be worn for 2–3 days, with good skin tolerance. For improvement in lymphatic flow, the tape is applied with no tension, and in most cases, the body part to be taped is in a lengthened position while the tape is applied. Because the tape is applied to the paper backing with slight tension, it creates a slight lifting tension to the skin and the underlying subcutaneous tissue, creating space for fluid flow. The clinician skilled in tape use will determine the shape, size location, and direction of tape application for best results. Tape removal is done slowly with attention to skin tolerance. Difficulty removing tape can be rectified using olive oil or baby oil to loosen the adhesive, make removal easier, and minimize stress to the skin (Fig. 15.2).

Self-Care

Any of the abovementioned interventions can be performed by the patient or family member after instruction and demonstration of competence. Periodic review of techniques is recommended.

Elastic and Nonelastic Compression

Compression use is an essential component of comprehensive lymphedema management. It is used to control and reduce swelling and can be used in combination with foam padding or chip foam pads for improvement in soft tissue fibrosis. There are numerous products on the market for compression ranging from self-adherent wrap (e.g., Coban™) to custom-made garments. The selection of the appropriate product will depend on multiple factors including cost, skin condition, time since surgery and/or radiation, vascular precautions, the patient's ability to apply and remove the compression device, and the patient's tolerance for compression.

To assess initial tolerance and benefit, the clinician can use short stretch bandaging or Coban™

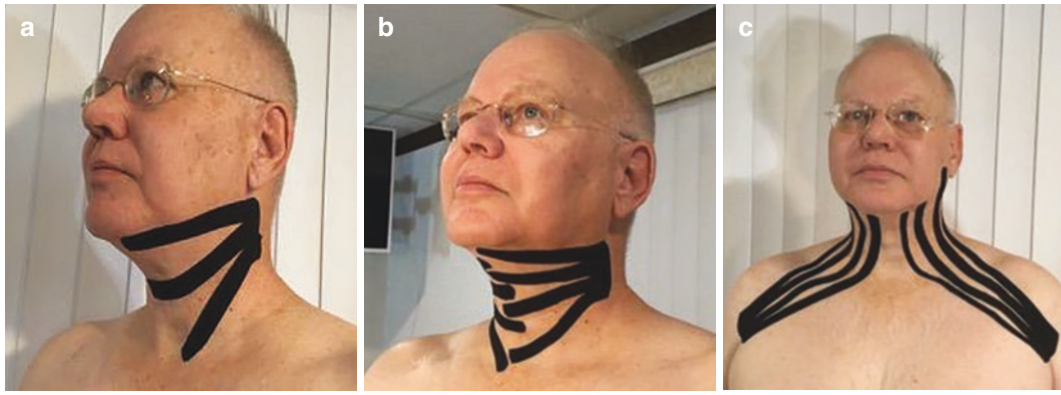

Fig. 15.2 Kinesiotaping of the lateral neck (**a**), bilateral neck (**b**), and neck and axilla (**c**)

wrapped gently and secured in place. Padded compression wraps with a soft inner liner and Velcro closure can be used (Fabrifoam®) to determine tolerability.

Patient tolerance to compression may vary as does a patient's willingness to wear it in public. As such, there can be a disconnect between the goal of the clinician for prolonged use and the patient's tolerance or willingness to comply. Encourage initial use to comfort followed by increased time of use as tolerated. Nighttime use is generally acceptable and can be combined with sleeping with head of bead elevated 20–30 degrees to minimize edema from building up at night in those patients who experience lymphedema.

When using compression around the head and neck, light forces are used, around 10 mmHg. It should be comfortable to the patient, allowing mouth opening and breathing without difficulty. Patients should not feel a sensation of choking, light-headedness, or dizziness. If tension in the compression is too strong, accumulation of fluid may occur above or below the compression. Although temporary, this can be concerning to the patient. When compression is placed over areas of decreased sensation, regular skin checks should be performed in order to prevent tissue damage (Fig. 15.3).

Patients undergoing head and neck surgery and radiation greatly benefit from consultation with a certified lymphedema therapist and a compression vendor with experience in caring for patients with lymphedema, and application of compression should not be done without a thorough assessment.

Negative-Pressure Medical Devices

Negative-pressure medical devices such as LymphaTouch® consist of a mechanical suction cup that can provide variable strength of suction to the treated area. The negative pressure (suction) creates a lifting force to the skin and subcutaneous tissue, and the on/rest time can be adjusted according to patients' needs. The negative pressure is thought to open lymphatic capillaries to onboard lymphatic fluid to the lymphatic system and create space to promote lymphatic flow. When combined with manual lymphatic drainage, there can be improved decongestion of lymphatic fluid from the involved area; however, there exists little research in the efficacy of these devices in the head and neck region.

Pneumatic Compression Devices

There exists some controversy regarding the use and efficacy of pneumatic compression pumps for the treatment of lymphedema. Clinically, some patients can and do benefit from the use of pumps as part of a comprehensive self-care program, which should also include self-manual lymph drainage (or caregiver), exercise, and bandaging or elastic compression.

Pneumatic compression devices can be used at home as part of self-care and can aid in overcoming barriers to care such as limited access to head

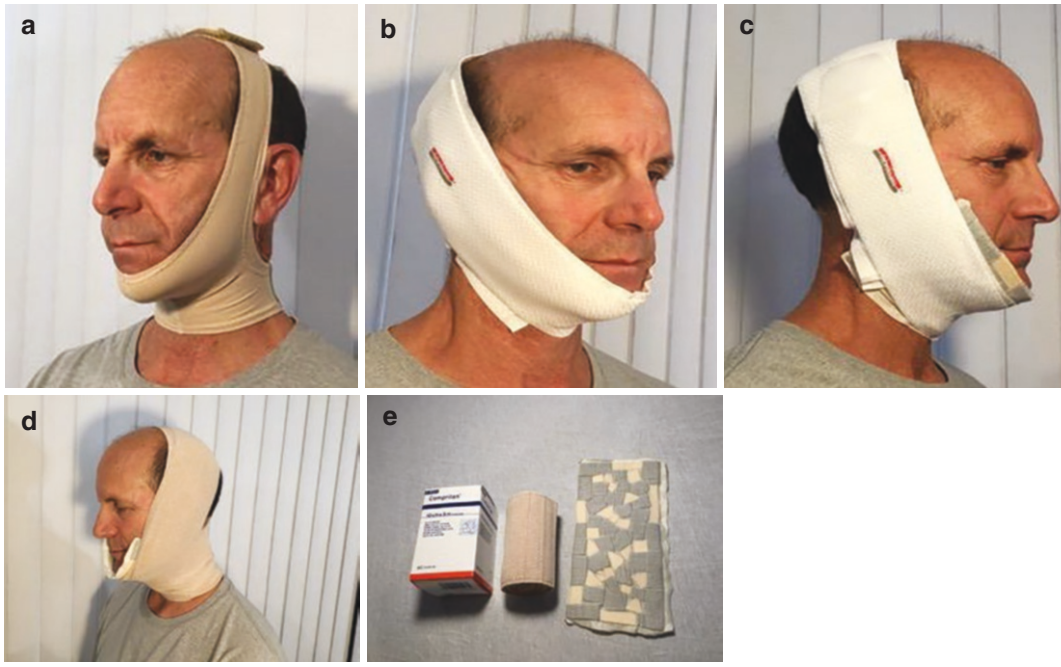

Fig. 15.3 Compression can be used alone with a custom wrap (**a**), with foam padding wrap (**b**), or with foam padding wrap and chip foam (**c, d**). Chip foam insert is created using adherent padding and foam pieces (**e**)

and neck-trained lymphedema specialists. In 2016, the Food and Drug Administration approved the use of the Flexitouch system for head and neck patients. A 2020 study using patient reporting demonstrated a significant improvement in patients' perceived ability to control lymphedema through at-home treatment and ability to perform daily activities. The authors also report a decrease in head and neck pain and discomfort, and improvement in ability to swallow or breathe [63].

Radiation Fibrosis

External beam radiation is an essential part of medical management of patients with head and neck cancer. Patients may present to rehabilitation services having undergone radiation therapy in combination with chemotherapy (without surgery) or having undergone radiation with or without chemotherapy s/p neck dissection surgery. In the treatment phase, radiation can cause an inflammatory response with an increase in the production of extracellular matrix and collagen, thereby setting the stage for development of fibrosis. Despite its effective properties for the treatment of cancer, radiation can have detrimental local effects to the radiation field, which include damage to healthy tissue including skin, blood vessel, muscle, nerve, tendon, bone, and lung tissue. Local tissue involvement can result in reduced microcirculation and blood profusion, which will reduce lymphatic clearance and can make the area susceptible to local infection.

The condition, referred to as radiation fibrosis syndrome (RFS), is generally a later stage complication which can present clinically months and sometimes years after treatment. There is an increased risk of developing RFS when radiation is combined with chemotherapy, surgery, or endocrine therapy. There is some evidence that suggests that RFS may be associated with genetic predisposing factors such as epigenetic modifications to DNA and histones, and it has been reported in patients with Marfan syndrome, possibly related to elevated TGF-β that can be seen in patients with underlying collagen vascular disease [64].

Depending on the tissues and structures involved, the patient may present with a variety of clinical presentations. In general, patients with RFS may present with a combination of the following issues: reduced ROM, swelling, induration, and/or fibrosis of soft tissue; reduced tissue mobility; and skin changes. Specific tissue changes can include the following [65]:

Nerve damage may cause neuropathic pain, sensation loss, autonomic nerve damage, and weakness.

Nerve root involvement can cause UE myotomal weakness, as well as progressive neck weakness.

Skeletal muscle and tendon involvement can cause painful muscle guarding, weakness, and local muscle fatigue.

Bone effects can contribute to osteopenia, osteoporosis, and osteoradionecrosis, thereby making the patient susceptible to fracture.

Local skin effect results from acute inflammation, and skin burns are common. Function is often impaired due to progressive fibrosis and stiffening.

Lung and cardiac involvement an occur and should be taken into consideration when recommending functional activities and exercise programs.

Treatment of Radiation Fibrosis

Preoperative or early posttreatment evaluation with a lymphedema specialist can greatly improve patients' understanding of radiation side effects and provides patients with tools for controlling lymphedema. Early initiation of rehabilitation can have a profound effect on reducing the impact of the potential long-term effects of radiation. The type and intensity of intervention will vary depending on the stage of ongoing medical treatment, time since surgery, and patients' underlying medical issues.

In the early period following treatment, manual therapy and exercise away from the involved area protect involved tissue but can facilitate early mobility of tissues. Bringing patient attention to posture and positioning, as well as breathing patterns and joint protection, can be extremely beneficial. Encouraging active mobility of noninvolved extremities can be beneficial.

Fig. 15.4 Manual assisted stretching of the neck

In the subacute healing stage, exercises can be progressed. Manual therapy can begin in the involved area with respect to the radiation field and healing tissue. Techniques such as myofascial release and manual assisted stretching help to progress to the goal of maximizing ROM without exacerbation of fibrosis (Fig. 15.4). The patient should also be encouraged to partake in a walking or running program to aerobic capacity.

If patients reach the later stages of healing without achieving functional motion and improved range of motion, fibrosis and soft tissue contracture might become irreversible. It is therefore imperative that patients be evaluated prior to treatment or immediately after treatment is completed in order to avoid irreversible fibrosis of the head and neck [66].

Scar Management

Scar management is a critical component of rehabilitation after surgery for head and neck cancer. If scar tissue is left to tighten without intervention, the superficial tissue as well as the deep tis-

sue will become tight, which can limit range of motion and function of the neck and upper extremity. Lymphatic fluid flow may be restricted, which increases the chance for development of lymphedema. In addition, swallowing and tongue mobility can be impacted, as well as mandibular opening, with resultant trismus.

Understanding that scar tissue and fibrosis can worsen as a result of external beam radiation, it is suggested that restoring as much motion as possible prior to radiation is recommended. Early management can minimize distortion of the facial symmetry due to scar tissue, which can have a significant impact on reducing the psychosocial impact of the scarring [67].

For more involved disease, reconstruction may be needed, including local and regional tissue as well as free tissue reconstruction. If left unattended, scarring can lead to impairment as scar tissue shortens and matures. Addressing scar tissue formation is important to reduce morbidity and help patients regain motion and function.

Treatment of Scar Tissue

Specific intervention techniques will be dictated by the type of surgery, time since surgery, and other medical comorbidities. The benefit of general movement cannot be overemphasized. Gentle active mobility should be started as soon as possible in so far as it does not negatively impact the surgical sight and should be done in consultation with the surgeon.

Early exercise can include gentle active range of motion, diaphragmatic breathing, posture awareness and correction, as well as walking to tolerance, and if possible manual soft tissue mobilization in areas around but not directly on or over the surgical field. As mentioned previously, special consideration should be given for patients who have arterial disease and are undergoing radiation or who have undergone dissection of the carotid sheath. These patients are at increased risk for carotid blowout as soon as 2 weeks after surgery [26]. Early on, the patient may also benefit from the use of a mirror to begin to work on facial expressions, and if appropriate mandibular range of motion, as discussed above.

As healing continues, motion can be progressed and additional exercise can be added as needed. Manual soft tissue mobilization can begin, working from outside the surgical field and progressing to work in the surgical field as tolerated. Continuing MLD and beginning work in the area of the surgical field are recommended. These techniques are done gently and lightly and can be done without significant stress to the involved tissue.

Management of Hypertrophic Scar Formation

Hypertrophic scar is a thick raised scar that is an abnormal response to wound healing. They more commonly occur in wound healing areas of tension after skin trauma, burns, or surgical incisions. Silicone has been used since 1982 [68] in the treatment of burn scars, is available over the counter, and has been considered a key in noninvasive scar management. Silicone can be applied as a gel, as an adhesive sheet, or as a silicone-filled cushion. This technique can improve the appearance and mobility of scar tissue and is easy to apply and painless. For best results, it is recommended to use between the second week after surgery and up to 3 months. Patients may benefit from use after 3 months; however, the results may not be significant. It is recommended that silicone sheets be worn between 12 and 24 h per day, with the pad or sheet placed directly on the scar tissue and held in place with a light adhesive or light compression with self-adherent wrap. Tight compression is not needed. The skin should be monitored for maceration upon initial use [69].

The use of compression garments has also been used successfully in the treatment of hypertrophic scarring with positive effects on collagen remodeling [70]. Compression or pressure therapy should be started early, with the use of individually measured garments. It is recommended that compression garments be used for 23–24 h a day, continuously for up to 1 year. This is generally well tolerated with the exception of the head and neck region due to risk for airway compromise and patient intolerance [71, 72]. As above, close monitoring of skin upon initial use is

needed. Compression use is to be undertaken with caution on any patient with reduced sensation and any chance of skin breakdown.

Range-of-Motion Assessment

Range-of-motion assessment (ROM) is simple and easy to perform and can provide important information. It gives insight on the patient's willingness and ability to move the part of the body being assessed, any pain with movement, as well as specific limitations of movement and asymmetry. If preoperative measurements were taken, they can now be compared to current measurements to determine the effects of surgery. It should be part of every initial evaluation as well as evaluations during ongoing physical therapy treatment to measure improvement. The most accurate measurement method is the use of a standard goniometer or cervical range of motion (CROM) device. A tape measure can also be used. Whichever method is used, it is important that the measurement method be consistent throughout treatment; ROM should be assessed with the patient in the same position each time, and the exact patient position and technique should be documented [73].

Benefits of Pretreatment Physical Therapy Baseline

There are many advantages of performing a preoperative or pre-radiation assessment when possible. A baseline assessment allows the clinician to identify preexisting impairments, such as neck or arm tightness or weakness and trismus, and begin working on these areas as needed. Preoperative evaluation provides an opportunity to educate the patient and family on expectations and the post-op therapy program. In addition, it may provide some level of legal protection by identifying pre conditions.

Expectation of this Visit

The exact details of this visit will depend on planned medical or surgical intervention but should include the following information: healing time frame and progression of postoperative rehabilitation, when exercise will begin, possible impairments and what to look for, risk of developing lymphedema, how it may present, and what to do. Because compression is relatively simple for the management of lymphedema, some patients may try it on their own; however, it is recommended that the patient or family member contact the clinician or medical team prior to this in order to determine the appropriate patient-specific intervention.

The clinician can discuss and demonstrate early posttreatment exercises and activities for the acute stage of healing. These will all be patient specific but may include some or all of the following:

- Postural control and joint protection
- Neck ROM
- Breathing—diaphragmatic
- Scapula elevation and retraction
- Mandibular opening/stretch
- Upper extremity ROM—fingers, wrists, forearms, elbows, shoulders

It is encouraged that a review of the clinicians involved in the patient's care be performed routinely to determine which one would be appropriate to contact for any specific issue. At the time of the visit, patients have the opportunity to ask specific questions and express any anxiety about the upcoming procedure. Often, simple and empathetic explanations can go a long way to reducing the anxiety the patient or family may have. Simple relaxation techniques are easy to learn yet well worth the time spent if needed. Specifics of the preoperative evaluation are described in Table 15.3, and details are collected in the *Physical Therapy Pre-operative Examination Intake Form*.

Physical Therapy Pre-operative Examination Intake Form

Please answer the following questions. Circle yes or no. If you answer yes, please add details such as date, if you have fully recovered, and any information about the incident. We will review this information with you at your preoperative visit.

Do you have any prior shoulder injuries, or surgeries?

Yes No If yes:_____
_____
_____.

Have you ever had a frozen shoulder?

Yes No If yes:_____
_____
_____.

Do you have, or have you had, any prior neck injuries, or surgeries?

Yes No If yes:_____
_____
_____.

Do you have, or have you had, any disc or joint problems in your neck?

Yes No If yes:_____
_____
_____.

Do you have, or have you had, radiating arm pain?

Yes No If yes:_____
_____
_____.

Do you have full and pain-free movement of your shoulders and neck?

Yes No If yes:_____
_____
_____.

Are you limited in any activity that requires the use of your arms or neck?

Yes No If yes:_____
_____
_____.

Do you have any jaw pain or problem opening your mouth?

Yes No If yes:_____
_____
_____.

Postoperative Care

There are many patient-specific factors that inform the treatment plan for head and neck cancer patients, including pretreatment function; type of treatment, such as surgery, radiation, chemotherapy, or a combination of these; and patients' goals. In the absence of a specific protocol from the referring physician, the following guideline is meant to assist that process.

Table 15.4 identifies the structures involved in the surgical field and the potential clinical implications of impairment of these structures. It is important that donor sites for major head and neck reconstruction surgery be addressed as well.

Start time for therapy will vary based on surgical technique, patient response to healing, pain, any patient comorbidities, as well as current, ongoing, or future medical interventions.

If a preoperative or pre-radiation assessment was done, repeat measurements should be taken at follow-up visits. The patient is then assessed to determine the appropriate intervention if any for this time. This initial post-op visit is an ideal time to review education on issues such as lymphedema, posture, joint protection, diaphragmatic breathing, and any others that are appropriate.

Other considerations include CROM and shoulder ROM. If CROM is restricted after 8 weeks, it is recommended to assess passive joint play at the atlanto-occipital (AO) and atlantoaxial (AA) joints, C2–3 and through T3 joints, in addition to normal soft tissue assessment.

If shoulder ROM is limited, it is recommended to assess passive joint play assessment at the acromioclavicular, sternoclavicular, and glenohumeral joints, in addition to soft tissue assessment.

Patients should undergo evaluation for cervical radiculopathy. Preexisting degenerative vertebral disc disease will directly inform patients' preoperative and ongoing evaluations as well as progress throughout physical therapy treatments [74]. The following maneuvers are done to evaluate for cervical radiculopathy:

Table 15.4 Structures involved in the surgical field of head of head and neck surgery and the potential clinical implications of impairment of these structures

Anatomy	Function	Clinical implications
Surgical field • Anterior border of trapezius • Levator scapula • Subplatysmal plane		Soft tissue involvement. Scarring/fibrosis can cause significant functional limitation
Platysma muscle (innervated by CN VII)	Pulls angle of mouth down Pulls skin of chest up	Limits neck extension Limits contralateral neck rotation and side-bending Can develop trigger points
Sternocleidomastoid (SCM) (CN XI)	Active rotation opposite side Superficial neck flexor AO extension, forward head posture	Can restrict ipsilateral rotation Weakness of contralateral rotation Weakness of neck flexion
Spinal accessory nerve (CN XI)	Trapezius and SCM innervation	Shoulder/neck/scapula weakness Limited AROM Pain
Hypoglossal nerve (CN XII)	Innervates tongue and intrinsic muscles: • Styloglossus • Hypoglossus • Genioglossus	Tongue function Impaired swallow Impaired articulation Coordinate with SLP
Phrenic nerve	Innervates respiratory diaphragm	Impaired respiration
Internal jugular vein	Drains dural sinuses in brain and face and neck areas below brain	Swelling/edema of ipsilateral face if ligated
Common carotid artery	Supplies oxygenated blood to head and neck	Possible stroke
Scalenes	Neck movement and stability Accessory respiration Superficial neck flexors	Brachial plexus courses between Possible thoracic outlet syndrome Limited ROM in side-bending, rotation, and extension Weakness of neck motions
Posterior belly of digastric muscle (CN VII)	From mastoid process to hyoid bine Stabilizes hyoid bone to assist anterior digastric in mandibular opening	Limited contralateral neck rotation Can impact active mandibular opening
Omohyoid muscle (cervical plexus)	From scapula to hyoid bone via clavicle. Stabilizes hyoid bone	Can limit neck ROM

- Quadrant test: side-bend head and add axial compression, or side-bend and rotate head away.
- Distraction: patient supine, and examiner stands at the head of the bed, places each hand around the mastoid process (or one on forehead and the other on occiput), and gently flexes and pulls patient's head toward himself or herself. A positive test is the resolution of symptoms with traction.
- Upper limb tension test: brachial plexus tension test, evaluation of peripheral nerve compression.

Physical Therapy Treatment Considerations for Free Flap Donor Sites

For patients who have undergone head and neck reconstruction with free flaps, attention should be given to donor-site range of motion and function during the postoperative period. The following are four examples of donor-site management of commonly used free tissue reconstruction, including manual techniques and exercises. The considerations below are not comprehensive, and thorough evaluation of the patient will guide a comprehensive patient-specific treatment program.

General considerations—assessment of donor and recipient sites:

1. Superficial soft tissue mobilization:
   (a) Straight plane and diagonals as well as circular/rotation
2. Deep facial mobilization:
   (a) Can include facial bone interface
   (b) Distraction
   (c) Distraction with rotation
   (d) Joint mobilization if needed
3. ROM—osteokinematics—measure with a goniometer
4. Functional ROM to include rotations (proprioceptive neuromuscular facilitation (PNF) patterns)
5. Regional mobility—consider facial planes of multiple joint segments
6. Exercises to maintain between sessions
7. Exercises to help maintain after discharge
8. Strength and functional capacity

Upper Extremity Soft Tissue Flap (e.g., Radial Forearm Free Flap)

When a free tissue flap is harvested from the arm, a split-thickness skin graft is often used to replace the forearm skin that was harvested. Initial consideration must be given to not disrupting the skin graft, while also preventing scar tissue formation around the flexor tendons of the forearm. Once the graft is adequately healed with good blood supply, gentle AROM for the wrist and forearm may begin. If normal healing is progressing around 3–4 weeks after surgery, gentle scar tissue mobilization can be performed along with wrist and hand strengthening.

1. *Manual therapy*
   (a) Soft tissue mobilization—begin superficial and work deep (Fig. 15.6).
   (b) Joint mobilization as needed (wrist, forearm, and elbow).
2. *Exercises*
   (a) Tendon gliding exercises started as early as possible.
   (b) Maintaining the wrist in neutral position, these exercises are not performed with any force, NO hard gripping. Use just gentle flexing and extending of the fingers, curling from the tips to the palm, keeping finger straight flexing from the knuckle.
   (c) Gentle AROM to elbow and shoulder as appropriate.
3. *Stretching* (Fig. 15.7)
   (a) Prayer stretch
   (b) Passive wrist extension
4. *Strengthening*
   (a) Active wrist ROM
      • Flexion, extension, supination, pronation, deviation
   (b) Hand dexterity exercises
   (c) Progressive strengthening

Osseous or Osteocutaneous Fibula Free Flap

As mentioned above, patients who have undergone osseous or osteocutaneous fibula free flap reconstruction are kept on non-weight-bearing restrictions for 4–7 days. Gentle active dorsiflexion at the ankle as tolerated is recommended for tendon and nerve gliding and to help control swelling. After 4–7 days following surgery, progressive weight-bearing is begun.

Wound healing issues are common at the donor site and should be addressed as soon as possible. Muscle necrosis is a rare sequela and may occur 3–6 weeks postoperatively. Other possible long-term issues can include chronic edema, ankle instability, weakness of ankle dorsiflexion, plantar flexion, pseudo-compartment syndrome, and neuropathic pain. As appropriate, there will be a steady progression of lower extremity strengthening, gait, and balance.

1. Manual therapy (as appropriate)
   (a) Soft tissue mobilization
   (b) Fascial mobilization
   (c) Joint mobilization:
      • Ankle
      • Proximal tibia-fibula joint
      • Knee if needed
2. Exercises
   (a) Active exercise:
      • AROM to ankle and knee
3. Stretching

(a) Increase dorsi and plantarflexion, inversion, and eversion
4. Strengthening
   (a) As appropriate for ankle, knee, and hip

Latissimus Flap

1. Manual therapy.
   (a) Soft tissue mobilization in area around incision and, when healed, over the incision
   (b) Assess regional motion with respect to facial planes
   (c) Work on shoulder ROM planes
   (d) Measure and work on rib cage mobility—lateral expansion
   (e) Work on trunk and low back ROM, side lying with involved side up, arm in elevation, trunk inside bending
   (f) Work on scapula mobility
   (g) Work on quadratus lumborum muscle motion for separation of trunk and pelvis
   (h) Distraction of arm
2. Exercises
   (a) Stretching:
      - Stick stretch (Fig. 15.5)
      - Doorway stretch
      - Quadruped stretch with shoulder in extended rotation
      - Side-bend stretch with arm in elevation (Fig. 15.5)
   (b) Strengthening
      - TheraBand shoulder extension from 40 degrees of flexion into extension
      - TheraBand shoulder extension from overhead (130 degree if able) to neutral
      - Trunk stabilization

Fig. 15.5 Stretching exercises following latissimus dorsi flap, stick flexion (**a**) and stick abduction (**b**), and side-bend stretch with arm in elevation (**c**)

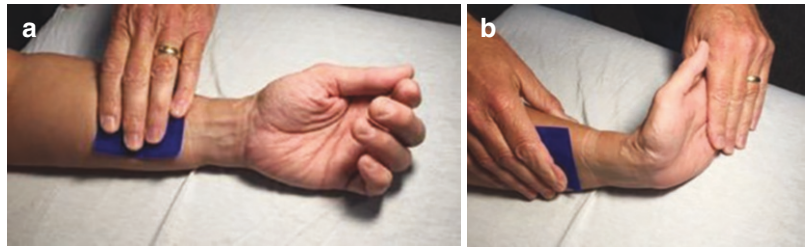

Fig. 15.6 Soft tissue mobilization after radial forearm free flap. Begin with superficial tissues and then work on the deeper tissues using nonslip padding (e.g., Dycem) with forearm in neutral position (**a**) and in extension (**b**)

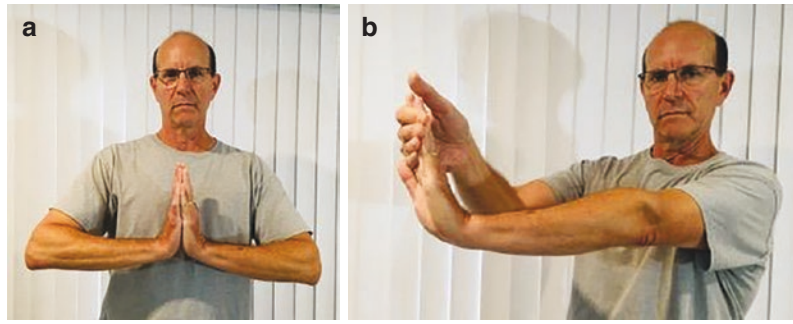

Fig. 15.7 Upper extremity stretching following radial forearm free flap. (**a**) Prayer stretch, (**b**) wrist extension

Spinal Accessory Nerve

If the spinal accessory nerve remains intact after surgery, the initial phase of treatment following surgery involves protection of the shoulder and healing nerve by passively off-loading or reducing tension on the nerve with a sling or arm support. It is important to maintain range of motion at the glenohumeral joint to decrease the chance of adhesive capsulitis forming. Combinations of active ROM, passive ROM, and functional activities are all beneficial. Postural awareness should be emphasized. Weakness of the scapulothoracic musculature combined with anterior scar tissue can produce a forward head posture and protracted shoulders that has the potential to become fixed without intervention [75].

Upon return of nerve function, which can take up to 12 months following surgery, exercise can focus on return of strength and function to the reinnervated musculature.

Manual therapy consists of joint mobilization, soft tissue mobilization, as well as mobilization with movement, which is a manual correction of scapular thoracic position while active motions are performed of the shoulder.

Mobilization to the glenohumeral, acromioclavicular, and sternoclavicular joints is recommended. Soft tissue mobilization to help loosen anterior structures may be needed as well. Exercises may consist of:

- Scapular stabilization-type exercises
  - Scapular squeezes
  - Bent row
  - External rotation
  - Wall flexion with ball compression
  - Rotator cuff strengthening with TheraBand progression
  - Eccentric flexion using band
  - Shoulder shrugs
  - Functional PNF

Predictors for mid- to long-term shoulder disability after neck dissection include the following [76]:

(a) Decreased AROM for abduction and flexion after SND
(b) Shoulder droop
(c) Pain with passive shoulder extended rotation
(d) Increased pain on a numerical rating scale

Trismus

Trismus is the progressive reduction in the ability to open the mouth and can lead to difficulty eating and resultant malnutrition, poor oral hygiene, difficulty with speech, and possible airway compromise. Trismus can occur between 5 and 38% of patients undergoing treatment for head and neck cancer [6, 77]. The prevalence varies across studies based on the definition of mouth opening used, which is typically ≤3.5 cm [6]. Trismus can result from surgical intervention, such as mandibular reconstruction, as well as radiation-induced fibrosis.

Proper mandibular function requires bilateral symmetrical function of bilateral temporomandibular joints (TMJs). Upon initial mouth opening, the condyles of the mandible roll in the mandibular fossa. This rolling alone allows 35–50% of opening. For further opening, the condyles must slide or translate forward along

the articular eminence of the temporal bone. Normal range of motion for mandibular opening is between 40 and 55 mm measured between the upper and lower incisors. It is generally accepted that normal lateral deviation is approximately 25% of opening. Normal protrusion is estimated to be between 6 and 9 mm. Involvement or tightness of one TMJ will result in a deviation of movement to the involved side upon mouth opening and protrusion, and asymmetry of lateral translation.

Assessment of Trismus

As mentioned previously, patient positioning should be consistent between tests. The patient is initially observed for movement and limitation. A cursory evaluation of the status of dentition and any signs of infection is highly recommended. Measurement of the distance between the mandibular and maxillary incisors during maximal mouth opening can be done with a simple clear plastic ruler. Another simple way to measure mouth is to assess the number of the patients' fingers that can be placed between the incisors upon opening. Generally, three fingers are considered normal functional and fewer than three is considered limited opening. Protrusion can be quantified by measuring the distance between the incisors while a patient maximally protrudes the mandible. Lateral translation is measured by the amount of movement between the central upper and lower teeth. It is important to note any differences between the two sides.

In addition to ROM measurements, the therapist can palpate the mandibular condyles when the patient opens and laterally deviates, to assess for asymmetry between sides.

As an example, a patient presents with right-sided TMJ involvement. Mouth opening is 29 mm with deflection of mandible to right upon opening. Protrusion is 2 mm with deflection to right. Lateral translation to right is 7 mm and 2 mm to the left. Palpation of TMJs reveals increased tissue turgor on right. Passive joint play of right TMJ reveals slight reduction of distraction and more notable reduction of translation.

Fig. 15.8 Soft tissue mobilization of the right TMJ using nonslip padding, for the management of trismus

Treatment of Trismus

Delaying treatment can lead to secondary tissue changes in joint and muscle, making the recovery of function difficult. Therefore, early treatment is important for return of function.

Based on the clinical presentation above, treatment could include:

- Soft tissue mobilization to right (Fig. 15.8)
- Joint mobilization to right TMJ for distraction and anterior translation
- AROM/home program
- Use of tongue depressors on right side, with tongue blades placed between back molars and slowly adding tongue blades to allow a gentle distraction/stretch

Devices such as TheraBite for assisted opening can be helpful. These should be combined with manual distraction or use of tongue blades for distraction of the joint.

Conclusion

Initiation of rehabilitation and physiotherapy after head and neck oncologic resection and reconstruction is crucial for the eventual return of function for head and neck patients. Management of functional complications and other surgical sequelae can be addressed during physiotherapy. Patients benefit from continued care long after surgery has been performed as they continue to improve function and quality of life.

The rehabilitation therapist will be challenged by the complexity of care involved when treating patients that have undergone surgical and/or radiation treatment for head and neck cancers. The complex surgeries that involve the vital anatomic structures of the head and neck may contribute to significant impairments and functional limitations. A wide range of skill in assessment and manual techniques is needed to provide comprehensive care. In addition, patient-specific clinical problem-solving is needed to be able to provide the best treatment at the appropriate time, with respect to tissue healing, ongoing medical care, and medical comorbidities. Herein, we have addressed in detail the morbidity that can follow major head and neck surgery and the critical role that physiotherapy and occupational therapy play in rehabilitation of these patients in the peri- and posttreatment setting.

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Speech and Swallow Therapy

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What Is Speech Pathology, and Why Are They Needed?

Speech-language pathologists (SLPs) are trained to assess, diagnose, and treat speech, language, social communication, cognitive-communication, and swallowing disorders from infancy through geriatrics. SLP's scope of practice includes counseling, screening, prevention and wellness, assessment, and treatment [1]. Assessment and treatment aspects focus on receptive, expressive, and nonverbal means of communication; motor speech production; fluency; voice; resonance; cognition; feeding; and swallowing. SLPs also assist in determining upper airway patency, implementation of general speaking valves, appropriate tracheostomy device selection, and tracheostomy management and eventual decannulation [2]. These attributes make an SLP highly qualified and instrumental to service the population of head and neck cancer patients.

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Research has shown that this patient population runs an increased risk for impairments related to speech and swallowing, with up to 60% of patients experiencing difficulty during or after treatment [3, 4]. Dysphagia in particular is the highest functional morbidity in this population and has the potential to remain chronic with lasting effects on overall psyche and quality of life [4]. Consulting an SLP is essential to maximize the ultimate success of reconstructive surgery and rehabilitation after treatment [5].

Speech and Communication

Preoperative Counseling and Assessment Tools

Research demonstrates that early and frequent involvement of SLP improves communication and overall quality of life for head and neck cancer patients and is correlated with improved speech and swallowing outcomes [6, 7]. Prior to intervention, if not emergent, a preoperative counseling consultation is the best practice. These can be obtained either at an affiliated outpatient clinic before the scheduled treatment or once admitted utilizing the acute care SLP staff. It is critical to identify the patient's baseline function before intervention to guide the posttreatment plan of care [8]. In the USA, only 18.3% of this population obtain proactive intervention/

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education, whereas in the UK 50% and in Australia 75% receive preoperative services [9].

Within a preoperative counseling session, information such as the patient's prior medical, surgical, and rehabilitative history is discussed, along with current medications, patient's goals for communication skills and concerns (e.g., return to work, social interaction), baseline speech skills, and cognitive-communication abilities. Prior to chemoradiation, swallowing function and diet intake consistencies, pulmonary toileting/tracheostomy presence, as well as trismus and change in taste, smell, motor speech, and voice should be addressed [1]. A thorough assessment of the oral mechanism should be completed, where the oral mucosa, dentition, degree of oral opening, facial symmetry, and cranial nerves are evaluated, as well as strength, range of motion, and alacrity of the oral structures [1]. Diadochokinesis is utilized as an assessment and therapeutic measure to address the oral structures of the speech production mechanism to show chronicled structural and physiological changes related to the central nervous system, as compared to the peripheral via a count by time measure [10].

Pulmonary function is addressed by identifying respiration patterns, assessing body posture, coordination of respiration and phonation, fatigue with speech production, and addressing tracheostomy status [1].

Maximum phonation times are compared to limited normative data to glimpse into the laryngeal function and phonatory mechanics [11]. The speech pathologist will then evaluate voice and resonance and overall speech production. Many perceptual quality-of-life scales are present to address these aspects and to determine a baseline such as the Voice Related Quality of Life questionnaire (VRQOL), the Voice Performance Questionnaire (VPQ), and the Voice Activity and Participation Profile (VAPP). Specific questionnaires frequently utilized related to speech and voice include the Voice Handicap Inventory (VHI), which consists of 30 statements addressing voice related to functional, physical, and emotional aspects and includes overall quality of the voice [12, 13]. A higher score denotes more perceived impairment. A condensed and newer version known as the VHI-10 is just as reliable and valid with only the most poignant questions addressed [14]. The Speech Handicap Index (SHI) is the same format as the VHI but addresses speech problems in daily life and provides an overall speech quality score [12]. Global rating scales described by good, moderate, and poor are generally utilized after listening to standardized texts/sentences to describe dysphonia [12]. The more popular scales of the GRBAS—grade, roughness, breathiness, asthenia, and strain—and the Consensus Auditory Perceptual Evaluation-Voice (CAPE-V) are both easy to complete and reliable in assessing vocal quality [15].

Within assessment of the voice, diagnostic videostroboscopy is employed to effectively identify vocal fold characteristics at rest and in motion and is measured by the Stroboscopy Evaluation Rating Form (SERF) to rate laryngeal parameters [16]. This is completed either by the otolaryngologist independently or in combination with the speech pathologist. Another diagnostic tool is flexible endoscopic evaluation of swallowing (FEES), which will guide the clinician on velar function and competence for resonance. Acoustic analysis measures can be employed via software programs such as VisiPitch, Multidimensional Voice Program, PRAAT, and Dr. Speech to evaluate speech recordings for pitch, rate, and loudness [12].

Finally, the SLP will assess verbal communication through connected and conversational speech identifying overall intelligibility and baseline communication abilities. Clinicians tend to utilize perceptual global scores in quantifying degrees of intelligibility due to time limitations. Additionally, two formally used standardized assessments include the Frenchay Dysarthria Assessment (FDA) (which measures motor speech function) and the Assessment of Intelligibility of Dysarthric Speech (ASSIDS) (which gives the percentage of word and sentence intelligibility, words per minute, and a rating of communication efficiency) [17]. If warranted, alaryngeal speech production can be addressed during this time frame [1, 12].

In addition, depending upon the nature/extent of the surgery, the SLP will discuss the potential for recording the patient's voice for future use with alternative communication/speech-generating devices. The patient may also choose to develop recordings in the form of memos or letters or even read children's stories for use with grandchildren. Initiating and coordinating with appropriate augmentative and alternative communication (AAC) devices are preferred to avoid delay in training and use. Dexterity, cognition, vision, and readiness/willingness should be discussed. There are two types of AAC: low-tech, such as gesture, pen and paper, LCD writing tablet, and communication boards, and high-tech, such as speech-generating devices (SGDs), mobile devices, and AAC apps [18]. If the patient is undergoing a total laryngectomy procedure, thorough preoperative evaluation and education are imperative [19]. Preoperative counseling should address anatomy and physiology changes, stoma accessories, respiration, and alaryngeal speech methods. Demonstrations with risks/benefits related to supportive care groups, family training, safety aspects for emergencies, and restrictions such as diving/swimming, as well as coping mechanisms, are also performed. It is also beneficial if an appointment can be arranged with a survivor. The opportunity to discuss from patient to patient is more dynamic as the survivor can discuss the feelings, perceptions, and changes more adequately than the therapist. This type of preoperative evaluation is also indicated in the total glossectomy population due to the nature and severity of deficits and lifestyle changes. The clinician should provide counseling regarding the nature of the surgery, anticipated changes to communication, hearing, and swallowing and discuss the projected course of rehabilitation needs in addition to the responsibilities of the patient to complete the preoperative evaluations for increased successful outcomes [1, 20].

Research shows that preoperative counseling sessions reduce patient anxiety and increase their willingness to undergo operative intervention [21, 22]. It is increasingly beneficial if all support members of the patient can participate [20]. Some pre-counseling sessions may take multiple appointments, and adherence to said counseling will most likely vary depending upon patient compliance, socio-economic status, and educational level. When possible, have the same SLP follow the patient both inpatient and outpatient. This ongoing continuum of care optimizes patient outcomes [9].

Perioperative Evaluations

Facilities vary widely on the time of referrals to inpatient speech pathologists with some as soon as postoperative day (POD) 1. Others vary from 5 to 7 days out to 2 weeks posttreatment [12]. Once the referral is received, the postoperative evaluation of speech looks similar to that of the previously discussed preoperative assessment. The SLP should take special focus on the surgeon's postoperative surgical note to know the anatomical and physiological changes and associate them with the impact on function and structure. The evaluation should commence with a thorough oral motor evaluation in addition to a particular focus on the intraoral flap location and size [12]. Oral structure and function should be assessed as previously discussed for strength, range of motion, alacrity, and overall coordination/sensation. Speech function should be assessed at the basic syllable level and then increased accordingly with concentration given to the lingual palatal articulation and the fricatives/affricates production due to tongue control as precision may be changed in postsurgical intervention [12]. Incidentally, if a neck dissection is included, labials may be affected as lower lip depression and movement can be often compromised.

Although institution dependent, if the inpatient therapist is completing an evaluation on POD 1–2 in an acute care setting following reconstructive surgery, the evaluation should focus on postoperative counseling and education to the patient and caregivers with a focus on the plan of care. A general motor exam can be performed, but no range of motion or oral hygiene care should be performed without surgeon approval, as the patient is generally with strict non-oral means of nutrition orders for

healing and flap viability. The SLP should ensure that the patient has nonverbal means of communication present such as pen and paper, dry erase boards, low-tech communication boards, or previously discussed AAC. If the patient underwent total laryngectomy, POD 1–2 should focus on continued supporting education and training. The SLP should also place the heat and moisture exchange (HME) filter in line to aid with filtration, mucus reduction, and pulmonary function as soon as possible for the greatest benefit [23].

Treatment interventions are often initiated on POD 3 and continue until discharge from the acute care center. Skilled treatment intervention varies based upon the location of surgical intervention, type of cancer, and overall surgical healing and appropriateness of intervention [1]. While in-house, POD 4–5 focus on trach management (if present) and speech communication. If appropriate, a speaking valve can be placed to aid in weaning, decannulation, communication, and improved quality of life [2]. Unless contraindicated, gentle range of motion can be initiated during this time frame as well.

The SLP should reinforce NPO status and educate on the importance of flap health, oral care, and aspiration sequelae if indicated. Utilize case managers for any follow-up rehabilitation orders for home health or outpatient services to ensure a continuum of care for discharge readiness. For total laryngectomy patients, initiate electrolarynx training via an intraoral adaptor or buccal placement. Due to edema, suture lines, and risk of pressure against the surgical site, most patients are unable to tolerate submandibular placement in acute care settings. Depending on the institution, nurses or SLPs should include proper care and cleaning of the lary tube and stoma with recall demonstration for tasks, as well as HME placement. The SLP should identify barriers and facilitate communication so the patient can adequately and efficiently communicate in their home or next level of care [1].

Postoperative and Long-Term Management

Perioperative management is often limited and narrow in scope by the growing trend for early discharge and decreased hospital stay, resulting in the need for intensive therapy regimens from postoperative outpatient resources [12]. Functional deficits will correlate with the amount of tissue resection, with larger defects showing a commensurate increase in difficulty with articulation, intelligibility, and swallowing function [20]. For instance, sizeable oral tongue and base of tongue resections are proportional to poorer speech intelligibility and articulation [12]. Subsequently, robust reconstructions also demonstrate increased unfavorable impacts to speech and swallowing, while the opposite is known for primary closure techniques and smaller/thinner flap choices, which demonstrate improved functional outcomes [12]. Therapy modalities, methods, and interventions are directed by the anatomic location and guided by the extent of the surgical resection and morbidity.

General therapeutic interventions at this stage are aimed at exercise training for strength and range of motion to improve muscle coordination and to counteract trismus (if present) [1]. Treatment will also address how chemotherapy and radiation may impact voice, alaryngeal speech methods, and cognition [1]. Length, time frame, and amount of rehabilitation services are dictated by the nature of the surgery, compliance of the patient, insurance type, and ability to meet goals developed in the plan of care.

Post-op Functional Outcomes for Partial and Hemiglossectomy

Minor effects on speech and swallowing are generally related to intelligibility and directly related to location and amount of resection area. If location is the anterior tip, then the accuracy of consonants is impacted, whereas lateral defects have less impact overall [20]. SLPs utilize the International Phonetic Alphabet (IPA) guided by

place of articulation and manner of articulation to shape and train phonemes. For example, if the tongue tip is impacted, sounds such as /t/, /d/, /n/, /s/, /z/, and /th/ (amongst others) can become distorted and pronounced incorrectly. It is beneficial to review the IPA charts to understand the correlation between the location of surgical intervention and the impact on targeted speech sounds. Expectations are that speech improves as edema and oral anatomy adapt with limited need for further rehabilitation efforts. If rehabilitation is indicated, therapeutic tasks of tongue range of motion, control, strengthening exercises and biofeedback tools are provided [12]. These exercises target the specific anatomical deficits to improve syllable pronunciation through conversational speech [12]. This results in perceptually appropriate sound substitutions [24]. Phonetic placement and exaggerating consonants can also aid to support intelligibility [25]. Use of a tool such as the Iowa Oral Performance Instrument has shown effectiveness in measuring the strength for lateralization, protrusion, elevation, and depression with benefits of patient feedback [26].

Post of Functional Outcomes for Total Glossectomy

Total glossectomy results in severe effects on speech and swallowing, significant change in oral cavity resonance, and overall mobility [20]. Rehabilitation efforts focus on phonatory aspects of speech (e.g., utilizing increased vowel duration, reduction in intensity and rate, elevation/widening of pitch) in addition to shaping methods previously discussed [20]. These patients may also benefit from high- or low-tech AAC. One study reported speech rehabilitation being effective in speech intelligibility with all forms of glossectomy when utilizing therapeutic training of shaping by constricting the vocal tract both anteriorly and posteriorly to form associated phonemes, although this can be difficult to achieve and train [27]. Prosthesis options also increased the intelligibility of spontaneous speech and syllables [28]. SLPs can provide feedback to aid orthodontists and prosthodontists in prosthetic design that can improve articulation patterns [29].

Post-op Functional Outcomes for Maxillectomy

Effects on speech vary due to the number of structures removed and whether reconstruction or a prosthesis is present. Overall, research has shown no major differences in speech outcomes via objective measures if reconstructed or via palatal prosthesis [30]. Regardless of reconstruction, all experienced minimal intelligibility deficits and minor impact on quality of life [31]. The patient's perception of vocal quality will likely be forever altered due to the change in shape and structure of the oronasal cavity [20]. Rehabilitation efforts focus on prosthesis training and care and use of low-tech or high-tech AAC means if reconstruction/prosthesis is unavailable. In some cases, shaping techniques may need to be utilized, as well as the use of shown phonetic placement and practicing in a hierarchy [32]. If expansive surgery or adjuvant radiation is planned, patients may benefit from jaw exercises to reduce potential trismus [12, 20].

Post-op Functional Outcomes for Mandibulectomy

Effects on speech have varying degrees depending upon the type and extent of surgery as the mandible is the anchor for many muscles related to speech and swallowing. Anticipated deficits are associated with range of motion, misalignment impacting speech intelligibility, and trismus [20]. Per Naik, voice is not directly affected by the nature of the surgery; however, some patients may develop complications related to reduced speech intelligibility [33]. Rehabilitation efforts focus on the use of instrumentation to increase jaw range of motion. Multiple modalities have been suggested to increase oral opening (e.g., manual stretching, tongue blades, bite openers, and TheraBite Jaw Motion Rehabilitation System (Atos Medical AB; Hörby, Sweden)). Research indicates that the deployment of devices significantly decreased trismus when compared to the use of wooden tongue blades or manual stretching [34]. Myofascial release completed by a trained physical therapist (PT) or SLP has also shown results to decrease pain, improve range of motion, and increase function and is a widely uti-

lized postradiation therapy [35]. Traditional methods previously discussed are utilized to support intelligibility methods.

Post-op Functional Outcomes for Retromolar Trigone (RMT)/Tonsil

This area has low significance to speech with little impact postoperatively. Most effects are related to discomfort with speech tasks that resolve quickly. However, if damage occurs to outlying tissue and anatomy, longer term deficits can arise. Rehabilitation efforts focus on strength training tasks, compensatory shaping techniques, velopharyngeal insufficiency management via tasks and/or prosthesis, and dentition management [20].

Post-op Functional Outcomes for Floor of Mouth (FOM)

Effects on speech are dependent upon the use of reconstruction. The speech was negatively impacted with reconstruction with varying rates of intelligibility as compared to superior outcomes with primary closures [36]. Another study reported that 96% of participants had difficulty with certain words, but overall intelligibility was excellent with reconstruction [37]. Anticipated deficits are related to articulation and intelligibility due to tongue tethering and range of motion [20]. Rehabilitation efforts focus on compensatory strategies of previously discussed exaggerated articulation and deployment of slow speech rate, gesture to supplement writing, as well as communication boards, repetition with word breakdown, and drill practice with a hierarchy of task load [36].

Post-op Functional Outcomes for Total Laryngectomy (TL)

Due to the surgical removal of the vocal tract and anatomy, clinicians are faced with choices regarding nonsurgical and surgical voice restoration options for rehabilitation management via esophageal speech (ES), artificial larynx (AL), and tracheoesophageal (TE) speech.[12] It is imperative that the healthcare professionals limit biases towards speech method as this can limit the options the patient pursues [12]. Rehabilitation efforts focus on supportive education and counseling for both patient and caregiver, pulmonary rehabilitation, supporting communication training, implementation of stoma care accessories, and use of myofascial manual therapy. It is imperative to initiate pulmonary rehabilitation as soon as medically appropriate due to the disconnect of the upper and lower respiratory tracts where a loss of humidification, filtration, and increase in mucus production with risk for plugging can occur [12]. This is addressed by utilizing a heat moisture exchange (HME) system where the air is conditioned and moistened. It also improves muscle recruitment for lung ventilation and facilitates removal of particles from the air [38].

All artificial speech methods have advantages and disadvantages; however, none showed definite superior results as measured by patient-reported outcomes [39].

Esophageal speech: Before the SLP can select this as a viable option for communication, a careful review of the extent of surgical resection must be considered as this method relies on the hypopharynx and pharyngeal esophageal segment in addition to the tongue for articulation [12]. Clearance from the medical team before initiating training is required. The benefits of esophageal speech being hands-free, device-free, efficient, and cost effective are countered by the negatives of increased length of training time to acquire skill. Additionally, it requires personal motivation because the speech has a short phonation time, low intensity, and few syllables per breath [40]. The SLP commences training on either inhalation or injection methods for insufflation and then focuses on articulation, loudness, pitch and variation, duration, rate, and quality. Few SLPs are knowledgeable and comfortable training this aspect of speech [12]. Only around 2/3 of total laryngectomees will achieve fluent esophageal speech [40]. Manual myofascial techniques have proved beneficial in decreasing esophageal pressure and tension for acquisition and improved esophageal speech [41].

Artificial larynx: An electrolarynx (EL) is a great tool because no airflow is needed to produce sound. Additionally, it is cost effective and rela-

tively easy to learn. An intraoral option is also available if surgery has altered neck anatomy [40]. Around 66.6% achieve good communication skills with EL use [42]. Despite these advantages, the EL has a monotone quality (e.g., mechanical vibration), impacts appearance, and requires hand/manual dexterity to manipulate [40]. The SLP will implement training related to placement, on-off timing, articulation, appropriate rate and phrasing, and nonverbal behaviors, as well as attention to decreasing stoma noise (e.g., mouthing speech not whispering) [12]. The Ultra Voice is an alternative to the typical EL. Ultra Voice is a retainer/denture-like system that receives a signal to operate a loudspeaker where the sound is shaped into speech and intensity and prosody is shaped by a control circuit. Unfortunately, these devices have to be charged, are expensive, and are rarely covered by insurance.

Tracheoesophageal speech: Patient selection and candidacy are paramount to the successful implementation of this speech method. A good candidate will have appropriate stoma size and shape, appropriate tissue, good pulmonary reserve, manual dexterity, vision, financial resources, and responsibility for maintenance and hygiene [40]. Strengths of this system include natural airflow from trach to pharynx or neopharynx for easy air implosion with no aspiration backflow, increased phonation times, intensity, and intelligibility, with overall increased outcomes of speech [40]. Hands-free methods are available, and limited overall teaching is required to obtain fluent speech. Achievability of success with this method is rated at 90%, and most closely resembles natural speech [12]. Depending on the surgeon, this method may require a secondary surgery to form the puncture site. Furthermore, the device may fail or the patient may experience leakage resulting in aspiration. Other issues include biofilm/reflux impaction, overall selection/fitting issues, granulation tissue development, tight or breathy voice quality, device dislodgement, and infection [12].

Augmentative and alternative communication (AAC): As discussed in the preoperative section, a patient may desire or only be successful with AAC. The ability to voice bank and utilize text-to-speech methods through speech-generative devices is an undisputed advantage and an opportunity to increase the quality of life [43].

Speech rehabilitation following head and neck reconstructive surgery is multifaceted, and numerous instruments are available to achieve optimal patient outcomes. Intervention and education by the SLP are imperative in the pre-, peri-, and postoperative period to ensure success and to achieve patient goals.

Assessment of Swallowing Disorders in Head and Neck Cancers

Comprehensive dysphagia assessment in patients with head and neck cancers includes an in-depth medical history, clinical oral examination, and instrumental diagnostics. Contemporary practices favor evaluation of swallowing function that should be performed prior to oncologic intervention to determine a patient's baseline function [44]. Postsurgical and postradiation swallowing assessment should also be performed to determine changes in swallowing function from oncologic treatments.

Medical History

Dysphagia assessment begins with a thorough review of the patient's medical chart that should be conducted to obtain information regarding a patient's current and previous health history. Pertinent medical history includes oncologic history such as tumor site and stage, and previous or planned surgical and medical interventions for head and neck cancer. Information on previous or existing dysphagia, current oral diet, need for diet modifications, use of alternate methods of nutrition, unintentional weight loss, and current or previous history of aspiration pneumonia should be obtained. Disease processes and pharmacologic agents that contribute to dysphagia such as comorbidities and certain medications should be noted.

Clinical Oral Examination

The clinical oral examination provides information regarding the form and function of the oral apparatus. Evaluation of both sensory and motor functions of the oral-facial structures is necessary to determine cranial nerve and muscular pathologies that may impact swallowing function.

Assessment is first initiated by evaluating the anatomic symmetry and integrity of the oral and facial structures at rest. Tasks to elicit sensory and motoric function of the olfactory, trigeminal, facial, glossopharyngeal, vagus, and hypoglossal nerves should be performed. Abnormal movements such as flaccidity, spasticity, dyskinesia, fasciculation, or tremors resulting from cranial nerve pathology may contribute to dysphagia [45].

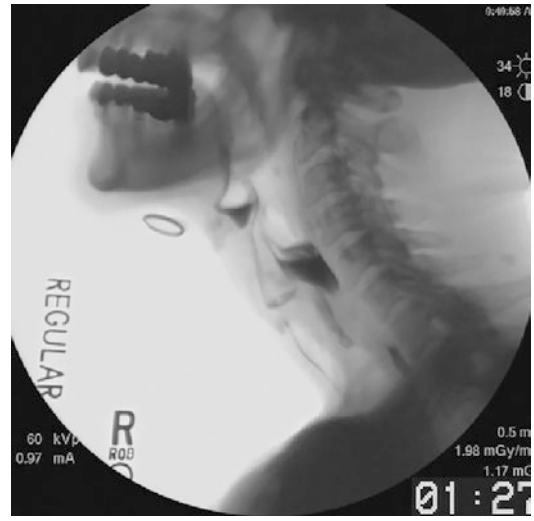

Fig. 16.1 Aspiration in the lateral plane during VFSS

Instrumental Evaluation

The use of instrumental diagnostics allows for evaluation of the anatomy and physiology of the swallowing mechanism. The most common instruments used in the evaluation of swallowing in patients with head and neck cancers are the videofluoroscopic swallow study (VFSS) and fiber-optic endoscopic evaluation of swallowing (FEES). The clinical utility of each diagnostic method will be discussed.

The VFSS allows for visualization of the oral preparatory, oral, pharyngeal, and upper esophageal phases of the swallow. Anatomical structures and physiologic biomechanics of the swallow are visualized. During VFSS, the patient is seated in an upright position, and a radiopaque contrast in varying consistencies and volumes is administered. Swallowing kinematics of the oral cavity, larynx, pharynx, and upper esophagus can be evaluated in the lateral and anterior-posterior planes (Fig. 16.1) [46].

Both descriptive and objective interpretation of VFSS includes analysis of structural presentation and physiologic kinematics of the oral cavity, larynx, pharynx, and upper esophagus. While VFSS is a widely used diagnostic method, there continues to be variability in the analysis of swallowing parameters. A variety of metrics have been developed to improve the standardization and objectivity of VFSS analysis. The Penetration-Aspiration Scale is an 8-point interval scale that describes the degree of laryngeal penetration or aspiration and the patient's response to such events [47]. To evaluate pharyngeal residue, the Pharyngeal Retention Scale describes the volume of residue accumulation in the valleculae and pyriform sinuses following a swallow [48]. The need for more accurate and precise interpretation of physiologic performance on VFSS has resulted in a more objective evaluation of swallowing biomechanics through the use of computational analysis. Objective measurements of swallowing biomechanics allow for quantitative analysis on the timing of swallowing gestures and displacement of structures. The use of objective measures reduces subjective interpretation of normal and aberrant swallowing physiology [49].

Fiber-optic endoscopic evaluation of swallowing provides direct visualization of the larynx and pharynx. Beginning with insertion of the endoscope into the nasal cavity, the FEES allows for visualization of the velum, oropharynx, and pharynx. The structure and mobility of the velum, tongue base, oropharynx, larynx, and hypopharynx are visualized. In addition to evaluation of the swallowing mechanism, the use of flexible

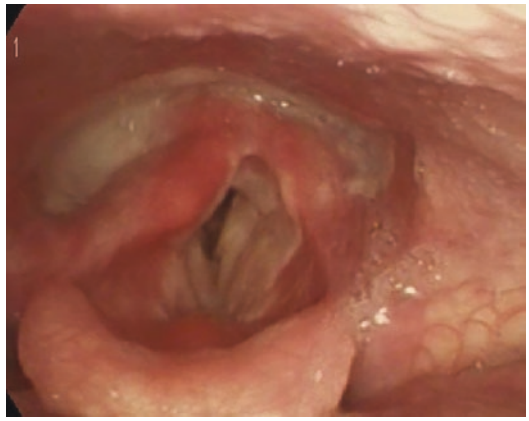

Fig. 16.2 Radiation-induced mucositis of the larynx

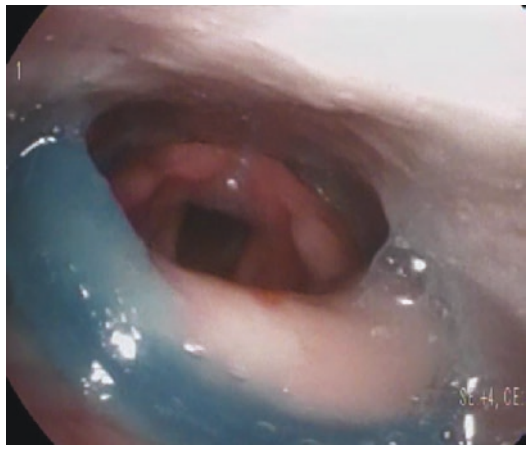

Fig. 16.3 Pharyngeal residue during FEES examination

endoscopy allows for appraisal of secretion management and possible laryngeal anomalies [50]. Specific to patients who have undergone oncologic treatment for head and neck cancers, endoscopy affords thorough evaluation of postsurgical and postradiation changes to the swallowing anatomy that may contribute to dysphagia (Fig. 16.2). To evaluate swallowing function during FEES, various food and liquid consistencies can be dyed white or blue for improved visualization under endoscopy. Laryngeal penetration, aspiration, and pharyngeal residue can be observed. In addition, the benefit of compensatory strategies and maneuvers to improve swallow safety and efficiency can be evaluated under visualization (Fig. 16.3) [51].

Treatment of Dysphagia in Head and Neck Cancers

Dysphagia intervention targets anatomical and physiologic changes that occur as a result of head and neck cancer treatments. Swallowing therapy may be recommended in the reactive or prophylactic settings for both surgical intervention and radiation therapies. Reactive intervention, or swallowing therapy implemented in response to already present swallowing dysfunction, has been the traditional approach to the management of dysphagia in head and neck cancers. Prophylactic swallowing therapy, or prehabilitation, occurs in anticipation of developing swallowing dysfunction. Prophylactic swallowing intervention is associated with improved physical outcomes, decreased hospital length of stays, and reduced overall healthcare costs [52]. Cavalot and colleagues evaluated return to oral intake following supraglottic laryngectomy with and without prophylactic swallowing intervention. Patients who received preoperative swallowing therapy were taught compensatory maneuvers for airway protection due to anticipated neoglottic incompetency and returned to oral intake sooner than patients who did not receive prehabilitation [53]. For many institutions in the USA, prophylactic swallowing intervention is the standard of care for patients undergoing radiation therapy. A prescribed regimen of prophylactic swallowing exercises has been shown to facilitate the maintenance of oropharyngeal muscle function during radiation therapy [54]. In addition to prophylactic intervention, dysphagia therapy may focus on dietary modifications, use of compensatory strategies or maneuvers during swallowing, and physiologic exercises to improve swallowing function.

Diet Allocation

Following oncologic intervention, patients may require changes to their oral diet to improve the safety and efficiency of swallowing. Depending on the severity of dysphagia, the functionality of

the swallow may be impaired. This may result in the need for changes in diet consistency, behavioral strategies, or alternate methods of nutrition and hydration to avoid malnourishment, dehydration, and pulmonary compromise [55]. Appropriate diet allocation can reduce lengthy mealtimes and improve nutritional status and quality of life in patients with dysphagia. Diet modifications to improve the safety and efficiency of swallowing function may include:

- Avoidance of solid consistencies due to impaired oral manipulation
- Thickened liquids for impaired airway protection
- Thin liquids if pharyngeal contractility is impaired
- Alternate methods of nutrition and hydration (nasogastric feeding tube or percutaneous endoscopic gastrostomy feeding tube)

Compensatory Strategies and Maneuvers

The use of compensatory strategies or postural maneuvers during swallowing may be needed to improve swallowing safety or efficiency by improving airway protection or bolus flow, respectively. In patients who have undergone surgical resection for head and neck cancers, appropriate postural changes have been shown to eliminate aspiration in 81% of patients [56]. The use of compensatory strategy or postural maneuver to improve swallowing dysfunction should be evaluated under imaging to confirm effectiveness. Compensatory strategies, swallowing maneuvers, or postural changes to improve swallowing efficiency and safety may include the following:

Postural Changes

- Chin-tuck posture (chin-down posture or neck flexion): The chin-tuck posture more closely opposes the tongue base to the epiglottis while widening the vallecular space. This posture may improve tongue base retraction, laryngeal vestibule closure, and laryngeal elevation [57].
- Head rotation: A rotational head turn toward the side of weakness in the pharynx or larynx can divert a bolus away from the side of rotation. With the bolus lateralized from the weak side, improved bolus clearance can be achieved. The head rotation posture is also beneficial to promote airway closure in unilateral vocal fold weakness [57].
- Lateral head tilt: Tilting the head laterally to the stronger side can improve pharyngeal clearance by diverting bolus flow from the side of the weak pharynx. The use of gravity can improve bolus flow in impairments arising from unilateral oral and pharyngeal weakness [58].

Compensatory Strategies

- Effortful swallow: The effortful swallow maneuver aims to increase tongue base retraction and pharyngeal constriction to improve bolus clearance through the pharynx and upper esophageal sphincter. Patients whose swallowing deficits result in pharyngeal residue may be asked to “swallow hard” to improve bolus clearance [59].
- Supraglottic swallow maneuver: The supraglottic swallow maneuver was designed to impose voluntary airway protection for patients who experience impaired airway closure resulting in aspiration before or during the swallow. The patient is asked to hold their breath, swallow with a breath hold, and cough following the swallow to eject the material that may have entered the laryngeal vestibule [58].
- Super supraglottic swallow maneuver: The super supraglottic swallow maneuver is designed to also improve airway protection similar to the supraglottic swallow. However, the super supraglottic maneuver provides further airway protection by engaging movement of the arytenoid cartilages to the petiole of the epiglottis and closure of the false vocal folds. The patient is asked to hold their breath, bear

down, swallow, and cough after the swallow to eject the material from the airway [58].
- Mendelsohn maneuver: The Mendelsohn maneuver aims to prolong laryngeal excursion and opening of the upper esophageal sphincter during swallowing. The patient is asked to hold their larynx in elevated position using the pharyngeal musculature [58].

Swallowing Exercises

Swallowing exercises are designed to improve the physiologic function of the swallowing musculature. Skeletal muscles can be categorized as type I or type II muscle fibers. Type I muscle fibers are thinner in diameter and produce less force and are suited for high-endurance activities. Type II muscle fibers are responsible for generation of quick, forceful movement. The combined effect of type I and type II muscle fibers is necessary for adequate swallowing function without fatigue during meals. Swallowing exercises are designed to improve range of motion and strength of the swallowing musculature. The selection of a swallowing exercise must be specific to the target impairment. For example, if pharyngeal weakness results in increased pharyngeal residue, exercises specifically targeted to increase the strength of the pharyngeal musculature within a swallowing task should be selected. Depending on the frequency, duration, and resistance load that a swallowing experience is performed, type I and type II muscle fibers can be trained to optimize strength and endurance of swallowing function [60]. Both range of motion and strengthening exercises can be prescribed to improve swallowing function. Examples of range of motion and strengthening exercises are given below:

Range-of-Motion Exercises

- Passive and active stretches for the jaw to improve interincisal opening of the mouth
- Tongue stretches and resistance exercises to increase lingual mobility and strength

Strengthening Exercises

- *Effortful swallow:* The effortful swallow is designed to activate muscle overload through contraction of the tongue base and posterior pharynx. The effortful swallow is performed by having the patient "swallow hard" to increase base of tongue-to-posterior pharyngeal wall apposition. Patients who participated in a 4-week training program where the effortful swallow was performed in isolation daily demonstrated improvement in anterior linguapalatal pressure, and maximum isometric pressure was observed in comparison to baseline performance [61].
- *Masako maneuver:* The Masako maneuver is a resistance exercise designed to improve base of tongue-to-posterior pharyngeal wall apposition. The patient is instructed to hold their tongue in between their teeth and swallow. If reduced tongue base retraction results in vallecular residue, the Masako maneuver can reduce vallecular residue by increasing contraction of the superior pharyngeal constrictors [62].
- *Shaker exercise:* The Shaker exercise improves anterior laryngeal displacement by targeting the suprahyoid muscles. Increased anterior laryngeal excursion results in the traction force that opens the upper esophageal sphincter. The Shaker exercise can be performed either as an isometric or as an isokinetic exercise. In a study by Shaker and colleagues, 11 gastrostomy tube-dependent patients with aspiration after the swallow were able to return to oral intake after completing a 6-week training program focused on both isometric and isokinetic performance of the Shaker exercise [63].

Expiratory Muscle Strength Training

Chronic aspiration due to swallowing dysfunction occurs in 31% of patients who undergo oncologic treatment for head and neck cancers [64]. Expiratory muscle strength training involves

a spring-loaded, resistive device that creates isometric resistance to the swallowing musculature. Expiratory muscle strength training has been shown to improve swallowing safety by targeting cough strength and airway closure. With consistent use of an expiratory muscle strength training, subglottic pressure can be increased and result in a more effortful cough production and subsequent clearance of aspirate from the airway. Expiratory muscle strength training further promotes airway protection through activation of suprahyoid muscles involved in airway closure during swallowing [64].

Improved maximum expiratory pressures and swallowing safety have been demonstrated in patients with dysphagia who completed multimodal therapy for head and neck cancers. After an 8-week expiratory muscle strength training program, patients with postradiation dysphagia and chronic aspiration exhibited a 57% improvement in maximum expiratory pressures on average. Reduced frequency of aspiration and laryngeal penetration and increased ability to clear aspirate from the airway were observed following the 8-week expiratory muscle strength training program [65].

Biofeedback in Swallowing Therapy

Consistent and accurate performance of specific therapeutic maneuvers, compensatory strategies, and strengthening exercises are needed for improved swallowing function over time. However, correct implementation of impairment-specific exercises and strategies can be challenging. Biofeedback can be an adjunct to traditional swallowing therapy to improve a patient's recognition of impaired swallowing performance and rehabilitative target swallow patterns. Biofeedback uses visual and auditory signals based upon kinematic measures to alter swallow physiology that results from structural pathology, impairments in neurosensory function, or failure of the neuromuscular mechanism. In addition, acquisition and mastery of targeted compensatory strategies, maneuvers, and strengthening exercises can be achieved with biofeedback [66]. Endoscopy, surface electromyography, and pharyngeal manometry can be used as biofeedback modalities in the management of dysphagia in head and neck cancer.

Endoscopy

FEES was traditionally developed as a diagnostic instrument in the 1990s. In recent years, fiber-optic endoscopy has been recognized to have a role in swallowing therapy through its ability to provide visual feedback to improve a patient's kinesthetic awareness during swallowing therapy. Patients are able to have direct visualization of their larynx and pharynx. Clinicians can provide tailored education about swallow physiology with direct visualization of a patient's velum, base of tongue, oropharynx, larynx, and hypopharynx [67]. Direct visualization can improve a patient's understanding of postsurgical and postradiation changes to their anatomy that may contribute to dysphagia.

Therapeutic maneuvers and compensatory strategies can be evaluated to determine their effectiveness in promoting improved swallowing safety and efficiency. An advantage of fiber-optic endoscopy as a biofeedback modality is the ability to use real foods and liquids during skill acquisition and mastery of compensatory strategies and maneuvers. When compared to conventional swallowing therapy, swallowing therapy paired with fiber-optic endoscopy as a biofeedback modality resulted in patients returning to oral intake within a shorter length of swallowing rehabilitation [68].

Surface Electromyography

Surface electromyography (sEMG) provides a visual depiction of muscular activation during the swallow. Electrodes placed superficially on the anterior neck provide information about the onset and cessation of muscle activation [69]. Increasing effort and duration of target swallowing exercises can be achieved through biofeedback using visual or auditory signals to indicate

adequate physiologic performance. In addition to muscular strength, coordination of the swallowing pattern can be targeted through sEMG feedback on the correct temporal activation of the suprahyoid, infrahyoid, and pharyngeal constrictors and cricopharyngeus muscles [70].

Manometry

Pharyngeal manometry can be used as a biofeedback tool to provide information about the pressure and duration of swallowing biomechanics along multiple anatomical parameters. Pressures of the velum, tongue base, pharyngeal constrictors, hypopharynx, and upper esophageal sphincter are depicted on a color-coded visuoperceptual graph [71]. Pharyngeal manometry can be utilized to evaluate the effectiveness of compensatory strategies and maneuvers, serve as a therapeutic tool for feedback on specific swallowing exercises, and improve the timing of swallowing gestures [72].

Management of End-Stage Dysphagia

The consequential late toxicities of chemoradiation therapy can result in fibrosis, atrophy, denervation, and lower cranial neuropathies that result in a dysfunctional larynx. Irradiation-induced vocal cord paralysis is a rare complication with an incidence of 1–9%. The onset of vocal cord paralysis can be delayed extending to 35 years post-chemoradiation therapy. Vocal cord paralysis can result in dysphonia, dyspnea, and tracheostomy tube dependence [73].

Late-radiation dysphagia has an insidious onset with patients demonstrating functional swallowing for a long duration prior to the onset of swallowing dysfunction. Profound dysphagia from impairments in sensory-motor impairments can result in intractable aspiration. In feeding tube-dependent patients with severe dysphagia from late-radiation toxicities, 80% were found to have absent laryngopharyngeal sensation. Laryngopharyngeal sensory neuropathy increases the risk of aspiration and inability to clear the airway of aspirate due to profoundly impaired airway sensation [74]. Recurrent aspiration pneumonia and feeding tube dependence resulting from a dysfunctional larynx are not uncommon. In addition to comorbidities associated with late-radiation dysphagia, the 30-day mortality rate of intractable aspiration and recurrent pneumonias is 21% [75].

Development of a dysfunctional larynx from late effects of chemoradiation therapy is often refractory to swallowing therapy and minimally invasive surgical interventions. For patients with recurrent aspiration pneumonias, frequent hospitalization, feeding tube dependence, and reduced quality of life due to their profound swallowing dysfunction, a functional total laryngectomy to improve airway and swallowing functions may be pursued. Permanent separation of the airway from the digestive tract eliminates the risk of aspiration, thereby reducing the risk of aspiration pneumonia development. While the natural voice is sacrificed during total laryngectomy, alaryngeal voice rehabilitation can restore communicative techniques. Wu and colleagues reported that 100% of feeding tube-dependent patients were able to resume oral intake with or without feeding tube supplementation after functional total laryngectomy [76]. While functional total laryngectomy eliminates the risk of aspiration, previous surgically related and radiation-induced biomechanical swallowing impairments will persist and contribute to ongoing dysphagia in 17–72% of patients with total laryngectomy [77].

Tracheostomy Management

Evidence has shown that a multidisciplinary, protocoled approach to tracheostomy care leads to decreased morbidity and mortality with a reduced time to decannulation. There is significant variation amongst the management of tracheostomy tubes across institutions. Appropriate management of tracheostomy affects time to PO intake and hospital length of stay and has significant quality-of-life implications [78]. Airway safety is the commonest reason for the presence of trache-

ostomy in head and neck cancer patients, but management in the perioperative period becomes essential to limit morbidity and improve quality of life.

Effect on Dysphagia

Historically, it was felt that tracheostomy tube presence increased the risk of dysphagia and aspiration by limiting laryngeal elevation and desensitizing the larynx. In an early study of 125 head and neck cancer patients, 58 had a tracheostomy tube present. 58.6% of those patients demonstrated aspiration, compared to 23.8% of 63 patients who did not have a tracheostomy [79]. Recently, a similar study using scintigraphy was designed to measure aspiration risk in patients with tracheostomy. Smaller, capped tubes can limit the risk of aspiration and did not interfere with swallowing [80]. Nevertheless, evidence suggests that waiting until after decannulation to institute swallowing exercises can increase the chance of success.

Effect on Hospital Length of Stay and Patient Experience

Airway management in head and neck cancer patients remains challenging often related to restricted head and neck movement, trismus, reduction in airway space due to tumor, and distorted anatomy related to prior treatment. Tracheostomy is therefore a common management strategy in these patients. Studies have shown, however, that average length of stay is at least 2–4 days longer for patients with tracheostomy tubes and often requires longer intensive care unit stays [81]. Additionally, patients with tracheostomy have been more likely to require feeding tubes at discharge or had delayed oral intake [82, 83].

Not surprisingly, patient experience was negatively affected by the presence of a tracheostomy. Patients report a fear of choking, frustration with inability to communicate, throat or neck discomfort, and feelings of isolation. The majority of patients wished that they could avoid tracheostomy "if possible" [84]. The authors do not advocate avoiding tracheostomy for these reasons alone but do point out that it is necessary to be more selective in who truly requires placement during the perioperative period.

Determining Who Needs Tracheostomy

Over half of all patients who underwent free flap reconstruction were managed with a tracheostomy for airway protection postoperatively [83]. In recent years, increasing evidence has shown that this is unnecessary. Siddiqui et al. demonstrated that 80% of their patients were managed successfully without a tracheostomy, and none required urgent airway intervention postoperatively [81]. Similarly, Moore at al. found that overnight intubation was a safe alternative to tracheostomy in patients undergoing free flap reconstruction of the oral cavity [82]. In an effort to preoperatively determine who can safely be managed without a tube, two different groups have developed scoring systems to help stratify risk. Cai et al. [85] found that patients with defects of the bilateral mandible, tongue, oropharynx, and floor of mouth; bilateral neck dissection; bulky soft-tissue reconstruction; and a history of radiotherapy all increased the risk of requiring tracheostomy. In their scoring system, anyone with <2 risk factors could successfully and safely be managed without a tube, but >3 required tracheostomy placement [85].

Similarly, Mohamedbhai et al. developed a TRACHY score to help guide airway management [86]. Each patient had points based on T stage, type of reconstruction, anatomic location, medical comorbidities as determined by ASA status, prior radiotherapy, and laterality of neck dissection, with patients receiving bilateral neck dissections at a significantly higher risk. In their model, patients scoring less than 4 can be safely managed with intubation alone, whereas greater than 4 prompts tracheostomy placement [86].

Conclusion

There are many factors that contribute to whether or not a patient requires a tracheostomy tube and when they can be safely decannulated. Developing a strict decannulation protocol is beyond the scope of this chapter. In general, when patients have tolerated a capped tube for >24 h, they are safe for decannulation. Nevertheless, it is important to consider the risks involved with tracheostomy placement including longer ICU stay, longer hospital stay, increased risk of dysphagia, delayed PO intake, and need for feeding tube, as well as associated morbidity and patient anxiety. Multiple studies have shown that head and neck cancer patients can be managed safely without tracheostomy tube, and scoring systems have been developed to further stratify who is an appropriate candidate.

Multidisciplinary Team

The treatment of head and neck cancers requires ongoing surveillance from a team of healthcare specialists. With the support of a multidisciplinary team, patients undergoing head and neck cancer treatment have a greater understanding of their diagnosis, the early and long-term side effects of their oncologic treatment, and the psychosocial and emotional manifestations of their cancer journey.

The involvement of a multidisciplinary team begins at the initiation of cancer care. From the time of diagnosis, members of the head and neck cancer team develop a care plan. The members of the head and neck team include the head and neck cancer surgeon, medical oncologist, radiation oncologist, dentist, speech-language pathologist, dietician, and nursing staff. Prior to the initiation of head and neck cancer treatment, these members are involved in treatment planning, identifying risk factors for treatment-related complications, and establishing psychosocial supports. During treatment, communication amongst the multidisciplinary team focuses on a patient's current status, response throughout treatment, and need for treatment modifications to mitigate negative outcomes. At the completion of head and neck cancer treatment, the multidisciplinary team is involved in disease surveillance, management of treatment-related toxicities, and supportive care in quality-of-life issues [87].

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Surgical Site Complications and Management

17

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Introduction

Surgical site complications are commonly an issue of partial or total failure of soft tissue healing (wound breakdown/dehiscence with or without surgical site infections, haematomas and/or seromas). Alternatively, complications may be site specific, relating to specific surgical anatomy of the procedure involved.

Site-specific complications may or may not relate to impaired wound healing and therefore include a multitude of potential problems such as fistulae, plate/implant fractures, delayed/non-union of access osteotomies and bony reconstructions, plate/implant exposure, sialocoeles or even orbital compartment syndrome. Furthermore, ablative head and neck surgery commonly requires the use of either vascularised or non-vascularised grafts to reconstruct the head and neck defect, each of which comes with potential donor-site morbidities. This chapter discusses the evidence-based management of failed wound healing (dehiscence and fistula formation) as well as these site-specific complications in major ablative and reconstructive head and neck surgery, with some additional guidance based upon the author's own experience. The aim of this chapter is to provide an idea of when to consider '*going back to the operating room*' and when to stick to conservative management protocols. This chapter focuses primarily upon the management of complications once they have occurred (either at the time of primary surgery or as a secondary approach) but does touch upon preventative measures. There is also an emphasis on addressing underlying causative factors, which can be corrected to encourage spontaneous healing wherever possible. Surgical site infections are discussed in the context of managing wound sinuses and fistulae but not specifically regarding the management of cellulitis and abscess.

Head and Neck Wound Breakdown: Dehiscence and Fistula Formation

Wound dehiscence can be defined as 'partial or total separation of previously approximated wound edges, due to a failure of proper wound healing' and typically occurs between 5 and 8 days after surgery [1]. Dehisced wound edges can lead to the formation of a sinus or fistula,

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with the former being an 'abnormal channel that originates or ends in one opening' and the latter being an 'abnormal pathway between two anatomic spaces or a pathway that leads from an internal cavity or organ to the surface of the body' [2]. Furthermore, a sinus or fistula may arise independent of a surgical wound, for example from underlying pathology such as infection, neoplasm or obstructive salivary disease (such as a ranula fistulating through the floor of the mouth into the oral cavity). This chapter focuses specifically on those occurring at surgical sites and principally related to failure of wound healing.

In head and neck surgery, fistulae occurring at surgical sites (from superior to inferior) commonly include cerebrospinal fluid leaks through skull base defects and orocutaneous, oroantral, salivary, pharyngocutaneous, and chyle fistulae.

To effectively manage a dehisced or fistulating wound, the underlying cause should be identified and managed accordingly. In reality, this typically involves a period of conservative management (the mainstay being regular wound inspection and dressing to encourage secondary intention healing) alongside medical optimisation of predisposing risk factors [3]. In some cases, this alone is sufficient, whereas in others, a watch-and-wait policy is ineffective or inappropriate (where time for conservative management alone is not an option; for example, in the case of exposed major neck vasculature or airway compromise) and additional surgical interventions are warranted.

Diagnosis

History and Examination

It is commonly the surgeon undergoing routine hospital rounds who first identifies a dehisced or fistulating wound as the patient may not know what to look out for. It is important to ask questions pertinent to the type of surgical procedure performed. For example, in any patient having undergone skull base surgery, the surgeon should elicit any suggestion of leakage of fluid from the nose (CSF rhinorrhoea) or ears (CSF otorrhoea), postural headache (worse when sitting upright) or meningism (neck stiffness and/or photophobia), relating to either a CSF leak with associated low-pressure headache or meningitis arising from a dural injury. A patient with an oroantral fistula may complain of leakage of fluid from the nose when taking fluids orally. An established salivary-cutaneous fistula may precipitate mealtime-related discharge (or mealtime-related swelling in the case of sialocoele).

It is important to inspect all accessible surgical wounds daily in the early post-operative phase and routinely at post-operative appointments where, after a course of post-operative adjuvant radiotherapy in particular, fistulae/sinuses may present late. With floor of mouth and mandibulectomy resections, mucosal dehiscence allows sumping of oral contents into the neck. Inspection and palpation of the floor of the mouth (sublingual) and neck (submental and submandibular triangles) for any collection, even in the absence of a neck dissection, is crucial. When oroantral fistulae are suspected, as tempting as it is, we would advise against the use of Valsalva against a pinched nose to check for bubbling in the mouth as a diagnostic aid as this may unpredictably precipitate a new fistula or enlarge an existing one, especially in the early post-operative period.

Fluid Biochemistry

Fluid discharge should be examined macroscopically at the bedside for bloodstaining, turbidity and colour before sending for laboratory analysis. Beta-2 transferrin is 97% sensitive and 99% specific for CSF [4]. Drain fluid amylase concentration correlates positively with salivary fistula development following gland excision (levels above 51,100 U/L are almost diagnostic) [5]. Amylase concentrations in neck drainage fluid are also widely reported as indicative of pharyngocutaneous fistula formation [6–8] although blood (serum) amylase has also been reported as a relevant marker [9]. Although the thoracic duct is on the left side, milky-coloured fluid from any neck drain should raise suspicion of a chyle leak, since 25% of chylous fistulae reportedly occur at the right lymphatic duct. Milky drain fluids should be sent for the bio-

chemical assessment of triglyceride concentrations; greater than 100 mg/dL or presence of chylomicrons is diagnostic [10, 11].

Dye Tests

The blue dye test for orocutaneous and pharyngocutaneous fistula is 36.4% sensitive and 100% specific, as well as a simple, cost-effective bedside investigation with minimal risk to the patient and therefore makes an ideal primary investigation in suspected oro/pharyngocutaneous fistula. It involves the use of diluted water-soluble blue dye such as patent blue or methylene blue, with the latter having a lower risk of anaphylaxis. In our units, this is performed by the speech and language therapy team. Blue dye is diluted with water and held in the mouth for 5 s, and then the patient is asked to swallow. A positive test suggestive of an oro/pharyngocutaneous fistula is indicated by the presence of blue staining in drains or wound exudate [12, 13]. Lumbar puncture with intrathecal infiltration with fluorescein can play a valuable role in both pre-surgery diagnosis of CSF leak (particularly when beta-2 transferrin testing is negative in the presence of strong clinical suspicion) and following positive endoscopic and CT investigations for intraoperative localisation of leaks. In our practice, we would adopt a multidisciplinary combined CT/endoscopic and fluorescein approach to diagnosing, localising and treating post-operative CSF leaks in a fashion similar to the algorithm proposed by Marshall et al. (Fig. 17.1) [14].

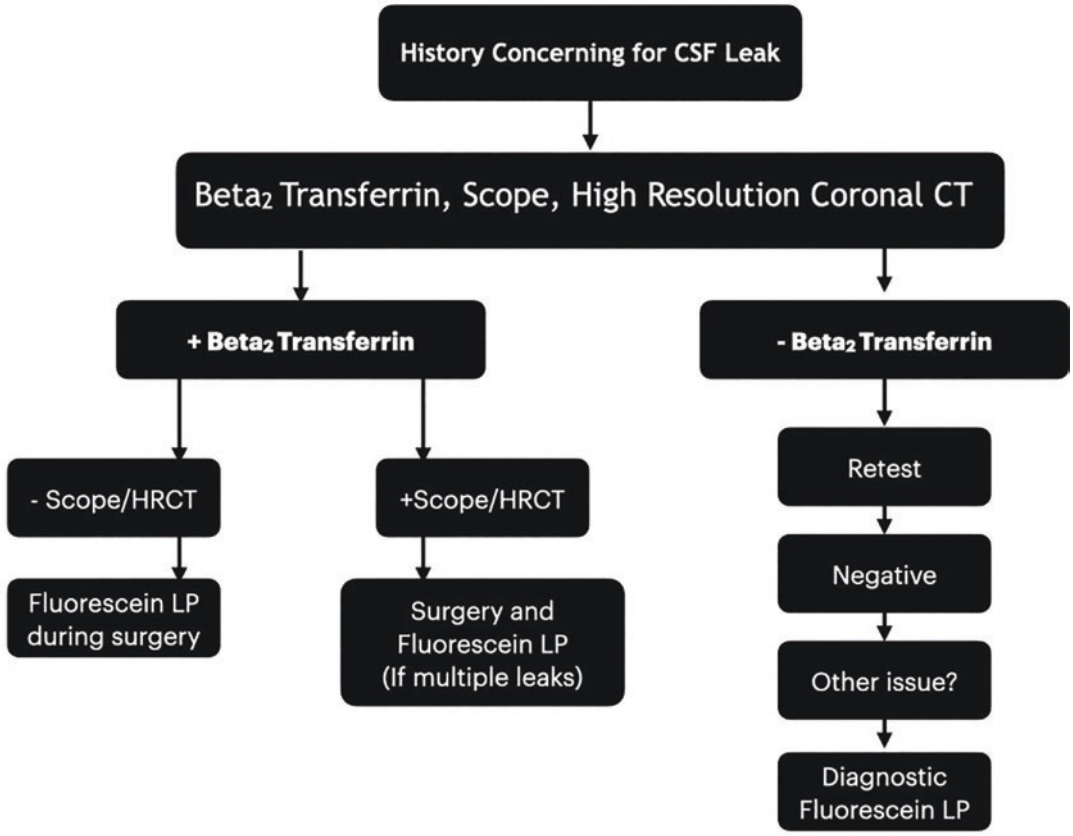

Fig. 17.1 Algorithm for CSF leak management, taken from Marshall AH, Jones NS, Robertson IJA. An algorithm for the management of CSF rhinorrhoea illustrated by 36 cases. Rhinology. 1999;37 (4):182–5. Note: *HRCT* high-resolution computer tomography, *LP* lumbar puncture

Imaging

For suspected infective neck-space collections, CT in combination with clinical examination is reportedly 95% sensitive and 80% specific. However, each method in isolation (CT or clinical examination) is inferior [15]. In the presence of clinical suspicion, we have a low threshold for the use of contrast-enhanced CT for primary diagnostic imaging of neck-space fluid collections (infective or non-infective). Although primary ultrasound imaging (plus/minus needle drainage) facilitates easy (almost bedside) imaging and treatment in one sitting, we find CT diagnostically reliable as it is not user dependent. Furthermore, we feel that it provides more anatomical detail as to the possible source of the collection and provides opportunistic cross-sectional evaluation of the surgical site in general.

Small-volume videofluoroscopy (VF) reliably demonstrates small pharyngeal leaks at internal suture lines following pharyngolaryngectomy. Routine postoperative use is associated with a significant reduction in progression to pharyngocutaneous fistula as oral feeding can be withheld allowing secondary-intention healing [16]. We would advocate the use of water-soluble contrast swallow routinely at 2–3 weeks post-operatively before commencing oral feeding, but other authors will feed patients orally as soon as 7 days post-operatively based upon negative VF findings [17].

For diagnostic imaging of CSF leaks, as discussed above, we typically employ non-contrast high-resolution CT (HRCT) scanning (with other investigations such as fluid biochemistry and endoscopy with/without fluorescein intrathecally) as it provides clear imaging of bony defects. However, other options exist with mixed benefits and limitations (and may be used depending on local imaging resources and availability of the aforementioned non-radiological investigations). CT cisternography not only can identify bony defects but also helps characterise the nature of the leak (small/profuse) but is invasive as it requires lumbar puncture and intermittent leaks may still be missed. MR cisternography involves no radiation but carries a significant false-negative rate and lacks bony detail. Radionucleotide cisternography is advantageous for detecting intermittent leaks but is a lengthy procedure and invasive and requires more significant doses of radiation [18]. Cisternography scans may be reserved for cases where non-contrast HRCT fails to locate the causative bony defect (for example, where multiple post-operative defects are present) [19].

Prevention and Management

Head and neck surgical site complications relating to failure of healing require both general and definitive measures (the latter being conservative or interventional). General measures address mostly systemic, modifiable factors that are commonly implicated in wound healing complications. Definitive measures specifically focus on the surgical site itself.

General Conservative Measures

Endocrine pathology and disorders of immunity are commonly found in 'head and neck' patients with wound-related complications. Hyperglycaemia as defined by a blood glucose level greater than 180 mg/dL (10.0 mmol/L) in the perioperative period is associated with increased surgical site infections, fistulae and wound dehiscence in patients undergoing major head and neck reconstructive procedures [20]. With regard to a diagnosis of diabetes mellitus (DM) itself, Eksander et al. demonstrated in their series of 515 patients undergoing head and neck reconstructive procedures that DM is an independent predictor for wound infection in patients undergoing head and neck reconstructive surgery, but the diagnosis was not directly attributable to any difference in wound healing per se [21]. Furthermore, a multicentre study of 31,075 patients, of which 13% had DM, suggested that DM is associated with a greater length and cost of hospital stay, with greater odds of postoperative infection, cardiac events and acute renal failure, but again, there was no significant difference in surgical wound healing rates [22]. Therefore, it is apparent that a diagnosis of DM itself may be associated with increased risk of wound infection but is not

directly associated with impaired healing. Instead, the importance of ensuring careful control of blood glucose (avoiding hyperglycaemia) in the perioperative period is the key consideration with regard to both avoiding and treating neck wound dehiscence or fistula formation. Recognising those patients at risk remains essential, but more importantly, careful control of blood glucose levels and avoiding hyperglycaemia with judicious use of oral hypoglycaemics and insulin regimes (including a variable-rate insulin 'sliding scale' where necessary) will both reduce the occurrence and aid the conservative management of established head and neck wound dehiscence or fistulae. It is important to pre-emptively involve diabetologists and/or diabetes nurse specialists to address the risk and presence of hyperglycaemia.

Other common endocrine pathologies to bear in mind when treating head and neck wound dehiscence and fistula formation in the perioperative and early post-operative period include liver cirrhosis and thyroid disease. Wound complications in head and neck surgery are reportedly the commonest indication for readmission to hospital after major head and neck cancer surgery and reconstruction. Furthermore, hypothyroidism and liver disease are, independently, significant risk factors for readmission [23, 24]. A 2018 multivariate analysis of 182 salvage laryngectomy patients identified a greater than 3-fold risk of fistula formation and greater than 11-fold risk of wound reoperation in patients with post-operative hypothyroidism (thyroid-stimulating hormone [TSH] greater than 5.5 mIU/L); the risk of fistula formation incrementally increases by 12.5% and reoperation increases by 10% for every doubling of the TSH level [25]. Hyperbilirubinaemia can induce a systemic inflammatory response and end-organ dysfunction, manifesting as nutritional impairment, coagulopathy and impaired wound healing [26]. The mechanism of impaired wound healing in liver cirrhosis may relate to the malnutrition element, with impaired epithelialisation and cancellous bone formation demonstrated in animal models following dental extraction [27]. It stands to reason therefore that in patients suffering from surgical site complications with concomitant endocrine/hepatic anomalies, early specialist input is warranted and the importance of monitoring and managing thyroid function following laryngectomy with hemi/total thyroidectomy cannot be underestimated.

Haematinics and nutrition need to be managed carefully. Low post-operative haemoglobin levels are associated with the development of pharyngocutaneous fistulae following total laryngectomy [28]. Patients receiving more than 4 units of red cell transfusions are particularly at risk [29]. There has been debate surrounding the potential immunosuppressive impact of blood transfusion leading to infective complications, with subsequent fistula formation [30]. However, to our knowledge, no clear causative relationship has been established between the blood transfusion and fistula formation, and in our opinion, this remains an association (perhaps relating to the acute perioperative anaemic requirement for transfusion rather than the transfusion itself). Patients with such complications in the presence of post-operative anaemia should therefore benefit from iron replacement therapy and blood transfusion where appropriate to aid healing. In our practice, a typical absolute threshold for red cell transfusion in post-operative anaemia (with the aim of avoiding wound healing complications) is <8 g/dL. However, this varies according to individual patient requirements, with a more liberal transfusion policy in symptomatic patients with higher haemoglobin levels, those likely to require post-operative radiotherapy or those with comorbidities that may be further compromised by post-operative anaemia such as ischaemic heart disease or cerebrovascular disease. Protein is required for collagen synthesis, angiogenesis and fibroblast proliferation. Carbohydrate starvation can lead to a catabolic state. Vitamin C and zinc deficiency also contributes to failure of healing [1]. In patients undergoing major head and neck procedures, early involvement of the dietician (commencing enteral polymeric tube feeding within 24 h of surgery) is recommended with regimes initially aiming for energy intakes in the region of 30 kcal/kg/day and 1.2 g/kg/day of protein [31]. There is evidence in head and neck free flap reconstructive procedures that early oral, rather

than enteral tube, feeding is associated with shorter hospital stay with no increase in the risk of flap dehiscence or fistula formation, suggesting that patients should progress to oral feeding as quickly as possible [32]. However, if dehiscence or fistula formation should occur, this may not be feasible, and the increased healing burden associated with this complication warrants even greater specialist dietetic input.

The use of long-term preoperative corticosteroids is thought to be an aetiological factor for wound dehiscence in surgery in general [33]. However, some postulate that it is the dose of steroids used that is key, particularly in the post-operative phase [34]. Where high-dose corticosteroids (such as dexamethasone) are required post-operatively in patients with wound complications for the management of post-operative swelling, regimes should be judiciously dosed, short and stopped if at all possible.

Tobacco smoking is associated with a significant increase in surgical complications overall in major reconstructive head and neck surgery. Specifically in the case of surgical site complications, a 2020 meta-analysis of 2155 smokers versus 3124 non-smokers reported a significantly increased risk of haematoma formation (19.12%) but no significant difference in flap failure, surgical site infection or fistula formation. Encouraging cessation of smoking pre-, peri- and post-operatively is important for surgical risk overall but is not an absolute prerequisite for surgery (to prevent the majority of specific surgical site complications) [35]. Nevertheless, for minority in whom surgical site complications do occur, smoking must cease by any reasonable means. Concerns have been reported surrounding the impact of nicotine replacement therapy (NRT) on wound healing. The evidence for the positive impact of NRT on smoking cessation however is strong. Although it has been noted that high doses of nicotine (higher than those seen with NRT) will impair skin flap viability post-operatively, there is a lack of evidence from human studies to suggest that NRT actually increases the risk of surgical site (healing-related) complications [36]. In fact, cutaneous microvascular perforation (subcutaneous blood flow and tissue oxygenation) is lower in smokers than non-smokers, but the use of an NRT patch normalises this [37]. Therefore, for patients with surgical site complications and struggling to stop smoking, we would advocate the use of NRT in the peri- and post-operative period.

Successful treatment of surgical site complications is entirely dependent upon patient compliance and cooperation; otherwise, medical and surgical interventions to address the above systemic factors are futile. Patient education (through careful explanation as well as information leaflets, images, smartphone/computer applications, 'serious games' and audiovisual demonstrations) is recommended for the prevention of surgical site infections [38]. In our experience, this is best achieved through a multidisciplinary approach, by team members who are intrinsically involved with the patient in the peri- and early post-operative period, including surgeons, specialist nurses, speech and language therapists and dieticians.

Specific Measures

CSF Leak

Not discussing spontaneous causes, CSF leaks may be traumatic or iatrogenic in origin (following head and neck surgery). The incidence of a CSF leak in trauma is between 2 and 9%, depending on closed vs. penetrating injuries [39]. Any head and neck surgery in the proximity of the anterior cranial cavity carries the risk of a CSF leak, for example functional endoscopic surgery or ablative surgery. In two medium-sized cohorts, the risk of CSF leak after surgery involving skull base resection was observed to be in the region of 5–7% [40, 41]. Surgery accessing the cranium via the sinuses, for example trans-sphenoidal surgery, carries a risk of CSF leak as high as 15%. Furthermore, the risk of CSF leak is increased in revision surgery compared to primary surgery [42]. Ninety percent of CSF leaks of the anterior cranial fossa will present with rhinorrhoea. CSF leaks can be defined as early (usually within 24–48 h), late onset (after 1–2 weeks) or very late onset [43].

Preventative Measures at Primary Surgery

Surgery involving, or close to, the base of skull should involve a multidisciplinary team, including maxillofacial surgery, ENT and neurosurgery. Adequate surgical planning should seek to avoid dural trauma and/or have plans in place as backup should intraoperative complications arise.

The so-called patch technique for dural tears is well described in neurosurgical texts to prevent CSF leaks, using an absorbable polymer sheet and some form of sealant or glue [44]. Subsequent reconstruction of overlying tissue should be in a multi-layered format to maintain integrity and prevent breakdown and CSF leakage by using autogenous bone, fascia or fat grafts, or synthetic dural substitutes as inlay and/or onlay grafts [45].

Conservative Management

Evidence of spontaneous closure of CSF leaks following head and neck surgery is limited—in the setting of trauma, up to 70% of CSF leaks may be expected to close spontaneously [39]. However, the risk of intracranial infection, notably bacterial meningitis, is high and the patient should be closely monitored for signs of infection. The use of prophylactic antibiotics is still debated. A meta-analysis by Brodie et al. of CSF leak patients reported a rate of infection of 2.5% in patients given antibiotics versus 10% in patients treated without antibiotics [46]. Ultimately, treatment will come down to surgeon preference and hospital guidelines or protocols.

Going Back to the Operating Room: Definitive Surgical Management (and Indications)

Surgical repair of a CSF leak can be classified as open or closed (i.e. endoscopic repair), and the method of repair will depend on the size of the defect and the flow rate of CSF. Over the past few decades, endoscopic surgery to skull base lesions and repair of CSF leaks have become the preferred surgical technique [45].

Larger defects or persistent leaks may require the use of vascularised tissue, of which the nasoseptal flap has gained most attention following several positive case series. The nasoseptal flap is a full-thickness mucoperiosteal/perichondral flap that can be raised endoscopically and if needed provide a large paddle of vascularised tissue to reconstruct small to large defects [47]. Combined with inlay/onlay grafts, as discussed above, this flap can restore the majority of defects and has become the first-line choice in many units. CSF leaks secondary to large tissue defects, especially with bony loss (as may occur in complications following free flap reconstruction), will require open repair and re-exploration.

Oral: Dehiscence and Orocutaneous/ Oroantral Fistulae

OAC, OAF and OCF

An oroantral communication (OAC) is a communication between the maxillary sinus and oral cavity. The most common reason for a small- to medium-sized OAC is iatrogenic, secondary to dental surgery, i.e. extraction of an upper posterior tooth or displacement of teeth/implants into the sinus. Other notable causes, which may produce larger defects, include following ablative surgery, for oral malignancy or bony cysts, or as a complication of flap failure and subsequent necrosis and dehiscence. If left untreated, this communication will rapidly become epithelialised, creating a fistulous tract, i.e. an oroantral fistula (OAF). In a small OAC, this process is thought to occur as rapidly as 7–8 days [48]. An OAC in the region of <5 mm can be considered 'small', while a defect approaching a socket width (i.e. 5–10 mm) is considered medium in size. Larger defects beyond this will require more extensive planning and treatment, as discussed below.

An orocutaneous fistula (OCF) is a persistent communication between the oral cavity and skin of the head and neck. OCF is a particularly troublesome post-operative complication after reconstructive surgery. In this situation, a fistulous tract develops as a result of chronic infection, secondary to dehiscence or wound breakdown often precipitated by a foreign body (i.e. an osteosynthesis plate).

Preventative Measures at Primary Surgery

Evidence is clear that immediate closure of an OAC results in success in greater than 90% of cases. In contrast, in delayed/secondary closure,

where multiple procedures may be required, success rate can drop to less than 70%, not to mention the considerable increase in patient morbidity from a protracted course of treatment [49].

Conservative Management

When an OAF/OCF develops, surgical intervention can sometimes be avoided; in an asymptomatic patient, or in those where further surgery is contraindicated, then non-surgical treatment is appropriate. In OAF cases, an obturator may also be of benefit.

A small OAC of 2–3 mm can be expected to close spontaneously; however, patients may present with symptoms of an acute sinusitis within 24–48 h which, if left untreated, can precipitate opening of the communication and creation of an OAF in the longer term. Therefore, if an OAC is suspected at the time of primary surgery, it is imperative to undertake preventative measures there and then, or instigate immediate medical management to increase the chances of spontaneous closure. The so-called antral regimen is the first-line management of any OAC, where immediate or preventative treatment has not been performed—comprising a broad-spectrum antibiotic, decongestant and analgesia as required. The aim is to reduce infection and improve sinus clearance to allow the tissue the best chance of healing.

Medical management of OCF will involve antibiotic coverage to treat chronic infection as and when. OCF discharge should be swabbed for culture and sensitivity, to guide appropriate antimicrobial treatment.

Going Back to the Operating Room: Definitive Surgical Management

Surgical management of an OAF/OCF will involve excision of the fistulous tract and closure in layers to restore the integrity of the two epithelial surfaces.

OAF

There are numerous surgical options available to close oroantral fistulae, spanning the entirety of the reconstructive ladder, from local and distant flaps to free tissue transfer and grafting—including autogenous, allogenic, xeno- and synthetic grafts.

The majority of small- to medium-sized OAF can be treated successfully with a local flap. Of these, full-thickness mucoperiosteal buccal or palatal flaps are most commonly employed. Numerous different flap designs or modifications have been reported in the literature, including advancement, rotation, pedicled, etc., and it is beyond the scope of this chapter to discuss them all in depth. A recent review by Parvini et al. provides an excellent summary [50]. However, the basic principles of flap design and fistula closure still apply—the flap should be of adequate size, have a broad base to preserve vascularity and be tension free. When raising a mucoperiosteal flap, horizontal 'scoring' incisions in the periosteum will aid flap mobility and placement.

The optimum strategy for closure of any OAF would be to reconstruct both oral and nasal/antral layers, with reports detailing the use of two local flaps to provide continuity of both mucosal layers [51]. However, single-layer closure is still an appropriate option in the majority of small- to medium-sized defects, with high success rates in well-planned cases. We particularly favour the use of a buccal fat pad flap in addition to a local advancement flap (most often a buccal flap as access to the buccal fat pad almost requires the raising of the flap anyway), placing the buccal fat superiorly to achieve dual-layered closure. In select cases, a buccal fat pad flap alone is sufficient to close smaller defects, undergoing rapid epithelialisation in the oral cavity.

Interpositional grafts can be of benefit, especially in medium-to-large defects when both mucosal layers are being reconstructed. Commonly, these may include autogenous bone or cartilage grafts, collagen/bone xenografts or engineered dermal/tissue substitutes. Larger OAF (especially those OAF that are persistent or have failed initial surgery with a local flap) may require a regional flap, of which a tongue, nasolabial or temporalis muscle flap is most appropriate. In our experience, the tongue flap is an effective option but can be uncomfortable for the patient until second-stage surgery to divide the pedicle. Nevertheless, it has a success rate reportedly of up to 95% [52]. The nasolabial flap is an alternative (as a one-stage island flap, or two-

stage flap procedure), providing a source of highly vascular tissue in close proximity to the maxillary alveolus, and is useful for larger defects. While the raising of a temporalis muscle flap is a more technically challenging procedure, it also allows a one-stage surgical approach for even larger oroantral defects.

OCF

The primary aim of definitive surgery for an OCF will involve removing any source of infection, debridement and wound closure. In the majority of cases, further reconstructive surgery will not be required, for example removal of a mandibular reconstruction plate. In complex cases, of paramount importance is adequate assessment to allow formal surgical planning. Scenarios where there is loss of tissue, for example an OCF secondary to mandibular osteonecrosis, may require grafting or free tissue transfer. In the case of large defects, surgical principles of hard and soft tissue reconstruction with appropriate planning are applied, as discussed elsewhere in this book.

Of paramount importance in the post-operative phase of OAF/OCF management is excellent oral hygiene. In addition, patients should adhere to a soft diet, and patient factors should be optimised to encourage successful tissue healing, for example smoking cessation or glycaemic control in diabetes.

Cervical: Pharyngocutaneous Fistulae

Preventative Measures at Primary Surgery

Reconstruction of the pharyngeal/hypopharyngeal defect requires careful consideration of the volume of tissue lost, and more specifically the volume and quality of remaining tissue. For previously untreated partial pharyngectomy defects, where more than 3.5 cm of pharyngeal width remains (unstretched mucosa), it is common practice to attempt primary closure (as the degree of tension on the suture line would be within acceptable limits to provide a relatively low risk of dehiscence and leaks) [53]. This should of course be on the basis of the mucosa appearing clinically healthy (i.e. soft and pliable vascularised mucosa). Where direct primary closure of the pharyngolaryngectomy defect is feasible, numerous techniques have been advocated to minimise the risk of developing a pharyngocutaneous fistula, including suturing and stapling [54]. We would advocate 3-0 Vicryl on a round-bodied needle with no strong preference over orientation of closure (T, Y or vertical) but prefer the use of full-thickness interrupted vertical mattress sutures with inversion of the mucosal surfaces into the lumen. Nevertheless, this is simply a preference as neither suture configuration, orientation of closure nor suture material appears to have a strong correlation with the risk of fistula formation [55]. In the case of post-chemoradiation salvage laryngectomy defects, the quality of tissue is poorer than in primary laryngectomy such that pharyngocutaneous fistula rates are doubled [56]. In these patients, there is a low threshold to proceed to flap reconstruction (pedicled or free tissue transfer), even in the case of apparently sufficient remaining mucosal width for primary closure because of a demonstrably greater risk of wound breakdown and pharyngocutaneous fistula with the latter approach [57]. Bulkier flaps may be advantageous in these cases to provide a better suture-line seal. For example, ALT free flaps have significantly lower fistula rates than radial forearm free flaps (RFFFs) [58]. In the authors' practice, we advocate the use of a significantly greater bulk of vascularised tissue. This can be achieved with two flaps such as an anterolateral thigh free flap to reconstruct the pharyngeal lumen with a pectoralis major pedicled flap overlying it (with/without using a skin paddle to reconstruct/relieve tension on the neck skin), effectively providing a 'double-breasting' effect and minimising the risk of direct fistulation to the skin surface should a luminal suture-line leak occur post-operatively. Even where primary closure is easy to perform in salvage laryngectomy, we would recommend wrapping the anastomosis suture line in vascularised tissue, such as the gastro-omental free flap or a pedicled pectoralis major (muscle-only) flap since it has been demonstrated by a meta-analysis that an 'onlay' flap-reinforced pharyngeal closure significantly reduces post-operative pharyngocutaneous fistula rates [59].

For previously untreated cases where less than 3.5 cm of healthy unstretched mucosal width is present, flap reconstruction is also proposed (using an ALT/RFFF 'patch', for example). Where a narrow strip (less than 1 cm) of mucosa remains, it is advisable to remove the residual mucosa and treat as a circumferential defect instead, with the use of tubed fasciocutaneous flaps or jejunal free flaps instead [53].

For all circumferential and most 'patch' repairs, the use of a salivary bypass tube is recommended to protect anastomosis suture lines. The inclusion of a salivary bypass tube with tubed fasciocutaneous flaps for circumferential defect reconstructions has produced lower fistula rates than those without [60] and has become standard practice in many centres. The tube is typically removed 2 weeks post-operatively (before routine VF imaging), but if there is any clinical suspicion of a pharyngeal leak or fistula formation, the tube should remain in situ for an extended period with serial cross-sectional imaging (for detection of collections and evolving fistulae).

Tissue shrinkage with healing can result in tension at suture lines connecting the flap to the residual mucosa, and this could result in post-operative leaks and pharyngocutaneous fistula formation. For this reason, flaps should be slightly oversized (by approximately 10–20% of the defect size) [61]. Circumferential anastomotic shrinkage at the distal (oesophageal) end of a tubed fasciocutaneous flap leads to stricture formation. To minimise this, the authors advocate slight oversizing of the luminal diameter of the distal end of the tube plus spatulating of oesophagus to a similar circumference by placing a linear slit in the anterior oesophageal wall [62].

Conservative Secondary Management

With the increasing use of non-surgical organ preservation treatment for laryngeal and hypopharyngeal SCC, total laryngectomy is commonly performed as a salvage procedure, thus making pharyngocutaneous fistulae an increasing problem because of the poorer quality and healing properties of radiotherapised tissue [63]. Most (60%) pharyngocutaneous fistulae close with conservative management (antibiotics during the drainage and debridement period with avoidance of oral feeding, followed by a period of pressure dressing and then further healing thereafter, typically lasting around 1 month until closure) [64, 65].

When a pharyngocutaneous fistula is suspected post-operatively, we adopt an approach similar to the algorithm proposed by Kiong et al. (Fig. 17.2) [12]. Although not a routine practice in our unit, hyperbaric oxygen therapy (HBOT) is a recognised treatment for pharyngocutaneous fistula in post-radiation cases, justified by a 2016 Cochrane review [66]. It improves tissue oxygen tension, promotes angiogenesis and induces free radical bactericidal activity [67]. In a study of eight male patients who had failed a trial of conservative treatment for pharyngocutaneous fistula over an average period of 1 month, successful closure was achieved in seven patients with HBOT (over periods ranging from 14 to 45 days) and local debridement [68]. Some have concerns over the potential for HBO to induce tumour growth although an animal study demonstrated no evidence for this [69]. In those who have used all treatment modalities and therefore are ineligible for further potentially curative treatment, one author group justifies its use on this basis [63]. There is however a general paucity of good prospective studies of HBOT for pharyngocutaneous fistula in salvage laryngectomy patients; therefore, further work on this topic is needed.

Negative-pressure wound therapy (NPWT) has been advocated as an effective approach to conservative management of pharyngocutaneous fistula [70–72]. Closure can typically be achieved within 20 days of commencing NPWT, although relatively high negative pressures (−100 to −125 mmHg) may be required to maintain an effective seal of the occlusive dressing [71]. It should not be used over exposed vasculature, nerves, organs or anastomoses, and extreme care should be taken in the case of coagulopathy or those with otherwise increased bleeding risk. Wound infection should be treated appropriately with antimicrobials and debridement as necessary before commencing NPWT [73].

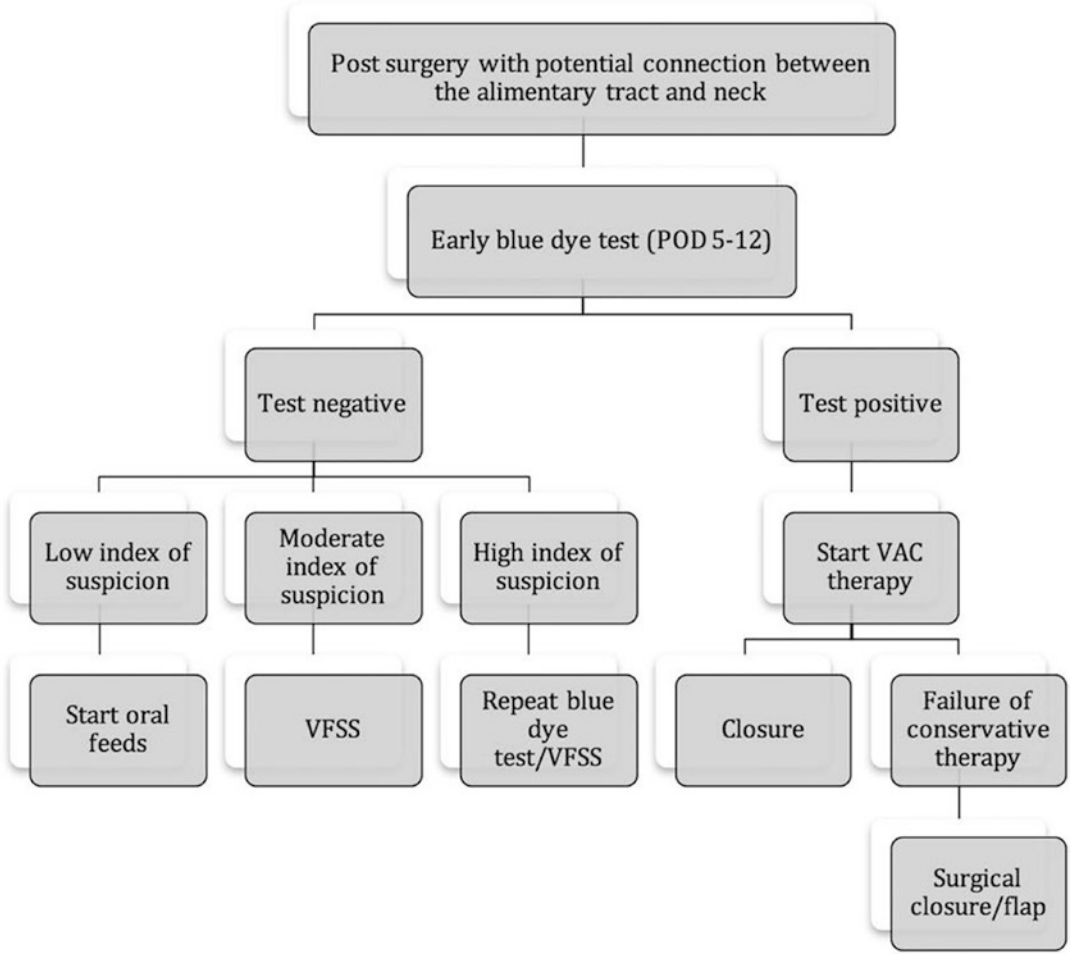

Fig. 17.2 Algorithm for pharyngocutaneous fistula management. Taken from Kiong KL, Tan NC, Skanthakumar T, Teo CEH, Soo KC, Tan HK, et al. Salivary fistula: Blue dye testing as part of an algorithm for early diagnosis. Laryngoscope Investig Otolaryngol. 2017;2(6):363–8 [12]

It is worth noting that pharyngocutaneous fistulae in patients who have had previous chemo-radiotherapy (rather than radiotherapy alone) appear to respond less to conservative treatment (with or without hyperbaric oxygen therapy); thus, in this subset, it is reasonable to progress straight to regional flap coverage rather than a prolonged (e.g. more than 4 weeks) trial of conservative treatment [63]. Prolonged conservative management may eventually lead to fistula resolution but in our opinion is more likely to result in significant stricture formation.

Going Back to the Operating Room: Definitive Secondary Surgical Management (and Indications)

Returning to the operating room to attempt definitive surgical closure of the pharyngocutaneous fistula is a decision that should not be undertaken without careful consideration of the underlying local and systemic factors that have contributed to its existence, as well as the potential risks of surgery (the main concern being relapse or even worsening of the fistula). For this reason, we would advocate that in almost all cases, pharyngocutaneous fistula is managed conservatively as

discussed above prior to attempting definitive surgical closure. Not only because conservative treatment may allow spontaneous closure (avoiding the risks of surgery altogether), but also because it provides time to assess and treat all contributing factors, be they local or systemic.

The need to return to theatre urgently for surgical treatment of neck wound dehiscence or fistula is rare in our experience and is perhaps only warranted when there is risk to life, for example airway or bleeding risk due to exposed major vasculature and/or active bleeding, acute infective neck-space collection or in situations where it would be harmful to the patient to undergo a prolonged period of conservative treatment (if there is a time pressure to commence further/adjuvant oncological treatment, for example). Even in these situations, the general conservative measures discussed above should be undertaken simultaneously, with as optimal pre-surgical resuscitation as possible (e.g. packed red cell transfusions for anaemia or variable rate insulin infusion for uncontrolled diabetes).

One of the key considerations in determining the technique of closure to be used depends on the size of the fistula defect. In our experience, we have found no hard-and-fast rule to the closure technique relating to fistula size as much of the decision depends on the mobility and quality of the available local tissues (relating to anatomical location and previous radiotherapy doses etc). Accordingly, the patient should be counselled and consented for the most invasive possible treatment (such as free flap reconstruction) even though this may be found to be unnecessary after surgical exploration. Nevertheless, as a rough guide, the 1980 classification by Hawkes and Stell provides an indication of likely surgical approach, inspiring the treatment algorithm proposed by Molteni et al. (Fig. 17.3) [54, 74].

In small-diameter defects, the fistula tract should be separated into an internal and external layer, with direct closure of each layer independently. Ideally, we would dissect and mobilise the two layers with a Swann-Morton No. 15 blade and close them independently with interrupted 3-0 Vicryl vertical mattress sutures, aiming to invert the internal layer edges into the lumen and evert the skin layer edges. If the fistula tract is too small to provide the access to do this, we would then employ a local semicircular turnover skin flap technique as originally described by Hawkes

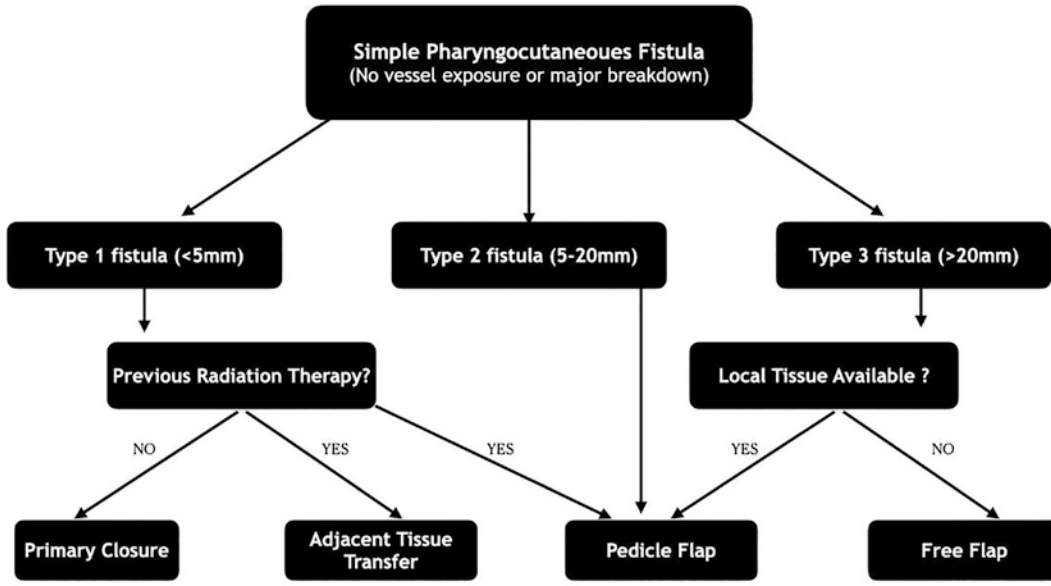

Fig. 17.3 Surgical closure algorithm based upon Hawkes and Stell's classification of pharyngocutaneous fistulae. Taken from Molteni G, Saccetto A, Saccetto L, Marchioni D. Optimal Management of Post-Laryngectomy Pharyngo-Cutaneous Fistula. Open Access Surg. 2020;13:11–25 [54]

and Stell, aiming for a tension-free repair to avoid wound dehiscence [74].

When local, regional or free flap reconstruction of the fistula defect is warranted, flap choice depends upon the location and size of the defect, plus the availability and quality of local tissues as flap donor sites. As with any defect in the head and neck, we would advocate a 'reconstructive ladder' approach, aiming to use the simplest but lowest-risk option available. Although local flaps are potentially the simplest option, they might not be the safest, since local tissues may also be compromised by previous irradiation. Therefore, the pectoralis major flap is the 'go-to' choice in most situations as unlike the deltopectoral, sternocleidomastoid or supraclavicular flap, it provides a large volume (bulk) of non-irradiated and reliably vascularised muscle. It is also relatively easy to harvest. However, we acknowledge that it can at times be aesthetically too bulky. In these situations, we would consider raising a muscle-only (myofascial) flap and placing a split-thickness (10/1000 in.) skin graft over the external surface of the muscle to avoid the bulk of the overlying adipo-cutaneous layer. Where the pectoralis major flap is unsuitable or unavailable, the internal mammary artery perforator flap is another useful regional flap that is typically outside the field of previous irradiation and should also be considered. After regional flaps, we would then consider either the radial forearm free flap or the anterolateral thigh flap. In our experience, the radial forearm free flap is robust and has a less than 4% failure rate. Furthermore, it is relatively safe to de-epithelialise and fold at the mid-portion of the skin paddle to create two separate skin paddle islands joined by subcutaneous tissue in order to provide a richly vascularised internal and external skin lining to the fistula defect. For larger defects, the anterolateral thigh free flap can provide larger skin paddles of variable bulk, as a fasciocutaneous perforator flap, a vastus lateralis flap or something in between. In addition, the flap can easily be harvested in a chimeric fashion to provide two completely separate fasciocutaneous skin paddles based on separate perforator vessels off the common pedicle (descending branch of the lateral circumflex femoral artery). Furthermore, wherever possible, the fascia lata layer of the anterolateral thigh flap is cut wider than the skin paddle to provide a circumferential 'skirt' such that it can be sutured into position as a separate layer to the skin paddle, providing an even more watertight closure.

Although not used in our practice, a novel, evolving and less invasive approach to surgical repair of pharyngocutaneous fistulae is with endoscopic techniques. Providing that transoral access is available, an endoscope can be used to explore the fistula tract and pass sutures through a cannulated needle into the pharyngeal lumen and back out again. This is then repeated multiple times in a circumferential fashion around the fistula opening, quilting the overlying platysma skin flap down onto it, and it was successful in all five cases reported by Fink et al. [75]. This technique does require an intact platysma skin flap overlying the defect nevertheless [54].

Cervical: Chyle Leak/Fistulae

Preventative Measures and Intervention at Primary Surgery

Chyle leak is uncommon but carries potentially significant morbidity, occurring in up to 8% of neck dissections, and after 24–48 h will typically result in electrolyte disturbance and, if prolonged, hypoalbuminaemia [76–78]. Furthermore, the irritant nature of chyle in the post-surgical neck space can lead to wound dehiscence and fatal rupture of the great vessels of the neck [77, 79]. It is crucial therefore to make adaptations to surgical technique wherever possible to minimise this risk and, when it does occur, to recognise a chyle leak intraoperatively, providing an ideal opportunity to remedy the situation (rather than discovering the leak several days post-operatively as is often the case).

Intraoperative detection of chyle leaks is in our experience most likely to be achieved at the exact time of injury; by performing careful and slow dissection of level IV, an immediate leakage of a seemingly tiny amount of clear fluid can usually be seen but may only last for a couple of seconds before leakage appears to cease because of

sudden decompression of the thoracic/right lymphatic duct. Thus, when dissecting level IV, the surgeon should actively monitor for sudden and brief leakage of small volumes of clear fluid. We advocate using a blunt spreading dissection technique and LigaSure™ (bipolar shears) resection of the most inferior limit of level IV, in order to help delineate and avoid accidental injury to any lymphatic duct that may be present as well as the transverse cervical artery and vein. Furthermore, it is our opinion that the use of loupe magnification provides the surgeon with a greater chance of identifying the duct and, if injured, any small leak that may occur at the time. In theory, one might try to capture any clear fluid for analysis at the time, but in reality, the immediate leak is too small and brief to capture and it is typically therefore only the large volumes that collect in the surgical drains post-operatively that provide the ample volumes needed for biochemical analysis. One other intraoperative opportunity to detect a chyle leak is during the Valsalva procedure (in combination with Trendelenburg positioning) at the end of the neck dissection; alongside detecting bleeding from vessels, we have found this to be another useful way to provide a 'second chance' to elicit and identify a small immediate discharge of lymph from any injured duct.

Some authors have investigated the impact of different surgical techniques on the prevention of chyle leak in neck surgery. In a series of 12 chyle leaks from 368 patients undergoing neck dissection, suture ligation of the inferior limit of level IV and monopolar electrocautery appeared to fare better than harmonic scalpel. However, the major scientific flaws of this study were the relatively low number of cases to compare the efficacy of three different techniques, each performed by different surgeons (thus not controlling for other potentially confounding variables such as inter-surgeon differences in tissue-handling skills in general) [76]. Nevertheless, another randomised study evaluating complications after neck dissection with/without harmonic scalpel for papillary thyroid carcinoma also found the harmonic scalpel, despite its benefits in performing the neck dissection more quickly, to be associated with an increased risk of chyle leak [80]. In our practice, we have not encountered a similar problem with the LigaSure™, and in our opinion, the key consideration to preventing post-operative chyle leaks is slow and careful dissection of level IV with avoidance of duct transection wherever possible and if necessary and then preferably proactive (rather than reactive) use of ligating clips on the duct and internal jugular vein.

When a chyle leak has occurred and is recognised intraoperatively, loupe magnification may also facilitate identification of the transected duct lumen and its tributary into the internal jugular vein for subsequent clip ligation. However, in our experience, it is uncommon to be able to clearly identify the duct when surrounded by the fatty lymphatic tissue at level IV. In this situation, we would firstly attempt to oversew the area of the fluid leak. However, this must be done cautiously as in doing so, excessive tissue manipulation can risk of making the leak worse [81]. In addition, we would advocate a second layer of closure (in combination with oversewing), which can be achieved with vascularised tissue (regional muscle flaps) and/or surgical glues (such as cyanoacrylate or fibrin tissue glue). We prefer to avoid the scalenus medius flap as its harvest presents an unnecessary risk to the brachial plexus, whereas the clavicular head of sternocleidomastoid can be mobilised and sutured into the wound bed without much difficulty. Should, however, sternocleidomastoid provide insufficient muscle bulk, we would have little hesitation in utilising a pectoralis major (muscle only) flap. The inferiorly based omohyoid muscle flap has been used to good effect by some authors for coverage of a thoracic duct injury by suturing the superior belly of omohyoid into the leaking wound bed [82]. However, in our practice, we would routinely harvest the superior belly of omohyoid with the level I–IV neck specimen as we believe that this provides a 'cleaner' and reliably thorough dissection, so it is not a flap compatible with our technique. Nevertheless, for those who do not dissect omohyoid routinely, this flap may be of value. Cyanoacrylate glue ('skin glue' or medical grade 'superglue') can be used intraoperatively to help seal transected lymphatics in the wound bed of

level IV. We might use this in addition to a sternocleidomastoid muscle flap and oversewing although one author group has found topical cyanoacrylate glue on the wound to be effective on its own, and also as an effective 'backup' option when muscle flaps alone are insufficient to stop further leakage [83].

Conservative Secondary Management

Chyle leaks can be arbitrarily described as high (>500 mL/day) or low volume, and this can, to an extent, guide management in that most low-volume leaks tend to respond to conservative management whereas high-volume leaks are significantly more likely to require definitive surgical intervention and sooner [11]. However, some authors characterise 'high volume' at >1 L/day or even 1.5 L/day, so the literature on management of chyle leaks and thresholds for surgery/intervention is highly variable [77, 79]. In our practice, we do not adhere to a hard-and-fast rule regarding volume and duration of chyle leaks as an indication to return straight to theatre for exploration of level IV. In almost all cases, we would employ some specific conservative measures and allow enough time for them to have any potentially useful effect (i.e. at least 48 h). The pattern of leakage thereafter then guides further management. For example, if the rate of leakage starts to reduce (even if high), we would continue with conservative treatment. If leakage continues to increase, or after a short period of improvement plateaus for several (e.g. 5–7) days at high volumes, only then would we proceed to interventional techniques.

Our experience supports the findings of others that chyle leaks are usually managed effectively with conservative measures alone. The key aims in conservative management are to reduce (minimise) the production of chyle and in turn (in combination with other methods) to aid closure of leaking lymphatics altogether.

When a chyle leak is suspected or confirmed post-operatively, we would modify the patient's feed to a medium-chain triglyceride (MCT) enteral feed (or non-fat diet if already feeding orally). Active (vacuum) drain systems are typically used in our patients, and these can help avoid associated wound complications of large chyle collections. Sometimes, however, we have found that removing the vacuum and therefore converting to passive drainage can help reduce the output of chyle into the drain bottle(s), and providing drainage in this manner is effective (with no associated swelling of the neck); we find this preferable to high-vacuum active systems in chyle leaks. If active drains appear necessary to remove chyle collections, we would still advocate relatively low-suction systems where possible. It is advisable to rest the patient at 45 'head-up' (or vertical in a chair) and optimise respiratory function (use of saline nebulisers to loosen and aid expulsion of airway secretions) to minimise intrathoracic pressures or Valsalva episodes, which could precipitate further leakage. If leakage continues after 2 or 3 days or escalates despite the MCT feeding regime, we would commence a somatostatin analogue such as octreotide and convert feeding to total parenteral nutrition (TPN) alone with assistance from our dietetic colleagues. Indeed, there is a rational argument that MCT feeding is something of a 'halfway-house' as it may still precipitate chyle production itself and does not provide sufficient post-surgical nutritional value anyway. As nutrition is a key consideration in effective wound healing, TPN in the presence of a confirmed chyle lead is arguably a superior feeding option altogether [77]. We would therefore have a low threshold to proceed to TPN in chyle leaks unresponsive to 'early' conservative measures. Applying a supraclavicular pressure dressing/bolster makes reasonable sense, principally because it reduces dead space in which chyle collections can form and may also aid direct compression and an early seal of leaking lymphatics in the supraclavicular fossa. However, this should be avoided with ipsilateral microvascular venous anastomoses and/or contralateral internal jugular vein ligation because of the potential sequelae of internal jugular vein obstruction.

Going Back to the Operating Room: Definitive Interventional/Surgical Secondary Management (and Indications)

In our opinion, surgical exploration should be considered only after conservative measures have shown to be ineffective. Furthermore, it is worth considering all other interventional or 'minimally invasive' options that may be available. Local infiltration of sclerosant agents such as tetracycline, OK-432 or povidone-iodine (achievable either via percutaneous injection or via surgical drains) in order to induce fibrosis and a seal of leaking lymphatics has been reportedly effective [78, 84]. One caveat to consider however is the possibility of failure and fibrosis induced by sclerotherapy, making subsequent surgical exploration more difficult and potentially risky. In our unit, before committing to sclerotherapy, we would seek advice from our colleagues who specialise in vascular anomalies as they have more experience in the use of sclerosants and can advise on the likelihood of success on a case-by-case basis.

Other possible 'interventional' approaches (avoiding open exploration of the neck) include transabdominal embolisation and thoracoscopic ligation of the thoracic duct. We have no experience in using these techniques and would require involvement of allied specialists with expertise in these approaches (interventional lymphovascular radiologists and thoracic surgeons). Transabdominal embolisation of the thoracic duct has a success rate between 45 and 70% [11]. It can be performed with coils and/or liquid embolic agents, with a seemingly greater efficacy when a combination of the two is used [85]. Thoracoscopic ligation of the thoracic duct can provide immediate cessation of a chyle leak following neck dissection [86]. There is little doubt that these approaches are a worthwhile consideration. However, they do add further risk of surgical site morbidity outside the head and neck region, whereas surgical exploration of an already established neck wound does not and fits within the remit of the surgeon who is ultimately responsible for the patient's care.

When conservative treatment and any suitable interventional options have been exhausted, and are insufficient or inappropriate, we would then undertake surgical exploration of the neck and try to identify the origin of the leak using the aforementioned techniques. A brief attempt would be made to identify the leaking duct and surgically clip or ligate it. However, this secondary procedure would typically be undertaken several days to weeks after the primary surgery, and therefore clear identification of transected lymphatic ducts is much less likely. In this scenario, we would harvest a relatively bulky pectoralis major myofascial flap (rather than smaller sternocleidomastoid or omohyoid muscle flaps typically used in primary surgical repair) and pack the muscle bulk into the supraclavicular fossa, oversewing to the underlying fatty tissue, followed by a covering layer of fibrin (Tisseel) tissue glue (or cyanoacrylate as an alternative).

Free Flap Donor-Site Morbidity: Prevention and Management for Specific Problems

Head and neck reconstructive microvascular surgeons typically have a handful of go-to free flaps with which they feel comfortable harvesting, insetting and anastomosing. In our practice, we would routinely harvest the radial forearm, anterolateral thigh, fibula, scapula and deep circumflex iliac artery free flaps for which we would comfortably manage any simple donor-site complications, calling upon allied specialty colleagues when appropriate. However, in our experience, the jejunal free flap is best harvested by upper gastrointestinal surgeons (assisted by the reconstructive microvascular surgeon who can provide guidance on the length of the segment to be harvested and desired pedicle length/calibre). The upper gastrointestinal surgeon can take principal responsibility for the donor site and therefore manage any abdominal complications themselves. Accordingly, jejunal free flap donor-site complications fall outside the scope of this section. Similarly, the scapular flap is another flap used infrequently, with brachial plexus injury being the main concern. Should a

brachial plexus injury be suspected post-operatively, this is best managed with an immediate referral to an expert.

Radial Forearm Flap

In our experience, by far the commonest donor-site concern for this flap is failed take of the full-thickness skin graft placed on the radial forearm skin paddle donor site. There are numerous possible reasons for this: inadequate preparation (defatting) of the full-thickness skin graft (typically harvested from the ipsilateral abdominal wall), haematoma formation underneath the graft (from inadequate haemostasis or coagulopathy/intraoperative use of anticoagulants) and wound infection or shearing forces (from excessive wrist and forearm movement). Furthermore, inadequate vascularity of the grafting bed is a key concern if the graft is not sitting on muscle but rather on tendon or paratenon. Ensuring that the graft is as 'fat-free' as possible is, in our opinion, a key requirement. We would prefer to raise the full-thickness graft without any visible fat on the undersurface from the very beginning of the procedure wherever possible. This is most reliably achieved by harvesting using a size 10 Swann-Morton blade in a deep dermal level rather than at the actual interface of the dermis and fat itself (i.e. essentially a very thick split-skin graft harvested with a knife). This provides a graft that is in effect full thickness but avoids the need for repetitive trauma to the underside (once harvested) if subsequently removing residual fat globules with tenotomy scissors.

Adequate preparation of the grafting bed is crucial. Exposed tendon should be wrapped in muscle; the free edges of flexor digitorum superficialis and flexor pollicis longus muscle bellies can be gently brought over any exposed flexor carpi radialis or brachioradialis tendon at the wrist defect with a few 4-0 Vicryl tacking sutures without any detrimental effect on wrist or hand movement in the long term. Ensuring adequate haemostasis of the grafting bed is crucial, but bleeding will inevitably happen at times. To minimise the risk of significant (graft-compromising) haematoma formation, we aim to suture the graft in place and staple an overlying pressure dressing (non-adherent membrane such as perforated silicone sheet/paraffin gauze and sponge) as quickly as possible. Insetting the graft with a continuous-running rather than interrupted suture technique makes this easy. If there is any delay, then we would consider flushing 10 mL of normal saline solution underneath the graft (and/or making a couple of perforations in the graft with the point of a blade) in order to evacuate any established haematoma before stapling the sponge pressure dressing in place. To minimise shearing forces on the graft, a dorsal plaster of Paris slab with crepe bandage ('back slab') can be placed (from the fingertips to the elbow joint) to almost immobilise the hand in the neutral position. We leave the back slab and sponge pressure dressing in situ for at least 7 days and as long as 10 days post-operatively to give the graft the best chance of 'take'.

Acute hand ischaemia is an extremely rare but disastrous complication of harvesting the radial artery and has been known to occur in the presence of a normal preoperative Allen's test and Doppler ultrasound and absence of a history of peripheral vascular disease. False-negative findings on these preoperative tests may relate to significant variations in arterial anatomy, including a defective superficial palmar arch. Nevertheless, ischaemia can occur even in the presence of normal preoperative angiography [87, 88]. Therefore, there remains considerable variation between units in their preoperative workup for harvesting this flap. Providing the Allen's test is clinically normal; in our practice, no additional investigations would be performed prior to harvest. An abnormal Allen's test would however prompt consideration of Doppler/duplex ultrasonography and/or angiography, or perhaps using the contralateral (dominant) forearm or an alternative donor site (such as the anterolateral thigh). For peace of mind, it is perfectly reasonable to take the tourniquet down (if used intraoperatively) after clamping the radial artery with a vascular clamp to ensure that good capillary refill remains in the fingertips before committing to division and tying off the radial artery at the

wrist. If, however, despite the above measures, acute ischaemia ensues, a vascular surgeon should be contacted immediately with consideration of revascularisation (either by re-anastomosing the radial artery or by placing an interpositional saphenous vein graft in the forearm, for example).

Anterolateral Thigh Flap

Unlike the vastus lateralis flap, the anterolateral thigh flap is a perforator flap with a minimal amount of muscle harvested with the fasciocutaneous paddle. Regardless, the vastus lateralis muscle is compromised to some extent with either technique and can, in theory, cause significant weakness and stiffness in knee joint extension post-operatively. There is little that the surgeon can do to avoid this, other than avoiding 'over-dissection' of perforator vessels; although it is tempting to trace every viable perforator when harvesting this flap, it is usually unnecessary from both a flap vascularity and donor-site morbidity point of view. Ultimately, only one (or two) good perforator vessels are usually required.

The anterolateral thigh flap is a popular choice in H&N reconstruction where a larger or thicker 'sheet' of soft tissue is required (compared to a radial forearm free flap). Nevertheless, the residual soft tissue defect at the thigh can be particularly large if primary closure is not possible. In this situation, for harvesting soft tissue paddles larger than 8 cm (thigh) width, we adopt one of the two possible approaches: either harvesting (fully or in part) adipofascial perforator flap (sparing the donor-site skin for primary closure) or placing a split-thickness skin graft at the donor site. Because of the considerable dead space generated in the thigh when dissecting this flap, suction drains are routinely used. Furthermore, a negative-pressure wound dressing ('VAC dressing') overlying the split-thickness skin graft can be particularly advantageous. It helps to reduce dead space (and therefore collections of exudate/haematoma) beneath the graft. The VAC dressing also splints the graft in position, and there is good evidence to suggest that it actually improves neovascularisation and graft take overall in the early post-operative period [89]. This in turn might make early mobilisation of the patient after surgery less of a concern with regard to graft take, especially seeing as portable VAC dressing pumps are widely available.

Fibular Flap

The fibular flap is a favourite for reconstruction of mandibular continuity defects because of the good pedicle length, ease of harvest, bone quality for osseointegrated dental implants, a thin skin paddle and general reliability. It is by far the commonest flap used in our practice for composite reconstruction of mandibular and low-anterior maxillary defects. We employ an in-house computer-aided design protocol to plan positions of osteotomies and placement of osteosynthesis plates and dental implant fixtures. Indeed, a reverse planning approach to mandibular reconstruction with patient-specific osteosynthesis plates/implants is widely purported to provide optimal dental rehabilitation because implant fixtures can be predictably and ideally positioned for later use, thus avoiding difficulties in dental rehabilitation further down the line [90]. The main issue with the harvest of the fibular free flap is the risk of subsequent distal foot ischaemia, which is a real concern in all potential candidates since congenitally anomalous trifurcation of the popliteal artery (leading to a dominant peroneal artery supply to the foot) is seen in up to 12% of the population [91]. Beyond the essential preoperative clinical evaluation of foot vascularity including palpation of the posterior tibial and dorsalis pulses plus assessment of toe capillary refill, imaging with CT angiography of the lower limbs provides a reliable evaluation of vascularity and is the modality of choice in our practice. Conventional CT angiography can even distinguish septocutaneous perforator vessels and periosteal branches, and it also provides the necessary DICOM data for virtual surgical planning [92]. Alternative approaches include MR angiography, plain-film angiography and Doppler-based imaging, although colour flow Doppler is less sensi-

tive to the congenital anomalies and we would therefore not recommend its use for this purpose [93]. At surgery, the foot should be prepped with disinfectant solution or wrapped in a clear sterile bag to ensure that the foot vascularity can be monitored clinically throughout the long day of operating. We avoid the use of a tourniquet as we do not find it necessary for the purpose of intraoperative haemostasis and the pedal pulses can easily be reassuringly palpated at any point, including after clamping the distal end of the pedicle with a haemostat before division and ligation. Should foot ischaemia ensue after division of the pedicle (with a pale, cold and pulseless foot), the first consideration would be to recruit the help of an experienced vascular surgeon since it is possible to revascularise the foot with interposition saphenous vein grafts in this scenario [94]. Obviously, this is something that the reconstructive head and neck surgeon has the technical know-how to do. However, in this high-stakes scenario, it is advisable to draw upon the experience of an expert vascular surgeon who may have access to alternative or perhaps better management options.

Musculoskeletal complications of this flap are another key concern. Tibiotalar (ankle) joint instability is a recognised complication of fibular flap harvest. As with most surgeons, in the average-sized patient, we aim to preserve the distal 7 cm of the fibula bone, measuring from the prominence of the lateral malleolus (not the distal tip); nevertheless, for taller patients (with longer fibulae), we would consider a slightly greater distance. Tibiotalar osteoarthritis has been reported as a complication of fibula harvest and is something best avoided by maintaining as much distal fibula bone as feasible without compromising the reconstruction [95]. Claw toe deformity is another recognised complication. Flexor hallucis is routinely divided when removed from the origin at the posterior surface of the middle third of the fibula, and scarring of the remaining muscle and tendon is thought to result in the aforementioned flexion deformity. We commonly take a large portion of the flexor hallucis longus muscle belly from this region, firstly because it provides excellent soft tissue coverage of the reconstructive osteosynthesis plate(s) and also provides additional vascularity to the overlying skin paddle. Furthermore, the more the muscle bulk removed, the less remaining for potential scarring, and it may explain why we have seen relatively fewer cases of claw toe than the reported incidence of 39% [96], although other authors suggest that the amount of muscle excised makes no difference [97]. Should this problem occur, delayed Z-lengthening and division of the flexor hallucis longus tendon has been successful [98]. As with radial forearm free flaps, we typically place a plaster of Paris splint from the knee to the tip of the toes to immobilise the leg for 2 weeks after fibular flap harvest. The primary aim is to minimise shearing forces on any split-thickness skin graft placed at the skin paddle donor site. Whether or not this additionally helps ankle joint stability and/or position of the great toe in the early post-operative period is unclear, but it certainly does no harm nevertheless.

Deep Circumflex Iliac Artery Flap

The main concerns surrounding the donor site in DCIA flap harvest relate to the visceral contents of the abdomen, namely damage to the bowel, paralytic ileus and herniation of viscera through a weakened abdominal wall. To harvest the flap, the external oblique muscle is divided laterally, and commonly all of the internal oblique is harvested (up to the linea semilunaris/lateral condensation of the rectus sheath) and the transversus abdominis divided laterally again along with a portion of the iliacus muscle in order to release a vascularised segment of bone. When dissecting the internal oblique, care must be taken not to encroach too medially into the rectus sheath as it can make dissection of the internal oblique off the underlying transversus abdominis muscle very difficult (with loss of intermuscular tissue planes), risking direct contact with and perforating the parietal peritoneum, or worse the underlying bowel. A considerable amount of retraction of the transversus and underlying peritoneum is necessary to raise this flap and can inadvertently lead to a paralytic ileus. For this reason, it is

important to monitor for the presence of bowel sounds after surgery. If bowel sounds are heard, then enteral feeding rates can be escalated. In the rare event that a bowel injury is not identified during surgery, regular abdominal examinations (twice daily in our unit) provide reassurance that peritonitis can be detected at the earliest opportunity and acted upon before leading to more severe sequelae of septicaemia and septic shock. If there is any suspicion of peritonitis or ileus postoperatively, a general surgical consult should be obtained without delay.

Division of layers of the abdominal wall and removal of the entire layer of internal oblique carry significant risk of incisional hernia. For layers which have been divided (where there is little continuity defect such as external oblique and transversus abdominis), these are repaired as best as possible using primary closure with continuous 2-0 non-resorbable monofilament (such as Prolene®). Within the plane of the missing internal oblique, a Prolene® mesh is sutured. Laterally, the mesh is anchored to holes drilled in the edges of the bony donor-site defect of the ilium and medially to the linea semilunaris of the rectus sheath. The mesh is also quilted to the underlying transversus abdominis layer. In our experience, this technique of mesh repair is robust and incisional hernias are rare.

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Hospital Discharge Planning

18

Waleed Zaid and Dina Amin

Introduction

In this chapter, we will discuss hospital discharge planning for patients who have undergone complex microvascular reconstruction for head and neck oncologic defects after they have successfully completed the postoperative milestones defined by their treating surgeon and are eligible for a safe discharge process. The discharge process can be lengthy, particularly when multiple services have been involved in the patient's postoperative care. Delays in discharging patients are associated with an increased hospital length of stay (LOS), which is the time medically necessary in the hospital until discharge [1]. This benchmark is applicable to a variety of surgical specialties. Prolonged length of stay (LOS) has a substantial impact on costs and can lead to negative medical outcomes. LOS can be divided into two main categories: a "medically necessary" period, when a patient needs inpatient care/services, and a "discharge (DC) delay" period, when the patient is medically ready to leave the hospital but is still waiting to do so [2]. The Centers for Medicare & Medicaid Services (CMS) provides payment for inpatient stays under the hospital inpatient prospective payment system (IPPS) in the Medicare Part A program. This program is part of the Medicaid system, dealing with the acute/inpatient portion, including inpatient rehab, long-term acute care, cancer, religious factors, and inpatient psych. The Centers for Medicare & Medicaid Services (CMS) establishes base payment rates for inpatient stays in advance, based on the patient's diagnosis and the severity of their illness. These rates are subject to certain adjustments, and the hospital receives a single payment for the case according to the Severity Diagnosis-Related Groups (MS-DRGs) under the Inpatient Prospective Payment System (IPPS) and Medicare Severity Long-Term Care Diagnosis-Related Groups (MS-LTC-DRGs), which are assigned at discharge [3].

Medical Necessity Hospital LOS and Delay in Discharge

Medical necessity of hospital length of stay (LOS) is defined as the period from the date of surgery to the date when all managing services (e.g., primary surgical team, hospital medicine, occupational therapy, physical therapy, speech pathology and swallowing, and any other consulted services during admission) deem the patient medically eligible for discharge. It is deemed that the patient's

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acute medical issues and/or complications have resolved or stabilized, allowing them to meet the physical therapy/occupational therapy criteria for discharge home or to a facility. Furthermore, the free flap monitoring has been completed, which is a surgeon-specific variable. In a study conducted by the University of Florida, it was agreed that external flaps should be monitored for 5 days and internal buried flaps for 7 days. Ancillary services assessed the patient/caregiver's ability to perform self-care, such as feeding, airway management (e.g., tracheostomy care), mobility at home, self-hygiene, and wound care; their findings revealed that 65% of patients experienced a delay in discharge (DC) with a mean of 4.8 days, resulting in an overall length of stay (LOS) of 13.1 days. This delay in discharge could be attributed to the age of the patients, as older patients are more likely to experience delays in discharge [4]. Social factors were strongly associated with DC delays. For instance, patients with children were 1.8 times less likely to experience a delay in discharge than those without children, likely due to the presence of adult children providing support after discharge. Additionally, those with dependents were more likely to be discharged to their home environment with familial assistance. The patient's insurance status had a significant influence on the discharge plan; those with Medicaid or self-pay were 4.4 times more likely to experience a delay in discharge, particularly if they were discharged to a facility other than home. As many destinations were unlikely to accept Medicaid or lower tier insurances, discharge options were limited such as intermediate care and skilled nursing facilities (SNFs), inpatient rehabilitation, and long-term acute care hospital (LTACH) [1, 5]. Insurance status was found to be a complicating factor across various surgical specialties, not only limited to head and neck cancer and microvascular reconstruction patients. Upon further analysis, the delay was due to a shortage of beds in the facility, the absence of an accepting facility, transportation, and other social obstacles [6]. Other factors that have been linked to an increase in the LOS specific to head and neck surgery are poor functional status, excessive consumption of alcohol, other associated medical comorbidities, operative time exceeding 8 h, need for blood transfusion, wound types, and history of radiation therapy [7]. The size of the case managers and social worker teams can contribute to delays in discharge. In some hospitals, head and neck oncology patients may have to share case managers and social workers with other surgical patients; the discharge process can be delayed, particularly when discharges are planned on Mondays and Fridays with a rotating case manager, as handoff delays become more likely.

Post-acute Care for Head and Neck Cancer Patients

Post-acute care for head and neck cancer patients includes home healthcare (HHC). Home healthcare (HHC) offers a comprehensive selection of healthcare services that can be provided in the comfort of one's home. These services are tailored to provide convenient and effective care, including wound care for surgical wounds, patient and caregiver education, and intravenous infusions or nutrition. Other post-acute care encompasses facilities such as skilled nursing facilities (SNFs), which provide skilled nursing and therapy care that must be administered by, or under the supervision of, qualified professionals or technical personnel. This level of care is typically necessary to provide treatment, management, and monitoring of patients. SNF offers a range of services, including physical therapy, occupational therapy, speech and language pathology, and ambulance transportation for follow-up care. The most advanced form of post-acute care for head and neck cancer patients is an inpatient rehabilitation facility (IRF). This necessitates intensive rehabilitation therapy, physician oversight, and a collaborative approach between various medical professionals and therapists. The primary objective of home healthcare (HHC), skilled nursing facilities (SNFs), and inpatient rehabilitation facilities (IRFs) is to restore function and independence, enabling patients to return home, become self-sufficient, heal, improve overall health, and prevent further deterioration. A study published in the New England

Journal of Medicine revealed that 50% of patients with Medicare as their primary insurance required post-acute care following surgical discharge, representing 16% of Medicare expenditures [8]. Research has indicated that the need for post-acute care in head and neck cancer patients that required microvascular reconstruction is higher than that of major abdominal surgical oncology, ranging between 14% and 16%. This cohort was likely composed of older, white, male, smoking patients with total/partial dependent functional status, low BMI, and low ASA class. This information is invaluable, as it allows the treating surgeon to assess the necessity of post-acute care early during the preoperative evaluation [9, 10].

How to Improve the Discharge Process

Efficiency in the discharge process is becoming an important quality metric for assessing the planning and coordination between the surgical team and other teams. Head and neck cancer patients have been known to experience delays in discharge, which has prompted us to identify and address these issues to ensure an early and safe discharge process.

Family Engagement and Participation

During the preoperative workup phase, involving direct or extended family members can be highly rewarding, as it not only helps the patient cope with the emotional burden of a head and neck cancer diagnosis but can also expedite discharge and facilitate disposition. In the absence of children, close friends can become a valuable source of support and help expedite disposition.

Preoperative Medical Optimization

Medical optimization reduces the length of stay, enhances recovery, and minimizes potential complications. The positive effects of medical optimization can be bundled with other postoperative improvement initiatives that are specific for head and neck cancer patients and overall hospital protocols like early regular mobilization, decreasing ventilation time, implementing pathways that eliminate the need for ICU, and avoiding tracheostomy when clinically possible along with early decannulation when clinically tolerated [11].

Early Coordination

It is essential to initiate early coordination and communication with the social worker/case manager to verify insurance benefits and limitations during the postoperative period in order to avoid any delays in hospital discharge. The early commencement of the process permits the discharge teams to identify facilities that accept the patient's insurance and facilitates the preparation of home care supplies/equipment prior to the patient's discharge date. Studies have demonstrated that insurance status/plan can extend the length of hospital stay by up to 3 days [1]. In order to facilitate discharge and avoid delays, early preparation and coordination of postoperative discharge supplies, such as wound care supplies, wound VACs, feeding formulas, walkers, and portable suction, should be anticipated (Table 18.1).

In summary, the average cost of hospital care for head and neck patients per day is around 2500$. This emphasizes the necessity for treating surgeons and hospitals to expedite the discharge process while ensuring the safety of the patient to avoid the setback of readmission. Readmission has been utilized as an increasingly reliable indicator of the quality of healthcare systems that discharge the patient. This process starts in the preoperative period by screening the patients for the availability of family support and optimizing any medical comorbidities along with nutrition. This process resumes in the early postoperative period, engaging the social worker/case manager promptly to acquire discharge supplies, assessing the necessity of a post-acute care facility, and navigating the intricate process of insurance authorization to identify a post-acute care facility that accepts the patient's insurance and has available beds to accept the patient.

Table 18.1 Examples of supplies needed for head and neck cancer patients upon discharge

Tracheostomy supplies	• Suction system • Cleaning supplies for the tracheostomy – 4 × 4 gauze – Q-tips – Saline – Hydrogen peroxide – Tracheostomy brush to clean inner cannula – Red caps (extra) – Passy Muir Valve (if clinically indicated)
Wound care supplies	• Xeroform petrolatum dressing • Kerlix • ACE bandage • Aquaphor • 4 × 4 gauze • Wound VAC machine
Tube feeds	• 2-cal (TwoCal) tube feeding formula • 50 cc syringes • Gauze to pack around the PEG tube in case of a minor leak

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19 Cancer Site-Specific Discharge Planning

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Safely discharging surgical patients from the hospital requires thoughtful planning and a multidisciplinary team approach. Discharge planning is the process of preparing for a patient's anticipated healthcare needs as they transition to leave the hospital. Prior to discharge, the patient must be assessed that the process can be completed safely, and the patient is able to maintain health outside of the inpatient hospital setting. The patient must be able to follow discharge instructions, complete activities of daily living (ADLs) with or without the assistance of a caregiver, and have the ability to obtain appropriate follow-up care. ADLs are an important benchmark of functional status, as they represent the ability to complete essential and routine tasks, and inability to perform them leads to unsafe living conditions and poor quality of life [1]. For head and neck reconstruction patients, this process becomes much more complex, as the demand on the patient and caregivers needed to meet these criteria becomes much greater. Furthermore, due to the complex and individualized special needs of these patients, the time period during the admission can be inadequate to establish appropriate goals of care, and coordinate continuity of care, leading to patients and families often feeling rushed and uninformed in their post-discharge decision-making [2]. For any patient, discharge is a vulnerable period, making it imperative for structured discharge planning to provide an adequate transition of care and reduce potential adverse outcome [3]. Any transition point in a patient's care, especially the discharge, represents a well-documented potential for increased morbidity, mortality, treatment delays, complications, and overall poor patient and caregiver experience [4, 5]. Therefore, when working with these medically complex patients, we must establish a collaborative process to mitigate against this potential harm.

An unplanned readmission to the hospital is just one metric of successful discharge planning. A readmission is when a patient has been medically cleared and discharged from the hospital; however, they are then readmitted back to any hospital for an unplanned adverse event, usually within the time frame of 30 days. Readmissions are seen negatively in most countries, where hospitals in the United States are often penalized financially or through decreases in quality ratings

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[6]. This is because the hospital either incorrectly cleared the patient for discharge too early or discharged the patient to an environment unable to meet their medical needs [7]. Head and neck patients are at high risk for readmissions, as they are generally older and from poorer socioeconomic status, with a high number of comorbidities, and frequent users of the emergency department for their primary healthcare needs [8]. They also have many postoperative needs that require complex care, and may require procurement of multiple expensive supplies. Studies show the average 30-day readmission rate after complex head and neck surgery to range between 10 and 20%, with more readmissions being associated with an increased number of needs at discharge [7]. Screening tools exist to identify patients at risk for readmission. The 8Ps tool both identifies risk factors and provides recommendations for intervention based upon the identified variables [9]. Preventing readmissions is a difficult balance of predicting successful continued care, while performing a timely discharge, as keeping a patient hospitalized too long can also delay future adjuvant care [10].

The ability to anticipate a surgical patients' expected hospital course and discharge needs can lead to safe and cost-effective admissions and safe and timely discharge. This is even more prominent when it applies to complex head and neck microvascular surgery patients. After surgery, these patients are admitted to either the intensive care unit or a progressive floor for postoperative monitoring. From there, they may be downgraded to a surgical floor as they progress towards discharge over the course of approximately 1–2 weeks. During their stay, as soon as possible, they should be evaluated by rehabilitation services including physical therapy (PT), occupational therapy (OT), speech language pathology (SLP), as well as dietitians, and other appropriate services. These evaluations are crucial for determining a timeline for safe discharge, including a discharge location and what supplies the patient may need to be successful at their discharge destination. A delay in these evaluations inevitably may delay discharge planning, resulting in a hold due to missing supplies or inadequate time for training of the patient and caregivers. Additionally, it is crucial to assess a patient's home and family support as these patients will often require daily wound and tracheostomy care, delivery of tube feeding, administration of multiple medications, and help with ADLs, i.e., the basic skills to care for oneself. Some patients require special durable medical equipment (DME) to be discharged home, especially those with free flap donor sites that impair ADLs, including rolling walkers, walking boots, shower chairs, and transfer benches. For those patients that are unable to be discharged home due to various medical or social conditions, a discharge to a skilled nursing facility will need to be arranged. Failure to obtain or arrange these supplies and care will result in a delay in discharge, even if the patients are medically cleared. This can be costly to the patient and hospital system, as well as put the patient at risk for hospital-acquired infections, medication errors, and delayed adjuvant therapy [11].

Facilitation of necessary discharge needs can be better managed with the help of case managers and/or social worker services. As there are many nuances to the discharge of head and neck microvascular patients, as well as complex medical healthcare systems to navigate, utilizing a case manager can be critical to efficient and timely discharges. The purpose of a case manager, defined by the Case Management Society of America, is "to coordinate the process of assessment, planning, facilitation, care coordination, evaluation, and advocacy for options and services to meet an individual's and family's comprehensive health needs through communication and available resources to promote patient safety, quality of care, and cost-effective outcomes" [12]. It is important to work closely with a case manager to arrange the postoperative supplies, rehabilitation services, and home health care, in conjunction with patients' individualized special needs. Having a case manager becomes even more important when we realize that being at risk for head and neck cancer is consistently associated with lower socioeconomic status, meaning that they are more likely to be unemployed, live in poorer neighborhoods with less social support

services, and have lower levels of educational attainment [13]. These patients often lack the resources to properly complete their care at home, and a case manager to advocate on their behalf becomes imperative. Poor socioeconomic status has been linked with worse overall survival, though to be attributed to treatment delays, poor health literacy, and being underfunded or underinsured [14, 15]. A study looking at multiple cancers found that nurse case managers significantly decreased unplanned readmission rates from infections and overall provided better control on continuity of patient treatment [16]. Therefore, a case manager can be critical to overcoming these difficulties, by quickly recognizing potential barriers to care and finding patient center solutions.

Oral and Oropharyngeal Cancers

Oral cancer ablation and reconstruction patients generally stay in the hospital for at least 1 week, or longer if there are postoperative complications. As surgical sites are within the aerodigestive tract, patients will likely have difficulties with nutrition, caused by postoperative dysphagia, and the need for a short period of nothing by mouth (NPO) to protect the surgical site. They may also have difficulties with speech and communication, may have complex wound care, may have increased risk for infection, and may require a temporary tracheostomy. Summary of considerations for oral/oropharyngeal cancer patients' discharge planning is detailed in Table 19.1.

Table 19.1 Typical discharge needs after ablation and reconstruction for oral/oropharyngeal cancer

• *Nutrition*
– Discharge with a feeding tube (nasogastric or gastric)
Tube feed formula
Tube feed supplies for delivery and cleaning
Education to family and caregiver
– Consult dietician early for recommendations
• *Airway*
– Discharge with tracheostomy or laryngectomy
Tracheostomy/laryngectomy supplies—extra tube supplies, suction, form of humidification, supplies for wound care
Education to family and caregiver on daily maintenance and emergencies
• *Wound care*
– Arrange for stock wound care supplies
– Patient and family teaching
– Can arrange for home health nurse
• *Rehabilitation*
– Continue rehabilitation services as outpatient:
Speech and swallow, physical, occupational therapy
– Durable medical equipment
Evaluate patient for needs and order as needed
Rolling walkers, walking boot, shower chairs, transfer benches, etc.
• *Medications*
– Assistance with costs
– Education/medication reconciliation

Nutrition

Nutrition is often the largest barrier to discharge for these patients and can be very difficult to manage. It has been found that 40% of head and neck cancer patients are already considered malnourished at presentation [17]. Many have suffered long-term inadequate nutritional intake secondary to dysphagia, as well as concurrent alcohol and tobacco use. After surgical ablation of the tumor, even with inpatient admission, it can still be difficult to meet nutritional demands. As surgical sites are located within the upper aerodigestive tract, taking food by mouth postoperatively can lead to contamination, compression, and saturation of the free flap leading to flap failure or infection [18]. Furthermore, ablation and reconstruction of the upper gastrointestinal tract will often cause alteration to the oral and pharyngeal anatomy, such that chewing and swallowing can be temporarily or permanently dysfunctional [19]. Therefore, evaluation after surgery, as well as prior to surgery, by SLP can be greatly beneficial to patients to reduce the risk of aspiration and malnutrition and improve their quality of life [20]. Speech therapists can offer teaching sessions as well as exercises and maneuvers to reduce aspiration when swallowing. Additionally, they can give overall recommendations on the safety of oral intake and

modify the diet regarding textures to prevent aspiration [21]. Continued speech and swallow therapy long term is important to reduce impairments, and maintain effective swallow function, and should be maintained throughout adjuvant therapy.

A temporary nasogastric tube is often used after surgery to provide the patient with nutrition through this period of expected dysphagia. Additionally, the feeding tube is placed to protect the free flap from mechanical stress and tension as well as contamination from food and secretions [22]. Ideally, nasogastric tubes are a short-term solution as they can cause mucosal injury, esophageal stricture, pleural effusions, and bronchopleural fistulas. If longer term enteral feeding is anticipated, a gastrostomy tube should be placed [23]. "Early feeding" in this patient group is generally considered as oral intake on or before postoperative day 6. It is important to note that newer studies are showing benefits to this practice, with reduction in total length of stay and early return of the biomechanics of swallowing, without increase in morbidity [24]. Still, many patients will require the use of a feeding tube at discharge and will therefore require arrangement for tube feeding supplies. Dieticians can assist with recommendations for tube feed formulation and daily volumes, and supplies should be arranged with case managers as soon as it is determined to be necessary. Teaching patients and family is necessary, to assure that they can deliver the proper volume of tube feeds, as well as keep the tube clean and functioning.

Airway

Tracheostomy is usually elective in this population and performed in anticipation of postoperative swelling, which could occlude the airway. Therefore, the majority of patients are able to be decannulated prior to discharge home. However, it is not always possible to safely decannulate some patients in the immediate postoperative phase due to poor baseline lung function, infection, or inability to tolerate secretions [25]. These patients will need to be discharged home with a tracheostomy tube, as well as a plan for monitoring and pulmonary rehabilitation to ready them for decannulation once the etiology for tracheostomy dependence is resolved. It has been found that many patients retain their tracheostomy tube longer than necessary in the outpatient setting, mostly due to lack of communication, poor patient follow-up, and lack of recognition for readiness to decannulate. Improving communication between members of the head and neck team and establishing known benchmarks that must be met to be decannulated help lessen this problem [26].

At the conclusion of surgery, if required, a patient will generally leave the operating room with a cuffed tracheostomy tube. A cuffed tracheostomy tube is mandatory if the patient will require mechanical ventilation, or it can be inflated to prevent aspiration in those with excessive secretions or bleeding. Once the cuff is no longer necessary, prior to discharge, the larger cuffed tracheostomy tube should be downsized. This can occur as early as postoperative day 3 when the tracheostomy soft tissue tract is more established, making the procedure of exchange safer by minimizing the risk for passage of the tube into a false tract. It can be unsafe to discharge a patient with a cuffed trach as even when deflated, the cuff can irritate the trachea which will increase secretions that can also get trapped on the deflated balloon [27]. Long-term use of an inflated cuff can also cause pressure necrosis of the trachea. Downsizing to a smaller tube diameter, and with a fenestration, allows for patients to breathe more easily around the tracheostomy tube as it is occluding the airway less, and further allows for airflow through the vocal cords, allowing improved phonation and more effective cough. The tube should also have an inner cannula, as the patients will be able to quickly remove the inner cannula in case of tube occlusion, thus preventing loss of airway.

Proper tracheostomy home care requires that the patient or caregiver can demonstrate intricate and complex physical tasks to safely care for their new tracheostomy. Prior to discharge, they will need to complete comprehensive tracheostomy care education that involves hands-

on training. This education must cover daily maintenance of the skin and stoma, knowledge of the parts and function of the tracheostomy tube, how to place and when to change dressings, when and how to change the inner cannula, when to use humidification and suction, and how to handle complications and emergency situations [28]. This caveat complicates discharge, as not every patient or caregiver is willing or capable to perform these tasks. This is challenging, especially in populations that have a low medical IQ and are underfunded, or in an elderly population with decreased manual dexterity and are underfunded. Additionally, it is important for the team to realize that caring for a patient with a tracheostomy is recognized to cause a substantial amount of caregiver strain [29].

Proper maintenance of a tracheostomy requires equipment and a reserve of disposable supplies that need to be arranged prior to discharge. First, they will require spare tracheostomy tubes, in their size and one size down in case of dislodgement and inability to replace their existing tube. Lubricant gels should be available to assist in reinsertion of the tube. A good supply of inner cannulas is also needed as these will be changed at minimum weekly, even with daily cleaning. A portable suction machine with tubing and attachments for mouth suctions and soft suction catheters to clear secretions from the tracheostomy tube and trachea should be obtained. Supplies to clean the tube and stoma daily are needed, often just normal saline and gauze. There are various tracheostomy dressings, which are placed at the inferior portion of the stoma under the tube, to prevent rubbing of the flange on the skin causing breakdown and to absorb secretions. The tracheostomy collar should be changed weekly to prevent buildup of bacterial contaminants. Humidification is important to prevent drying of the respiratory mucosa in the trachea, leading to bleeding. As the tracheostomy tube bypasses the portion of the respiratory tract that humidifies air, the use of humidification machines and heat moisture exchange filters can prevent complications from drying of the mucosa [30]. For those that require home oxygen, portable tanks and tracheostomy collars will be needed. Patients cleared by speech language pathology may also have speaking valves, which should be worn as they facilitate phonation, and also assist with pulmonary rehabilitation [26]. Finally, non-sterile gloves should be worn when performing tracheostomy care.

Wound Care

Patients must be given directions and demonstrate competence to provide continued care of their surgical sites after discharge. Postoperative wound care must be individualized to each patient as there will be differences among wounds in the head and neck region, both intra- and extraoral, as well as different donor sites. Poor wound healing can be a serious problem for complex head and neck patients, increasing their length of stay, increasing readmission rate, and delaying adjuvant therapy, and it has been shown to reduce overall survival [31]. This is further complicated by contamination from upper digestive and respiratory flora, history of radiation therapy, poor nutritional status, and increased comorbidities often seen in this population [32].

The head and neck ablative and reconstruction site generally needs simple daily wound care without dressings. Suture lines on the neck should be cleaned twice daily with normal saline and gauze, and intraoral sites can be cleaned three times a day gently with Peridex rinse and a soft oral sponge. Cutaneous incision sites should be left open to air, with a thin layer of antibiotic ointment for the first week. Patients generally have drains placed at the conclusion of the surgery to prevent fluid accumulation, but most will be removed prior to discharge. For complicated head and neck surgical sites that show wound breakdown, often wet to dry dressings can be placed twice a day. Depending on the location of the wound, it is sometimes feasible to place a wound vacuum-assisted closure (VAC) device. Wound VAC therapy utilizes a vacuum pump and sealed wound dressing over both open wounds and incisions. It works by helping to draw wound edges together, promoting regrowth of healthy tissues by increasing blood supply to the wound

and removing excess fluids. Use of VAC therapy has been shown to be safe and effective for complex wounds of the head and neck after neck dissection and microvascular anastomosis [33]. A study of 31 patients receiving wound VAC to the neck showed significant reduction in wound infection and no instances of vascular compromise [34]. Patients can also be discharged home with this therapy but will need weekly outpatient appointments for exchange of the wound VAC to prevent infection.

Rehabilitation Services

Rehabilitation efforts unfortunately require a short delay after surgery, as patients usually experience some period of strict bed rest to protect the anastomosis immediately following surgery. However, patients need to begin rigorous physical, occupational, and speech therapy once they get outside of the more critical period of risk for the anastomosis. Thus, care must be taken when initiating new activities.

Physical therapy: Early ambulation is shown to reduce postoperative complications, as well as overall length of stay. While the flap is being closely monitored, patients will be kept on bed rest to help protect the anastomosis. Patients often feel weak after this period, and a physical therapist will evaluate the patient to determine their limitations. Some patients will be given exercises to complete in bed or in a chair to help improve movement and prepare for ambulation. It is the goal of the physical therapist to have the patient at their baseline ambulation at or before the time of discharge. This is keeping in mind that postoperatively these patients will now require durable medical equipment such as protective splints for the arm or leg, walkers, and transfer devices. A physical therapist is trained to evaluate surgical patients and determine if they qualify for a safe discharge home. This determination not only is based on the patient's physical limitations, but also takes into account the help they will have at home from family and friends and their current living situation. If it is determined that the patient is to be discharged home, the physical therapist will recommend a safe discharge home with no needs or a safe discharge home with home physical therapy to continue to improve their physiotherapy needs. If it is determined that the patient is unable to safely discharge home based on their evaluation, a recommendation to a skilled nursing facility will be given. A case manager will work alongside the physical therapist to help facilitate the patient receiving the appropriate DMEs and therapy on discharge.

Occupational therapy: Major head and neck surgery can impact all aspects of a patient's daily life. Occupational therapist's role in postoperative care is to help patients resume or maintain their participation in everyday tasks, such as their jobs, social activities, and ability to care for themselves. They work by teaching patients to regain their skills, or sometimes by learning new ways of doing things, or through the use of materials or equipment. Occupational therapy for head and neck cancer patients encompasses many different important aspects such as physical function, fatigue and coping with stress, lymphedema after neck dissection, social isolation, sleep hygiene, sexual health, and moving forward with survivorship after the conclusion of cancer treatment [34].

Speech language pathology: Rehabilitation of voice, speech, and swallow function is critical after surgery. Ideally, evaluation of the patient would occur prior to surgery for pretreatment counseling, teaching of prophylactic exercises, and swallowing maneuvers to maintain function and speed recovery and to evaluate baseline function. After surgery, speech therapy can assist with phonation with the tracheostomy, and begin evaluation and therapeutic intervention to improve swallow function as soon as the patient is cleared to take anything by mouth. This can be through bedside swallow or fluoroscopic swallow studies. They will remain a critical service throughout the postoperative course and further adjuvant therapies. Unfortunately, it has been shown that speech language is often underutilized for rehabilitation of tracheostomy patients [21].

It is important to familiarize each rehabilitation service with the specific protocols of the

head and neck surgery department, so they know how to appropriately progress patients, as they will be interacting with patients when their flap is still at high risk for compromise.

Medications

Medication errors are the most common patient safety error in the hospital. When patients are admitted for surgery, their current medications are often held, and many new medications are started. Thus, these abrupt medication changes can lead to medication discrepancies. Most errors are thought to result from poor medication reconciliation during admission, transfer, and discharge [34]. A proper medication reconciliation should occur at admission, detailing all prescriptions, herbals, vitamins, and nutritional supplements. Discharge is another critical point where good communication and documentation can help avoid medication errors. The most common source of the error at discharge resulted from not resuming medications that were held in the hospital, and poor communication and education with the patient [35]. These complications can be avoided with proper medication reconciliation, in conjunction with thorough and clear patient education about their new medication regimen at discharge. Assistance in obtaining post-discharge medications should also be available to patients.

Larynx and Hypopharynx

Surgery of the larynx and hypopharynx requires the same discharge planning as oral and oropharyngeal cancers, however with a few additional considerations. These patients will also generally stay in the hospital for 1 week or longer after surgery but will be required to be NPO for a longer time period, due to higher risk for pharyngocutaneous fistulas. These patients may also have laryngectomies or require long-term tracheostomies, and will require much more intense SLP to regain speech.

Nutrition

Traditionally, oral intake was restricted in this population for 1–2 weeks to prevent pharyngocutaneous fistula. Newer studies have been advocating for early feeding (<5 days postoperatively), showing no increase in complications [24]. Despite these studies, many patients are still being discharged with feeding tubes. Like oral/oropharyngeal cancer patients, this population will also need to have supplies and nutritional supplements/feeds arranged prior to discharge, sometimes for longer time periods, depending on the surgeon. They should also be under the care of a speech language pathologist to help them as they transition from tube feeding back to regular oral intake.

Speech

Patients undergoing partial or total laryngectomies will require intensive speech language therapy. They should be evaluated for baseline status and teaching prior to surgery. This pre-evaluation can be helpful as it is another touch point where patients can learn more about their surgery, the effects it will have on their voice, and available methods that can be used for speech after surgery [26]. Once surgery is completed, the speech pathologist should see the patient the next day after surgery to immediately begin rehabilitation. Patients can be started on electrolarynx immediately, and ideally will be trained to use the device before surgery. Discharge planning should be arranged for patients to obtain and be trained with this device. Later, as an outpatient, patients can regain speech through a tracheoesophageal prosthesis or by learning esophageal speech.

Airway

Total laryngectomy patients will require many of the same supplies for home as tracheostomy patients. The main difference is that laryngectomy patients have their own specific soft laryn-

gectomy tube. This tube can be taken out by the patient daily for cleaning and has special attachment sites for humidified heat exchange caps. They will also require suction machines, additional stock of laryngectomy collars, and wound care supplies.

Special Considerations by Free Flap Donor Site

Radial forearm free flap (RFFF) donor sites require specific care. The forearm donor site is typically closed with skin grafts or an equivalent substitute. This site will require a bolster or wound VAC for approximately 10 days. After the wound VAC is removed, the donor site is protected using a bolster or pressure wrap. This is commonly completed by using a non-adherent gauze dressing, gauze fluffs, and/or a Kerlix wrap. The site is further protected by placing the patient in a volar splint, which is recommended to be worn for 1 month. While wearing the splint, the patient will be void of use of the extremity so as to protect the graft site. Typically, a Jackson-Pratt drain is used postoperatively and is removed prior to discharge, but in some scenarios, the patient will leave with a drain and will require a drain care teaching for at-home management. The patient, or caregiver, is asked to care for the drain by stripping the drain and recording the daily output, which will be reviewed prior to removal. The patient might note that their forearm does not feel as strong as it was before surgery and should be kept in mind for patient safety. Additionally, the area might feel numb or tingly for several months following surgery and could potentially be permanent. Physical therapy may be necessary to regain baseline function after surgery.

Fibula free flap (FFF) postoperative recommendations are similar to those of an RFFF. Both a wound VAC and JP drains are routinely used for postoperative care and are managed appropriately. Once these are removed, or if wound VAC is not utilized, the donor-site skin graft will have a bolster and pressure dressing applied. Additionally, for FFF, patients will require the use of a walking boot, also called a Bledsoe boot, for 1 month. A rolling walker can be given to these patients after surgery to help with physical rehabilitation in the immediate postoperative period, and for home to assist with mobility.

Scapula free flap patients will additionally require a shoulder sling that secures the forearm to the abdomen. There should not be any straps around the neck, so as not to compromise the anastomosis. Patients can begin physical therapy for their arm on postoperative day 5 [36].

Conclusion

Discharge from the inpatient setting can be a vulnerable time for patients and caregivers, which can lead to adverse events in the immediate discharge period. Generally, planning for discharge should begin at admission, and use of a case manager can streamline the process and improve communication between the patient and all of the members of the head and neck care team. Discharge planning should involve a patient-centered plan.

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Functional Rehabilitation of the Orofacial Complex

20

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Assessment of the Defect

The complexity of an orofacial defect following ablation provides a substantial challenge to the head and neck surgeon. Classifications of the defect help stratify the treatment planning options to develop a reliable algorithm. Reconstruction after ablation of a tumor of the face is especially critical due to the significant psychological and physical trauma for the patient and family. Choosing free flap reconstruction with bone or soft tissue, versus dental and facial prostheses, can affect the operative time and outcome, decrease patient morbidity of surgery, and, pending the situation, provide a comparable esthetic outcome [1].

The Brown classification of maxillary defects attempts to provide recommendations to guide the optimum reconstruction in the midface by classifying the maxillary defects and then analyzing the reconstruction successfully used [1, 2], as illustrated in Fig. 20.1. The classification

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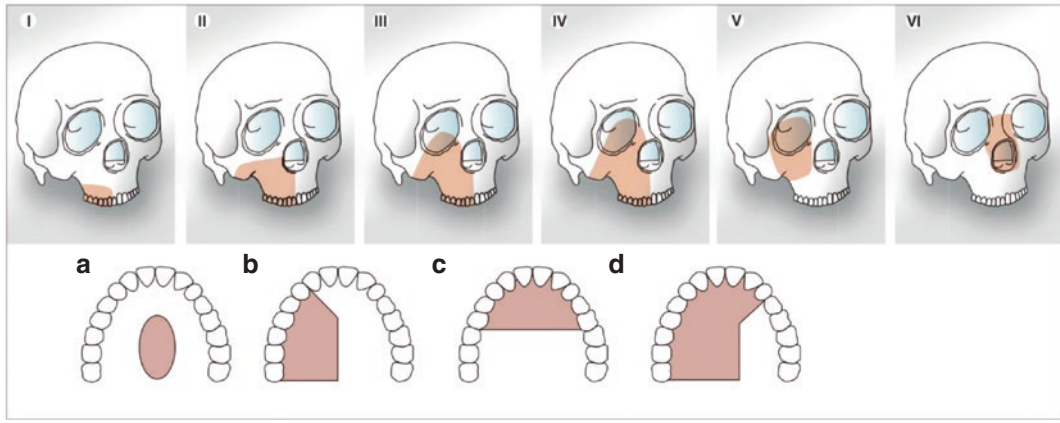

Fig. 20.1 The Brown classification of maxillary defects aims to elucidate reconstructive options [1, 2]

system considers the soft tissue and bone ablated, especially involving the essential midface buttresses, to delineate the esthetic defect, which is valuable in guiding optimal reconstructive options.

Brown et al. also analyzed and classified mandibular defects in their 2016 landmark paper; however, Brown cites the difficulty in guiding reconstructive options due to multiple confounding factors [3]. Pavlov's classification should be credited as the first for mandibular defects in 1974 [4], with multiple classifications additionally providing the framework for the Brown classification. As illustrated in Fig. 20.2, the classification system is based on the location of the defect and involvement of the condylar head. Brown then analyzed the literature to stratify the most commonly used free flap reconstructive options by class type [3]. Despite his admission of difficulty guiding the reconstruction with an algorithm with this classification system, it can be extrapolated that the type of flap used would subsequently dictate the feasibility of osseous dental implant reconstruction, as the main concerns are restoration of occlusion in the dentate patient and achieving a functional jaw in the edentulous patient [3].

Facial defects after ablative surgery, specifically of the ears, nose, and orbits, lack a cohesive classification system noted in the literature currently, instead focusing on congenital facial defects, such as the Tessier classification system [5]. Nonetheless, there is a plethora of literature on the reconstruction of such defects.

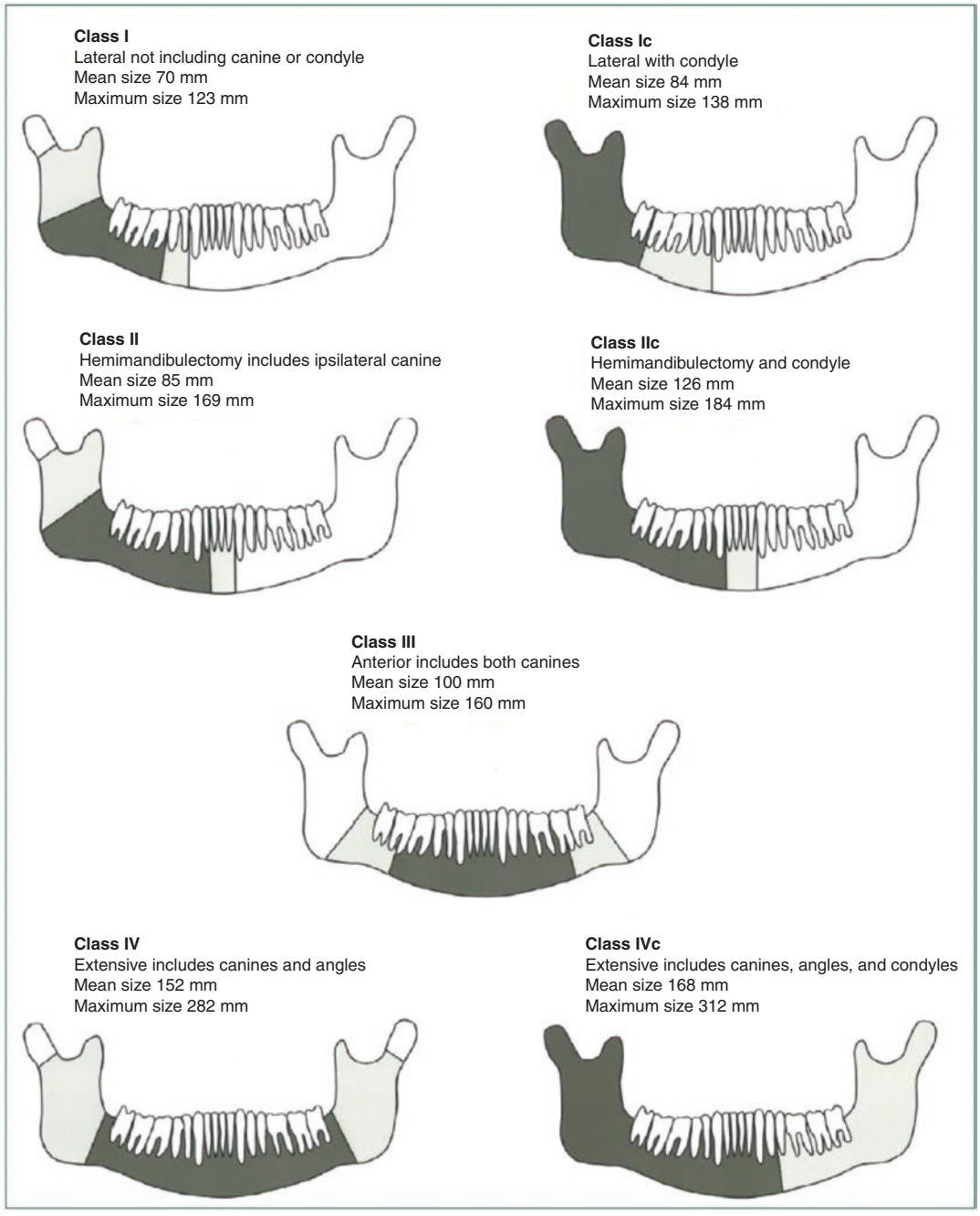

Fig. 20.2 The Brown classification of mandibular defects [3]

Assessment of Functional Goals

After assessment of the resulting defect of the ablative surgery, the functional deficits must then be evaluated in order to optimize functional outcome and decrease morbidity. Perhaps, the most important component of this is to assess and mitigate the patient's goals and expectations. A young and healthy patient, otherwise fully dentate, will have different functional expectations compared to an edentulous nonagenarian. Often, the expected goal is to return to a dentate state with optimal occlusion for the forces of mastication. Return to a functional diet is a goal of most patients [6]. The location of the defect and involved anatomy certainly defines the functional defect. The midface defect additionally may involve the orbit and affect vision, whether an exenteration is involved or not, as a total maxillectomy for a Brown class III defect can still cause significant diplopia and altered vision without the recreation of the orbital floor support, for instance. Furthermore, the additional palatal component of Brown class I through IV will surely create hypernasal speech without addressing the resulting oroantral or oronasal fistulae, as well as affecting nutritional intake with nasal regurgitation.

Perhaps, the most important reconstructive outcome is the esthetics and return to the premorbid state. Again, the patient's goals and expectations should be mitigated and coincided with the feasibility of each reconstructive option. An obturator or maxillofacial prosthetic may provide a comparable functional outcome, but may not address the esthetic desires of the patient.

Esthetically, one must consider the ablative defect in all planes, considering the facial projections and symmetry in the x-, y-, and z-axes, as well as the intraoral dental esthetics. Depending on the ablative defect, and resulting bony framework remaining, one can then consider if reconstruction with an osteocutaneous or soft tissue option, versus a maxillofacial prosthetic, will serve similar purposes, with similar esthetic outcomes, in fewer surgeries. All of these options also serve the purpose to eliminate the dead space as well.

Multiple studies compared the functional and quality-of-life outcomes of maxillary defects reconstructed with either an autologous free flap or a prosthetic obturation [7–9]. In these retrospective studies, they found that reconstruction has advantages, especially for larger defects, notably in swallow and speech [9]. In contrast, obturators simplify the surgery, provide immediate dentition, and allow cancer surveillance, though literature has not shown an improvement in surveillance.

Beyond the functional outcome is the modality of reconstruction. The young patient may not prefer a removable prosthetic such as a palatomaxillary obturator, or a maxillofacial prosthesis, and instead prefer autologous bone grafting in the form of an osseous free flap.

Dental Rehabilitation in Irradiated Patients

Special consideration must be taken in the setting of malignancy, especially when radiation therapy has been completed or planned. There is a paucity of concrete literature comparing the placement of implants prior to or after radiation therapy, but the risk of osteoradionecrosis and complications in a radiated patient is increased compared to the nonirradiated patient [10]. Consequently, patient expectations for implants during radiation treatment must be mitigated.

Recently, several manuscripts have reported on the success rate and complications regarding dental implant placement in the irradiated patient. When considering implant placement in irradiated patients, it is important to review radiation port films, as well as isodose curves to assess the quantity of radiation administered to the proposed surgical field and adjacent tissue [11]. Tanaka et al. reported higher rates of implant failure when cumulative doses exceeded 65 Gy, as opposed to sites receiving less than 45 Gy, which demonstrated survival rates equivocal to nonirradiated patients [12]. Implant survival rates appear to be higher in the mandible compared to the maxilla, which is similar to nonirradiated dental implant success rates, likely due to the higher

density of mandibular bone. Schaller et al. described similar findings in a systemic review and meta-analysis of literature, reporting implant success rates of 97% in nonirradiated patients and 91.9% in irradiated sites. Schaller also noted a 3% incidence of osteoradionecrosis in irradiated patients following implant placement [13]. High doses of radiation therapy to the planned implant site(s) should lead the practitioner to consider other means of dental rehabilitation, i.e., removable prosthodontics. Koudougou et al. reviewed manuscripts describing immediate implant placement versus delayed placement. Their finds demonstrated no statistically significant difference in implant survival, although delayed approach had a higher success rate, but more importantly noted that the delayed placement of implants led to improved prosthodontic rehabilitation [14].

Long-term outcomes of implants in irradiated patients are also a subject of much debate with little scientific literature. Ma et al. found that implant survival in vascularized bone flaps steadily decreased from the first year (96%) to the second year (87%) and the fifth year (81%). Risk factors for implant failure included poor oral hygiene, systemic diseases, and irradiated flaps [15].

Curi et al. reported a slightly higher 5-year implant survival rate of 92.9%; however, all implants were placed following completion of radiation therapy. Factors contributing to implant failure included a form of radiation therapy, conventional conformal radiation therapy demonstrating lower survival rates vs. intensity-modulated radiation therapy (IMRT), and patient sex, with the female cohort having lower survival rates [16]. Future research is needed in this arena prior to optimizing patient treatment planning and staging regarding placement of implants in irradiated or planned-to-be-irradiated bone.

The authors recommend a delayed, or staged, approach in malignancy cases. Ideally, implants and any required flap debulking are performed at 6–12 months post-completion of radiation therapy. Our experience is that this improves implant success rate and still leads to adequate and timely restoration of the patients' dentition, with a superior prosthetic result.

Planning with Your Prosthodontist and/or Anaplastologist

Well-trained prosthodontists and anaplastologists are invaluable for the head and neck surgeon. When assessing the defect with the functional and esthetic needs in mind, one must consider if osseous implants will be used to reconstruct the dental complex, the maxillofacial complex, or both. An intraoral scanner to capture the existing dentition, planned defect, and current occlusion preoperatively, sharing STL images with the prosthodontist, will assist in planning. The placement of implants must always be planned with the final reconstruction in mind.

With the innovation and evolution of the computer-aided surgical simulation and planning, we can create osseous free flap reconstruction with precise osteotomies to complement the resection exactly. The computer-aided models become increasingly beneficial with multiple segments and osteotomies, as any error in one segment inherently affects the next. Computer-aided planning facilitates complex reconstructions, minimizing surgical time and maximizing precision. This can then become even more crucial to optimize the dental reconstruction [17–19].

When planning a reconstruction, for instance with computer-aided surgical simulation and planning, you should consider involving the maxillofacial prosthodontist in the planning. If that is not possible, the planning must ensure that the final restoration is considered. For instance, when reconstructing occlusion with a maxillary or mandibular fibula, one must place the fibula at the optimum height in relation to the adjacent alveolus so as to have an adequate emergence profile. Furthermore, from a submental view, the fibula reconstruction should overlay the opposing dentition to facilitate dental rehabilitation.

When considering osseous implants for the facial reconstruction, such as for an orbit, naso-maxillary complex, or auricular prosthetic, a

mock-up of the size and proposed reconstruction should guide the placement of the implants. With the three-dimensional printing revolution, this may simplify and streamline the process of designing the prosthetic to plan implant placement, but this should still be verified with the maxillofacial prosthodontist to ensure optimal final reconstruction.

Dental Rehabilitation with Prosthodontics

While ablation of the tumor in question is the primary goal of the surgical case, just as important is the reconstruction. Within the reconstruction, the patient often does not appreciate the nuances of a planned and executed bony and soft tissue reconstruction, but instead focuses on the functional and esthetic outcome. After a detailed description of the surgical procedure, most patients simply ask the question: "When can I have teeth"? The options for dental rehabilitation usually lie in one of the three categories: jaw in a day immediate implant placement with immediate dental prosthetic placement, immediate implant placement with delayed dental restoration, and delayed implant placement with delayed restoration.

The *jaw in a day* technique, originally described by Levine et al. in 2013, and further popularized by the 2016 case report by Qaisi et al., provides patients with resection, reconstruction, and dental rehabilitation in one surgery [19, 20]. Traditionally, the osseous free flap was allowed to form a bony union to the adjacent bone prior to implant placement, usually in 3–6 months. Then, the implants were allowed osseointegration, with vestibuloplasty and flap debulking addressed during this hiatus. This process could take 6–12 months, causing significant psychological and functional effects on the patient. Levine et al. coined the term *jaw in a day*, focusing on an occlusion-driven reconstruction [19, 20]. Multiple innovations in immediate implant placement and reconstruction have led to the evolution of the *jaw in a day* technique [21–25]. With the precision of computer-assisted planning, the implants can be placed at the donor site, ideally positioned to support the prosthesis. The process allows for preferences such as a "resected medical model" to be used at the donor site to simulate the reconstruction and make adjustments, if any, prior to transection of the vessel and ischemia time. With the dental prosthetic placed at the donor site prior to transfer, once the reconstruction complex is ligated and transferred, occlusion only needs to be confirmed with a prefabricated occlusal splint if created in advance.

Patient selection for *jaw in a day* surgery is paramount. Computer-assisted planning is necessary for fabrication of the prosthetic, and the necessary time for fabrication must be considered. The benign, slow-growing tumor provides a perfect situation in a healthy patient with adequate remaining dentition. The sometimes rapid growth of a malignancy may preclude accurate oncologic resection margins, decreasing the presurgical planning accuracy. Furthermore, a recent meta-analysis demonstrated the significant increase in implant failure with radiotherapy but suggested that implants placed before radiotherapy showed slightly better survival (88.9% vs. 83.4%) [26].

Alternatively, the common treatment options in current standards of practice are immediate implants with delayed restoration, or the traditional delayed implant, delayed restoration, which could result in a 6–12-month treatment time prior to a final restoration. The placement of immediate implants with delayed restoration allows for minor intraoperative adjustments in the oncologic resection margins and donor-site harvest, while still keeping an occlusion-driven planning model and still decreasing the span of time until final restoration, and takes advantage of the benefit of placement of implants prior to radiotherapy, possibly slightly increasing survival rates. Delayed implants with delayed restoration allow the surgeon to focus on tumor resection, sometimes without computer-assisted surgical planning, and then consider dental rehabilitation in the future, maximizing implant placement precision and planning by profiting from the transplanted bone that is already in situ

and well integrated. The already edentulous patient may benefit from this approach, so as to plan the entire dental rehabilitation, maxillary and mandibular, as one process, after bony reconstruction.

When the traditional maxillary and midface bony reconstruction with endosseous implants is not a viable option, alternatives such as zygomatic implants and pterygoid implants should be considered. This is especially pertinent in the patient with multiple morbidities precluding bony reconstruction, due to either inherent anesthetic and surgical risks or morbidities at the donor site preventing a viable harvest. Furthermore, the microsurgical reconstruction also requires specialty trained surgeons and resources not available at every institution.

Zygomatic implants have provided an option for graftless complete maxillary dental reconstruction when there is insufficient maxillary bone for traditional implants. Goiato et al., in a systematic review, found a 97.8% survival rate at 36 months for 1541 zygomatic implants placed [27]. One of the many advantages of zygomatic implants is that they can be used to retain multiple restorative options such as fixed and removable dental prostheses, obturators, and complex multiunit maxillofacial prostheses [28]. Based on the Brown classification previously discussed, classes 2b, 2c, and 2d are best suited for zygomatic implants, but additional classifications of defects can be reconstructed for a complex multiunit maxillofacial prosthesis [1, 28]. Absolute contraindications to zygomatic implants include restricted mouth opening, and active osseous disease in the maxilla and zygoma, such as osteoradionecrosis or osteomyelitis, or malignancy. Chronic sinusitis may lead to continued sinusitis, but it is not an absolute contraindication, nor is a history of head and neck radiotherapy or medications predisposing a patient to medication-related osteonecrosis of the jaw (MRONJ), but these risks must be considered. Similar to the studies on placement of dental implants and radiotherapy, it can be extrapolated that placement of zygomatic implants prior to radiotherapy may slightly improve success rates, although there is no literature to definitively support this [26]. However, the surgeon must also consider interference in radiotherapy treatment planning from CT artifact and endosseous implants, confounding tumor target volumes and causing errors in dosing calculations that could affect radiotherapy outcomes [28].

Zygomatic implants can be planned with either a cone beam computed tomography scan (CBCT) or a medical grade CT to evaluate the zygomatic bone quality and quantity, considering the resection margins after completion of the ablative portion of the procedure. The clinical examination prior to tumor resection may provide little benefit to the surgeon placing the implants. Preoperative planning comes in many forms, including computer-based planning to visualize the zygomatic bone stock available and plan the planned angulation of the implants, as well as adjacent pertinent anatomy. Stereolithic models can also assist to visualize the implant placement, which can be fabricated by outsourcing to companies or three-dimensionally printed in-house with decreased costs. Navigation-guided surgery can facilitate orientation and angulation to maximize bony contact [29].

Pterygoid implants, first described by Tulasne in 1989 [30], engage the maxillary tuberosity, the pyramidal process of the palatine bone, and the pterygoid process of the sphenoid bone, anchoring in cortical bone, in order to achieve primary stability in the atrophic maxilla or the ablative defect [31]. The pterygoid and pyramidal processes are composed of dense cortical bone with an average thickness of 6–6.7 mm at their interface, and if the implant is placed at a 45-degree angle, the engaged cortical bone can be as high as 8–9 mm [32, 33]. Rodriguez et al. found the pterygoid region to have 139.2% greater bone density than that in the maxillary tuberosity region [34], highlighting the stability possible with placement of pterygoid implants. Similar to zygomatic implants, they also eliminate posterior cantilevers, improving axial loading [35]. Indications are similar to zygomatic implants, as are the contraindications, with the addition of the absence of a maxillary tuberosity and impacted third molars, both precluding a stable implant placement [31, 36]. A meta-analysis by Araujo et al. showed

94.87% survival rate in pterygoid implants, but minimal evidence-based literature is available [37]. From a prosthetic standpoint, the pterygoid implant eliminates long distal cantilevers, due to the emergence in the second molar region, and also allows for immediate loading of the implants [38, 39]. Pterygoid implants are especially indicated in partial or completely edentulous arches and maxillectomy defects [39]. The learning curve may be steep, but the surgical technique is straightforward.

Surgical Procedure

Zygomatic Implants

After obtaining a cone beam computed tomography scan (CBCT) at the initial consultation, or a medical grade CT if available, the presenting defect must be evaluated, or if warranted, discussion should be done with the ablative surgeon as to the resection defect if there is existing pathology. Evaluation of the zygomatic bone stock for both quality and quantity, maximum intraoral opening, type of maxillary defect present, and estimated implant depth is crucial. This will facilitate planning the number and angulation of the implants placed, with the final prosthetic in mind with your maxillofacial prosthodontist. If the patient cannot open their mouth adequately, the ablative surgeon may be considering a lip-split mandibulotomy for access (Fig. 20.3), or a Weber-Ferguson approach, both of which would facilitate zygomatic implant placement. As mentioned earlier, computer-assisted surgical planning and custom surgical guides would be especially beneficial if a vascularized flap will be used to reconstruct the defect [28].

The procedure can be performed under general anesthesia or intravenous deep sedation, but general anesthesia is preferable, as is a nasal intubation. Sterile drapes should maintain exposure of the lateral and infraorbital rims to decrease periorbital or globe injury and verify angulation. The exposure varies depending on if the maxillary defect has just been created with maximum exposure, or if the zygomatic implants are the only surgical procedure being performed. This technique will describe total maxillary reconstruction with four zygomatic implants. Local anesthesia can be administered intraorally to locally infiltrate in the maxillary vestibule, and to block the superior alveolar, infraorbital, and greater palatine nerves, and for hemostasis. A maxillary crestal incision is created from tuberosity to tuberosity, bisecting the keratinized gingiva, often with releasing incisions posteriorly and at the midline. If a vascularized free flap is present, although implant placement is ideally performed 6 months after reconstruction, the vascular pedicle is still avoided to ensure the vitality of the reconstruction [28, 40].

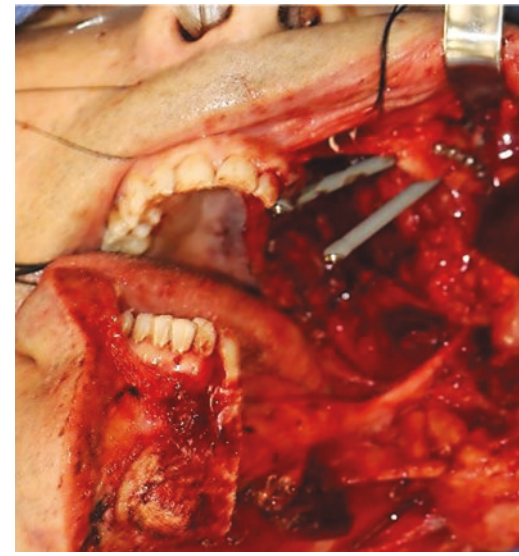

Fig. 20.3 A lip-split mandibulotomy for ablative access to a posterior maxillary tumor. Post-resection, this approach also facilitates the immediate placement of zygomatic implants

As the mucoperiosteal flaps are developed, it is noted that the anatomy is often greatly altered due to the bony defects and can disorient the inexperienced surgeon. The body of the zygoma is exposed, and if present, the alveolar crest, anterior and lateral maxilla, infraorbital rim, and lateral and infraorbital rims to ensure that the path of the implant does not involve the orbital contents. Ideal placement should lead to an emergence of the occlusal aspect of the implant at the maxillary alveolar crest. This can be challenging

in an ablative/reconstructive case due to lack of reference points in the midface. In this situation, the mandibular dentition or alveolar ridge can be used as a guide [28, 40].

Utilizing either prefabricated guides, as seen in Fig. 20.4, navigation, or excellent exposure and visualization, the osteotomies are planned as far posterior as possible, and a 105-degree zygomatic implant handpiece with a round bur penetrates the maxillary bone and sinus to the base of the zygoma. The zygoma is then infiltrated with a 2.9 mm twist drill, ensuring a depth through both cortices and lateralizing away from the orbital rims. The osteotomy is then enlarged with a 3.5 mm drill. The implant depth is then measured at the osteotomy and placed either with a handpiece or manually, as illustrated in Fig. 20.5a, b [28, 40]. Closure of the maxillary sinus is imperative to prevent oroantral communication, and this can easily be performed by harvesting and advancing a vascularized buccal fat pad.

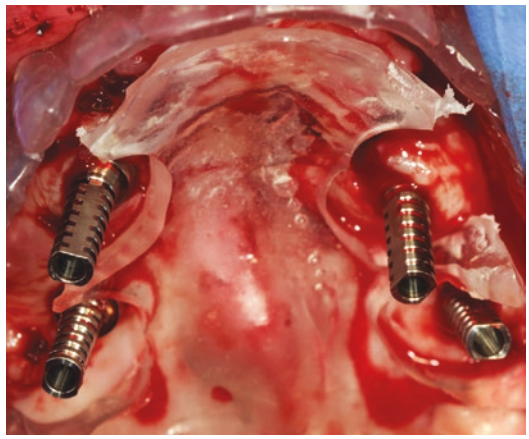

Fig. 20.4 Prefabricated guides to facilitate accurate placement of quad zygomatic implants with ideal emergence profile along the alveolus

Immediate implants placed in a maxillary defect allow for excellent exposure and angulation into the zygoma bone. Immediate loading can be achieved with cross-arch stabilization and an obturator if the defect warrants, as immediate loading is preferable but not always possible (illustrated in Fig. 20.6) [28].

The restoration of zygomatic implants is defined by the type of residual soft tissue present after the surgery and implant placement, which is

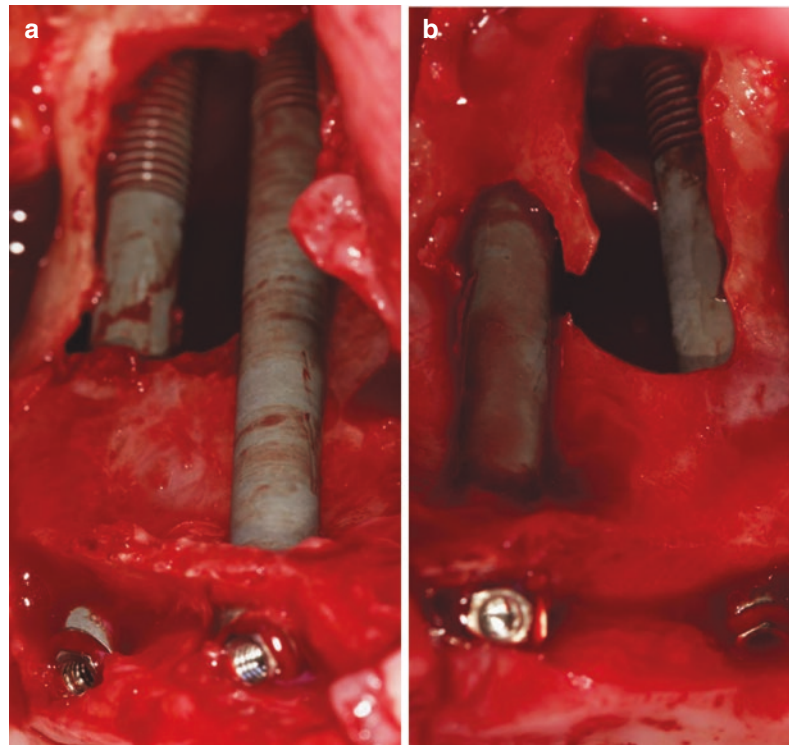

Fig. 20.5 (**a**) Visualization of right maxillary zygomatic implants placed intrasinus and within the wall of the sinus, emerging at the ideal mid-crestal alveolus. (**b**) Visualization of left maxillary zygomatic implants placed intrasinus and within the wall of the sinus, also with ideal emergence

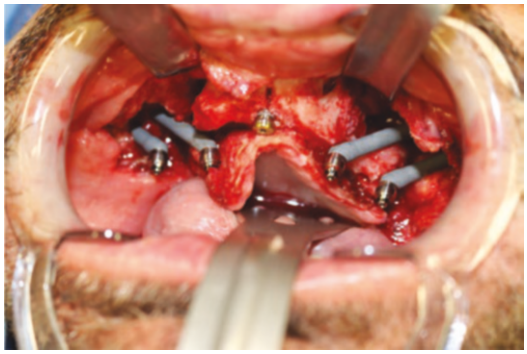

Fig. 20.6 Quad zygomatic implants with a midline endosseous dental implant for dental rehabilitation after resection of multiple maxillary central giant cell tumors

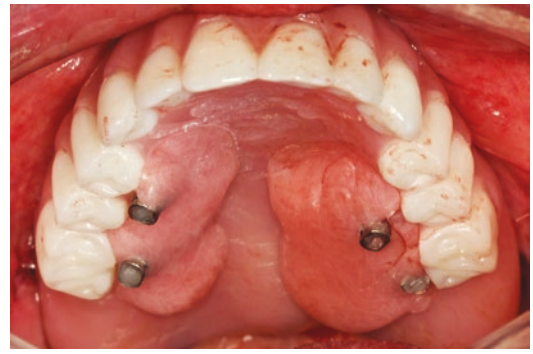

Fig. 20.7 The provisional prosthesis placed intraoperatively for immediately loaded cross-arch stabilization

typically accomplished as mentioned with static surgical guides, navigation, or robotics today. In the case of normal soft tissue volume and full coverage of the remaining maxillary bony architecture with complete closure, the preferred method is typically accomplished following contemporary immediate load protocols that allow for rigid, cross-arch stabilization of the implants at the time of surgery with a full-arch, fixed provisional prosthesis. This prosthesis is based on a completely digital workflow of prosthetic planning merged with the proposed surgical planning to be able to create the optimal provisional and ultimately the definitive outcome. The provisional prosthesis, shown in Fig. 20.7, is maintained intraorally for the first 4–6 months post-implant placement, and after osseointegration occurs, the definitive phase of therapy can commence. The benefits to the patient include a fixed provisional prosthesis at the time of placement, and it also allows the clinician to establish appropriate esthetics, occlusion, and ideal tooth position that can be tested by the patient for many months to ensure that the ultimate outcome is satisfactory [41].

In the cases where the surgical outcome results in a soft tissue deficiency or a residual oral-antral communication remains, a removable maxillary obturator prosthesis is recommended over a fixed solution. The need to obturate the maxillofacial defect with prosthetic material negates the ability to deliver a fixed prosthesis, which would not be cleansable by the patient, and therefore the restorative protocol for these patients requires conventional removable prosthodontic procedures. The zygomatic implants are not loaded at the time of surgery and are allowed to osseointegrate for 4–6 months. Once healing has occurred, impressions are made to fabricate CAD/CAM-designed and -manufactured titanium frameworks that can splint the zygomatic implants at least bilaterally if not in a complete cross-arch stabilized design. A removable prosthesis is then fabricated to engage the framework and, at the same time, obturate the defect [41].

Postoperatively, imaging should be obtained and the patient placed on oral antibiotics and a soft diet.

Pearls

Positioning and placement of zygomatic implants should be prosthetically driven; therefore, the emergence of the implants should be at or close to the alveolar ridge. This affords the prosthodontist the ability to create a prosthesis with less material on the palate, leading to improved patient comfort and satisfaction. For a non-ablative/reconstructive case, this is not challenging to do. For the post-ablative/reconstruction patient, this can serve as a challenge, mainly due to obscured anatomy and possible need for obturation. More challenging are the situations when prior soft tissue vascularized reconstruction has already occurred (Fig. 20.8a–d). When encountering an anterior-lateral thigh

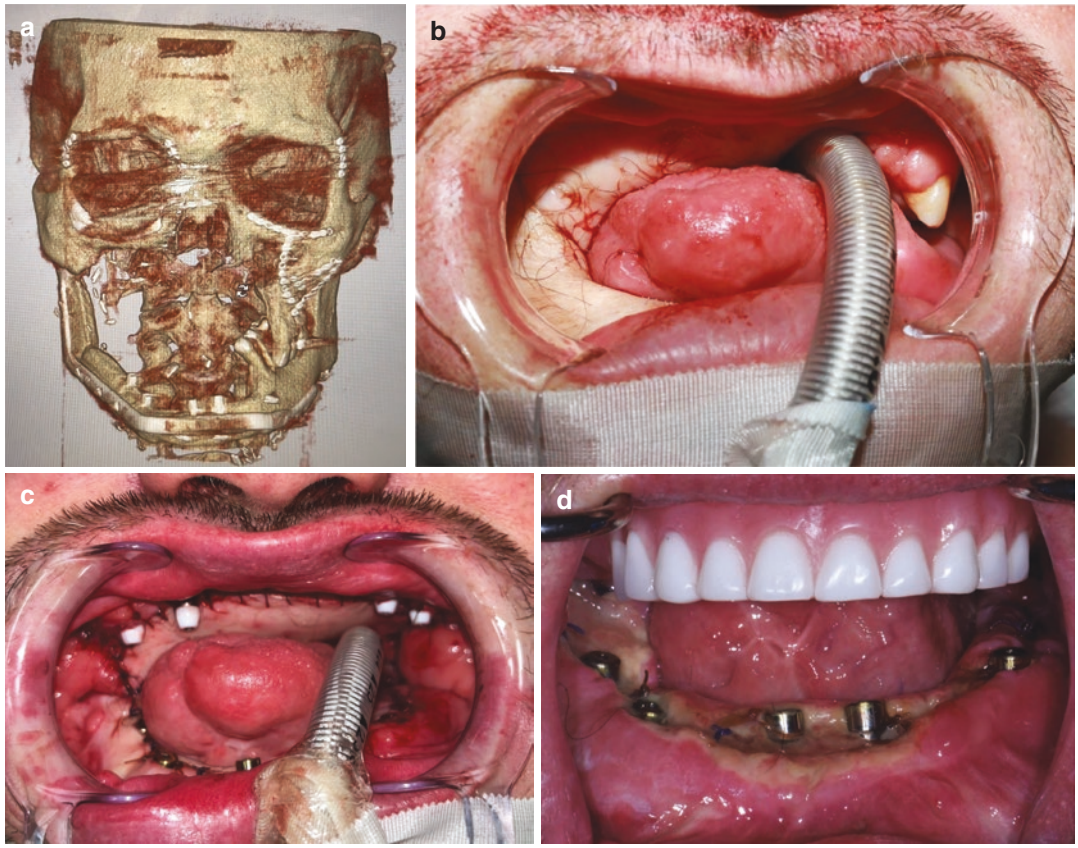

Fig. 20.8 (**a**) CBCT following primary reconstruction of self-inflicted gunshot wound. Mandibular reconstruction with fibula free flap and immediate implant placement. Maxillary defect reconstructed with an ALT flap. (**b**) Pre-op images prior to zygomatic implant placement, note thick and bulky skin paddles. (**c**) Post-op zygomatic implant placement and flap debulking to allow for improved vertical height for prostheses. (**d**) Interim prosthesis in place and mandibular implants uncovered

or radial forearm free flap previously used for sinus/nasal obturation, incision location is crucial, as is flap debulking. The authors recommend utilizing the opposing dentition, if present, to guide incision placement and emergence of the zygomatic implants. Dissection can be carefully performed to locate "known" landmarks, i.e., infraorbital rims and nasal apertures. Adequate flap debulking must take place to allow for vertical prosthetic restoration, i.e., implant emergence to opposing dentition should be at least 20 mm. It is only needed to maintain epidermal and dermal layers of the flap, and all or the majority of the underlying adipose tissue can be excised.

Pterygoid Implants

After a similar workup to the zygomatic implants described above, a CBCT can evaluate the maxillary defect, quality, and quantity of bone remaining in the pterygoid and pterygomaxillary region. The literature describes placement in either the pterygoid process or the pterygomaxillary region. Surgical access is similar to zygomatic implants, with a crestal incision with releasing incisions, raising a full-thickness mucoperiosteal flap. The implant is intended to anchor in the pterygoid plate of the sphenoid bone, with a distal angulation between 35 and 55 degrees. The angulation will depend on the height of the bony tuberosity

and the angulation of the posterior maxillary sinus wall [35, 42].

Following the technique described by Valeron and Valeron, the entry point is created with a round bur, the axis established by a pilot drill, and the site developed by consecutive drills and cylindrical osteotomes of increasing diameter [35, 43]. These implants placed in the pterygomaxillary region will be at a near-parallel angle to the posterior wall of the sinus, at a length as long as 7–8.5 mm according to some reports. If a pterygoid implant is instead indicated, then the angulation will be 10–20 degrees distoangular, with a 22 mm long implant to ensure anchorage in the pterygoid process [30, 35, 42, 43]. A rare risk of surgery is bleeding due to the venous plexus and the internal maxillary artery, which runs 1 cm above the pterygomaxillary sutures, although this has not been reported in the literature and remains only theoretical [35].

Implants in the Osteocutaneous Vascularized Reconstruction

The surgical placement of endosseous implants in the vascularized bone graft, whether in the maxilla or mandible, depends on the planned timing of the implant placement, as described above.

If the implants are planned to be placed in the vascularized free flap at a second procedure after the reconstruction, then implant placement is similar to traditional implant placement, with additional care taken to avoid the vascular pedicle and risking the vitality of the flap. Furthermore, attention should be taken with peri-implant soft tissue, as the osteocutaneous free flap will lack keratinized and attached mucosa and could be at a greater risk for granulation tissue formation due to the friction of the soft tissue around the implant and prosthetic.

Immediate implant placement with delayed restoration and the jaw in a day technique both have similar surgical techniques for placement of the implants. Especially useful is the computer-assisted planning with a virtually positioned vascularized bone graft to replicate the resected maxilla or mandible, as described above, with an example virtual surgical plan (VSP) shown in Fig. 20.9, and a dental/occlusal wax-up provided by the prosthodontist, and then a prefabricated osseous cutting guide with implant placement guides. If a jaw in a day is planned, the prosthodontist can utilize the prefabricated fibula replica and an occlusal splint with analog implants placed and fabricate a screw-retained fixed prosthesis [44].

This prosthetically driven process is based on a completely digital workflow of prosthetic planning merged with the proposed surgical planning to be able to create the optimal provisional and then definitive outcome. This begins with initial data acquisition including intraoral optical scans of the existing hard and soft tissues, CBCT of the maxillary and mandibular jaws, and facial surface scan to merge data for a digital smile design. Based on this proposal, the ideal position of the prosthetic teeth and implants and then underlying position of the fibula can be determined. Thus, the fibula cutting guide can be designed that also includes implant placement osteotomy preparation at the same time [44].

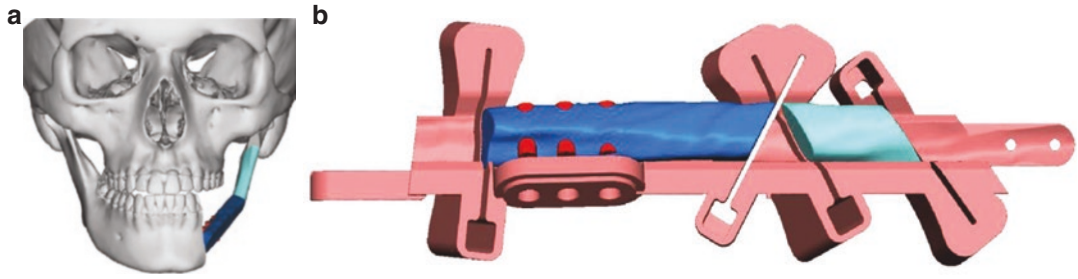

Fig. 20.9 (**a**) The virtual surgical plan demonstrates reconstruction of the left mandible status post-resection of a benign tumor and reconstruction with a free fibula flap, and immediate implant placement. (**b**) Fibula cutting guide with integrated dental implant guide for precise placement

Concurrent to the surgical planning, the implant planning can be imported into restorative CAD software that allows the planned position of the implants to be related in the correct spatial position with respect to the remaining teeth and jaw after the proposed resection. This allows for a provisional screw-retained prosthesis to be designed and fabricated through either an additive or a subtractive manufacturing process [44].

Once the fibula is resected but still attached to its vascular pedicle, the implants can be placed using the same surgical guide utilized for the fibula harvesting. The prefabricated provisional prosthesis is secured onto the implants using non-engaging intermediate abutments followed with delivery of the entire provisional/implant/fibula complex to the oral cavity. Following healing and osseointegration of the dental implants, the provisional prosthesis is replaced with a definitive prosthetic solution [44].

The advantages to this immediate placement and provisionalization technique at the time of fibula reconstruction include the patient's immediate return to function, obviation of intra- and postoperative intermaxillary fixation (IMF), and minimizing of intraoperative and flap ischemia [44].

The osteocutaneous free flap is harvested in standard fashion, and the maxillary or mandibular defect is performed as planned, utilizing the cutting guides. The implants would be placed directly into the vascularized bone graft while still attached to the donor-site vasculature, to avoid lengthening ischemia time. The implants are placed with pilot drills and consecutively larger drills as per the standard fashion, utilizing the prefabricated guides. The guides are then removed, and the implants placed. The prefabricated prosthesis is then secured onto the implants with multiunit abutments and screws. The osteocutaneous free flap can then be ligated and transferred to the head and neck for fixation into the head and neck defect. The occlusion should then be verified according to the presurgical plan with a planned <1 mm open bite to decrease the functional load. Closure of either the native mucosa or the flap inset proceeds in the standard fashion [44] (Fig. 20.10a–d).

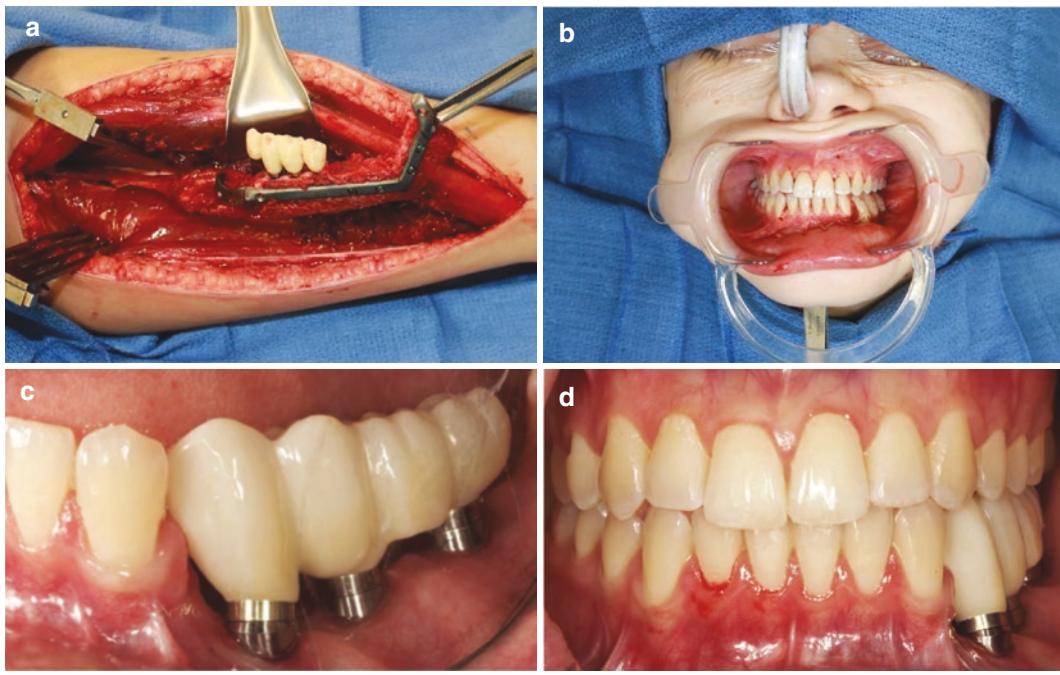

Fig. 20.10 (**a**) Intraoperative image of fibula flap harvest with patient-specific plate, dental implants, and restoration in place. (**b**) Immediate postoperative state. (**c**, **d**) Final prosthesis in place 6 months postoperatively

Pearls

Similar to zygomatic implants, and dental implant restorations in general, reconstruction should be prosthetically driven. The authors prefer mandibular reconstruction with fibula free flaps due to the bone quality, thickness, length, etc. Reconstruction should be positioned to align with the remaining native mandible and/or opposing maxillary dentition. This sometimes requires stepping the reconstruction more lingually, as the native mandible tends to flare laterally as it approaches the mandibular angle. Placing the fibula reconstruction in the native or resected mandibular position would position the mandibular implants in a buccal position, making restorative options more challenging. Insetting the fibula in a more lingual position helps to avoid this. Similar in concept, the authors also recommend fixating the fibula in a more cephalad dimension as opposed to in line with the inferior border. Most patients have adequate soft tissue to disguise any step in inferior border, and the more cephalad position of the fibula allows for a decrease in implant-to-crown height ratio.

Placement, position, and number of implants are resection/defect driven. The authors recommend fabricating a prosthesis such that the tooth closest to the osteotomy, i.e., fibula/mandible junction, be cantilevered. This is done to avoid placing an implant within 5 mm of the osteotomy site. The same holds true for multi-segment fibula free flaps in order to minimize the risk of hindering osseous union. For full mandibular (angle to angle) reconstruction, six axially positioned and evenly spaced implants are recommended, i.e., a three-segment fibula should have two implants each. Ideally, we prefer to place implants 10 mm apart from center to center of implant. When reconstructing segmental mandibular defects, ideal placement of implants is similar to non-ablative/reconstructive cases, meaning that placement of the implants should be at the central aspect of the tooth being replaced, i.e., central groove of posterior dentition and cingulum region of anterior dentition.

High-water bridge reconstruction is also recommended. This affords the patient the ability to adequately clean underneath the prosthesis and affords the surgeon the ability to more closely monitor for tumor recurrence (see Fig. 20.10c). Another benefit is to decrease the risk of formation of inflammatory or granulation tissue due to the contact of the prosthesis on movable mucosa. When a skin paddle is harvested as well, debulking as much as possible at the primary surgery is recommended. Even with this, future debulking may be required to decrease or minimize contact with the prosthesis.

Maxillofacial Rehabilitation with Prosthetics

Maxillofacial rehabilitation can come in many forms. Similar to reconstruction of the midface and mandible, there are many options, including osteocutaneous vascularized free flaps, cartilage grafts, synthetic implants, and maxillofacial prosthetics, either implant retained or otherwise retained. Patient selection for each treatment modality largely depends on the defect, the patient's comorbidities, and patient goals as discussed previously.

Similar to the jaw in a day technique, the same pre-planning with a maxillofacial prosthetist can allow for simultaneous implant and prosthetic placement, or immediate implant placement with delayed final restoration, or delayed implant placement and delayed restoration. Again, decisions for timing depend on the defect, the reconstruction, the need for radiation, and the goals of the patient.

Reconstructing the craniofacial complex provides unique challenges. Specifically, the nasal complex has a prominent three-dimensional projection, with the need for multiple layers including a nasal lining, bony support, and an esthetic external covering, with functional patency of nostrils. Orbital reconstruction is monopolized by synthetic implants. Auricular reconstruction can be addressed with either cartilaginous and soft tissue design of a neo-ear or endosseous implants for an excellent esthetic result as well. Vascularized reconstruction has its functional and esthetic limitations, in addition to the possi-

ble adjuvant radiotherapy and cancer surveillance postoperatively. Prosthetics can be retained with dermal adhesives or fusion with glasses, each with esthetic and functional shortcomings. Implant-retained nasal prostheses provide a retentive and stable platform for the prosthetic, with high success rates reported, although the literature is limited [45, 46]. Some of the literature within the prosthetic realm reports survival rates of prosthetics to be 1.5–2 years, but this appears to be related to the limitations in the biomaterials of the prosthetic themselves, not necessarily the endosseous implants [46]. Literature on orbital implant survival rate even after radiotherapy has proven to have a high success rate of 90.5% [47]. One systematic review compared irradiated and nonirradiated orbital, nasal, and auricular implants with irradiated sites negatively affecting the survival rate of the craniofacial implants, as would be expected [10].

Surgical Procedure

Nasal Reconstruction

Once the tumor has been resected with oncologic margins, the defect should be modified to improve the platform on which the nasal prosthesis will sit. The piriform aperture and bony septum should be trimmed for a flat base, and the inferior turbinate should be removed. Bicortical implants are then placed in the standard fashion at the bilateral nasal floor, taking precautions to avoid the dental roots if present. A skin graft can then be placed along the nasal floor. An additional implant can be placed at the glabella, depending on the extent of the maxillectomy [45, 48]. Based on the radiographic and clinical bone quantity present, longer implants show a higher success rate than shorter implants, with the majority of implants placed ranging from 3 mm to 13 mm [45, 49]. The bar-clip retention system is preferred in the majority of the literature for nasal prostheses [50]. Alternative techniques described to reconstruct the nasal complex based on intraoral dental implants, or zygoma implants, can be considered [51, 52].

Orbital Reconstruction

Similar to osseous implant in any other location, the soft tissue and bony reconstructive base should be prepared for implant surgery, in that the peri-implant tissue should be thin and previously debulked after reconstruction, as well as addressing any brow ptosis after exenteration to allow for symmetry. A CBCT should be evaluated, with surgical planning with your maxillofacial prosthetist. Implants for orbital reconstruction are most commonly placed in the superior and lateral orbital rims, targeting the stable zygomatic and frontal bones. A minimum of three implants, but preferably four implants, are ideal for adequate retention. The implants should be oriented in an arc, approximately 5 mm apart, and posterior to the orbital rim to camouflage the implants behind the prosthetic [48]. The most commonly used retention system for orbital implants is magnets [50] (Fig. 20.11a–c).

A surgical guide based on the presurgical planning should be used for placement of the implants under general anesthesia in the operat-

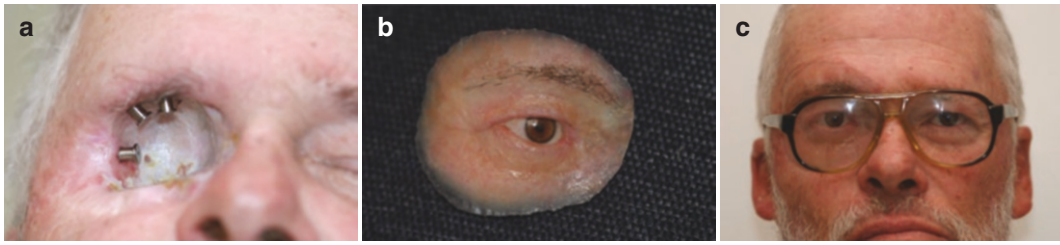

Fig. 20.11 (**a**) Orbital implants placed in the lateral and supraorbital rim. (**b**) Periorbital prosthesis with magnetic clips. (**c**) Periorbital prosthesis in place with excellent esthetic results

ing room. Exposure of the orbital rim is then performed, and the implants are placed in the standard drilling sequence similar to implants placed intraorally, torqued to 20–30 Ncm [48, 53]. The implant can then be covered with soft tissue overlying the cover screw for a two-stage implant, or placement of a temporary abutment for one-stage implants [48].

Auricular Reconstruction

Magnet and bar-clip retentions are the two primary forms of implant-retained prosthetics in the auricular region, and thus the placement of the implants in the temporal bone must be planned with the form of retention in mind, with preferably a minimum of three osseous implants placed [54, 55]. Implant length will depend on the thickness of temporal bone available based on location. Otherwise, the surgical procedure is identical to those previously described.

Pearls

Implants for facial prostheses pose similar problems to dental implants, with the risk of peri-implantitis and surrounding soft tissue inflammation. The authors recommend only maintaining a thin layer of epidermis around the implants when and if possible. Facial skin is innately more movable than keratinized gingiva and, therefore, more prone to developing granulation tissue surrounding the implant/skin interface. This is more problematic in climates that are more humid as well.

Oral and Maxillofacial Prosthetics Fabrication and Delivery

Implant uncovering and soft tissue management for maxillofacial prosthetics follow the same timeline as dental implants. The free tissue flap and reconstruction are ideally esthetically designed and sized at the initial reconstructive surgery to avoid the need for future flap debulking and shaping. However, should flap debulking and shaping be needed, this should be performed prior to final prosthetic delivery, for optimal emergence profile and adaptation of the intraoral or facial implant. The original reconstructive surgeon will avoid injury to the pedicle and anastomosis when debulking, and it is wise to debulk in stages to allow for neo-angiogenesis and avoid strangulation of the blood supply. Ideally, debulking should not be performed for 6 months after the initial soft tissue free flap, with an interval of approximately 6-month stages if excision of tissue is required in multiple directions [56]. For the craniofacial free flap, liposuction, tissue shaving, and skin grafting, in addition to direct excision, can be useful for tissue debulking [56].

Conclusion

Management of orofacial defects following ablative surgery poses a unique challenge in terms of restoring patient form and function. The primary goal of such treatment is the excision of benign and/or malignant lesions, and restoration of patient esthetics and function. In terms of dental rehabilitation, much has advanced in recent years with improved technology and customization of patient-specific implants. This has allowed us to provide patients with immediate reconstruction and dental rehabilitation at the time of ablative surgery. It is imperative to have detailed communication with a team of experts, i.e., prosthodontists and anaplastologists, to achieve an optimal result.

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