CASE REPORT

Radiation necrosis of the pharyngeal soft tissue: Unique clinical entity reconstructed with a previously unreported composite brachioradialis and flexor digitorum superficialis radial forearm flap

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Abstract

Background: The radial forearm free flap (RFFF) is a versatile flap commonly used in head and neck reconstructive surgery. We describe the use of a composite RFFF that includes muscle for reconstruction of a hostile wound of the posterior pharyngeal wall.

Methods: A 54-year-old male with a history of recurrent right palatine tonsil HPV+ squamous cell carcinoma developed severe soft tissue necrosis of the posterior pharyngeal wall secondary to reirradiation. The defect was reconstructed with a composite RFFF that included the brachioradialis (BR) muscle and the flexor digitorum superficialis (FDS) muscle.

Results: Restoration of this complex defect was successfully accomplished with minimal donor site functional deficits and satisfactory functional outcomes including decannulation and resumption of oral intake.

Conclusion: This composite RFFF can be effectively used to reconstruct a hostile wound of the posterior pharyngeal wall. Incorporation of muscle in the reconstruction of complex wounds with soft tissue necrosis is beneficial.

KEYWORDS
soft tissue necrosis, posterior pharyngeal wall, radial forearm free flap, brachioradialis, flexor digitorum superficialis

1 INTRODUCTION

The radial forearm free flap (RFFF), originally described for reconstruction of head and neck defects by Yang et al in 1981,1 is considered one of the most versatile free flaps for the head and neck region.2 Composite forearm free flaps involving the radial artery include the incorporation of muscles and other structures located in the flexor compartment such as the palmaris longus tendon and portions of the radial bone. For complex or hostile wounds, the addition of muscle to create a musculocutaneous flap is an effective method to obliterate dead space, inhibit bacterial colonization, and promote healing and tissue growth.3 However, most musculocutaneous flaps are very thick and pose a significant challenge to reconstructing a defect that requires thin tissue to attain a favorable functional result. To achieve this goal, the transfer of an RFFF in conjunction...
with muscle such as the brachioradialis and flexor carpi radialis has been described in several reports. We present a case of posterior pharyngeal wall radiation necrosis reconstructed with a RFFF, including a unique combination of the brachioradialis (BR) muscle and the flexor digitorum superficialis (FDS) muscle. To our knowledge, this is the first case that has safely and effectively incorporated the FDS muscle into a radial forearm free flap to reconstruct a defect of the posterior pharyngeal wall. Additionally, this is the first reported case of near total soft tissue necrosis of the oro and nasopharynx secondary to re-irradiation.

2 | CASE PRESENTATION

A 54-year-old male with a history of right palatine tonsil HPV+ squamous cell carcinoma (SCC) was seen with radiation recurrent SCC of the right tonsil. The patient initially underwent concurrent weekly Erbitux and radiation therapy (7000 cGy). One year after completion of radiation therapy, the SCC recurred in his right lateral pharynx. The patient subsequently underwent a right partial pharyngectomy and right selective neck dissection. The defect was reconstructed with a palatopharyngoplasty and a left radial forearm free flap. He healed uneventfully. Final pathology revealed a basaloid squamous cell carcinoma with anaplastic features. Carcinoma was close to the peripheral margins with evidence of diffuse lymphatic tumor emboli. In light of these adverse histological features, the patient underwent a course of proton beam therapy (60 cGy) administered to the tonsil and bilateral necks, in combination with concurrent cisplatin (100 mg/m² × 3 weeks).

Three months following the completion of his second course of chemoradiation, the patient was seen with severe neck pain and progressive dysphagia. He was admitted for inadequate caloric intake and underwent G-tube placement. Physical exam revealed severe tissue necrosis of the entire posterior pharyngeal wall with a foul odor. A cervical CT and MRI demonstrated what appeared to be osteomyelitis of the C1 and C2 vertebral bodies with soft tissue destruction of the prevertebral region spanning the entire width of the oropharynx, extending from the nasopharynx to the hypopharynx at the level of the arytenoids (Figures 1 and 2). A direct laryngoscopy showed radiation necrosis of the posterior wall with exposed bone at the anterior tubercle of C1 and the base of the dens. However, no cortical destruction was noted of the C1 and C2 vertebrae and multiple biopsies revealed no evidence of cancer.

At the time of definitive treatment, the patient underwent debridement of the necrotic posterior pharyngeal wall mucosa and submucosal layers. A mandibulotomy and mandibular swing approach were performed to achieve full access to the posterior pharyngeal wall, from
the level of the nasopharynx to the esophageal inlet, and to allow for the insetting of the RFFF. Severe radiation induced trismus and limited direct access through a transoral approach. The osteotomy was placed in the midline of the mandible, outside of the field of radiation, and as a result, the concerns related to hardware complications and malunion were minimized. The osteotomy was placed in the midline of the mandible, outside of the field of radiation, and as a result, the concerns related to hardware complications and malunion were minimized.

**FIGURE 3** A, The radial forearm skin paddle with proximally designed monitor paddle (MP). A perforator to the FDS muscle is shown (white arrow). More distally, the portion of the harvested BR muscle is shown (yellow arrow). B, The composite radial forearm musculocutaneous flap with portions of the BR and FDS muscles. Illustration by Jill Gregory. Used with permission from ©Mount Sinai Health System. BR, brachioradialis; FDS, flexor digitorum superficialis

**FIGURE 4** A, Inset of the radial forearm into the posterior pharyngeal wall defect. B, The composite musculocutaneous RFFF is shown with the FDS positioned behind the skin paddle and overlying the vertebral bodies. The BR muscle is located external to the pharyngeal lining at the suture line where the skin was sutured to the posterolateral pharyngeal wall and providing protection for the vascular pedicle, which was anastomosed to recipient vessels in the left neck. Illustration by Jill Gregory. Used with permission from ©Mount Sinai Health System. BR, brachioradialis; FDS, flexor digitorum superficialis; RFFF, radial forearm free flap
Following the removal of all nonviable soft tissue, the cortical bone of the subjacent vertebrae was found to be completely intact. An RFFF with the addition of the BR muscle was planned to reconstruct the defect. Since the patient refused to consent to undergoing a total laryngectomy, a thin tissue lining for the oropharyngeal wound was critical to restoring the patient’s aerodigestive tract function.

During the harvest of the RFFF, the BR and its perforator were located proximal to the designed skin flap, rendering the use of the BR muscle in the posterior pharyngeal wound bed less desirable. Further exploration of the forearm identified a major perforator to the radial head of the FDS muscle deep to the fasciocutaneous skin paddle. Due to this muscle's anatomical position in relation to the skin paddle, it was deemed optimal to cover the exposed bone. After intraoperative consultation with a senior hand surgeon, the radial forearm skin paddle with the incorporation of a portion of the BR muscle and FDS muscle was successfully harvested (Figure 3). The skin paddle and FDS were then used to restore the defect of the posterior pharyngeal wall by placing the entire FDS muscle under the RFFF. The vascular pedicle was tunneled to the virgin left neck, where recipient vessels were identified (Figure 4A). However, due to the severity of the tissue changes, there was significant concern for the development of a salivary fistula. To secure the exit point of the pedicle, the BR muscle was used to bolster the closure of the path of the pedicle to augment the skin to mucosa closure (Figure 4B).

The patient was discharged on postoperative day 10 and was successfully decannulated on postoperative day 35. Six weeks postoperatively, the patient reported greatly diminished neck pain and started taking fluids by mouth, supplemented by G-tube feeds. A hand exam performed 6 weeks postoperatively demonstrated no loss of grip strength in the fingers. On wrist flexion of more than 30°, he reported a pain score of 2 out of 5 along a Likert-like scale. His maximum achieved wrist flexion at this time was 40°. In a subsequent hand exam performed at 12 weeks postoperatively, the patient achieved wrist flexion with a range of motion (ROM) of 80° with no reported pain.

3 | DISCUSSION

In the case presented, the hostile wound bed of the posterior pharyngeal wall was reconstructed with a unique radial forearm composite flap including the BR and FDS muscles. There was severe necrosis of the posterior pharyngeal wall, which is considered to be a late effect of radiotherapy in the head and neck. To our knowledge, there are no cases of near total soft tissue necrosis of the posterior pharyngeal wall secondary to re-irradiation reported in the literature. Soft tissue necrosis (STN) has been reported to occur between 7 and 12 weeks after completion of radiation therapy, which is similar to the time course observed in our patient. It is hypothesized that late tissue injury occurs as a result of the process of denuding the epithelium associated with severe acute mucosal reactions. Studies have reported a high incidence of STN (23%-28%) following the treatment of oropharyngeal SCC with adjuvant radiotherapy following both transoral robotic surgery (TORS) and wide resection with primary closure. Comparison of STN occurrence between patients who underwent TORS or resection with primary closure and patients with microvascular reconstructive surgery has not been reported.

Risk factors for STN include location in the oropharynx, depth of resection, radiation dose to the surgical bed, and severe mucositis. Comorbidities that impair vascularity, such as hypertension and diabetes, are highly correlated to radiation-induced normal tissue injury. Surgical factors also contribute to STN. For instance, TORS leaves the resection bed relatively devoid of epithelial stem cells. Subsequent healing, which is normally dependent on the migration of epithelial cells from the periphery of the resection bed, is further inhibited by higher radiation therapy doses and fractionation schedules. STN is primarily managed with antibiotics, analgesics, and steroid treatments. More serious cases of STN may be referred for hyperbaric oxygen treatment.

Re-irradiated tissue is also at high risk for STN. A literature review by Kaspert et al identified soft tissue necrosis as the most commonly reported complication of external beam re-irradiation. Of patients who underwent re-irradiation with brachytherapy, 17% of patients developed soft tissue necrosis, while 20% of patients who underwent postoperative re-irradiation developed mucosal necrosis. Other toxicities associated with re-irradiation in the pharyngeal region include osteoradionecrosis, spinal cord myelopathy, and carotid artery blowout. The 5-year late complication rate of re-irradiated head and neck cancer patients ranges from 45% to 65%, although this may be an underestimate due to this cohort’s high mortality rate.

Of note, Kakarala et al reported a case of cervical spine osteoradionecrosis with necrosis of the nasopharynx. Similar to the case presented above, the patient’s defect was reconstructed with an RFFF, but did not include any muscle. However, for the reconstruction of complex or hostile wounds, such as those with severe STN, the incorporation of muscle into free flaps may yield beneficial outcomes. Muscle flaps are more effective in obliterating dead space than skin or fasciocutaneous
flaps. Additionally, in canine models, musculocutaneous flaps were found to suppress bacterial colonization more effectively than their fasciocutaneous counterparts. This difference was attributed to the robust blood flow and increased tissue ingrowth associated with the muscle flap. Increased collagen deposition has also been observed in muscle flaps. Thus, the benefits of a muscle flap as an effective barrier with optimal vascularity are unmatched by fat and fascial flaps, which can be harvested as extensions of an RFFF.

Due to thickness and bulk, most musculocutaneous flaps are unsuited for the reconstruction of the posterior pharynx. Julieron et al reported a patient series in which reconstruction with a pectoralis major flap (PMF) or platysma myocutaneous flap (MCF) of the posterior pharyngeal wall after larynx sparing cancer resections resulted in worse short-term functional outcomes in comparison with patients who underwent reconstruction with a RFFF. In the aforementioned series, the primary tumor site was the posterior wall at one of the three locations: the orohypopharyngeal junction (29 cases), the posterior or posterolateral hypopharyngeal wall (37 cases), or the posterior oropharyngeal wall (11 cases). Functional outcomes were measured by the median time in days until decannulation (PMF = 36 days, platysma MCF = 28 days, RFFF = 21 days) or removal of the feeding tube (PMF = 71 days, platysma MCF = 30 days, RFFF = 30 days). Other reconstructive options for the posterior pharyngeal wall include the use of enteric flaps such as a split jejunum or a gastro-omental flap. However, a major drawback of enteric reconstructive options is the need for abdominal surgery and the risk of aspiration due to mucous secretion. Thus, a radial forearm flap incorporating the BR and FDS muscles, as utilized in our patient, presents an optimal alternative reconstructive technique for the oropharynx.

3.1 Musculocutaneous radial forearm flaps

In the case presented here, following debridement of necrotic tissue, the patient’s wound was covered with a radial forearm flap including a portion of the BR and the FDS muscle. Incorporating the BR muscle with the radial forearm skin has been successfully documented in the reconstruction of the elbow, lip, tongue, orbit, and neck. The BR muscle is responsible for the pronation, supination, and flexion of the forearm. The functional significance of harvest of a portion of the BR muscle is considered to be minimal as previous literature has reported very limited functional deficits associated with the incorporation of the entire BR muscle. In an elegant anatomical study by Shen et al, the BR muscle was shown to lie within the radial and brachial arterial angiosomes and receives its blood supply segmentally from 8 to 10 vessels. Furthermore, the dominant pedicle supplying the BR is highly variable in source and position. It arose from the radial recurrent artery, radial artery, and brachial artery in 40%, 36%, and 24% of cases, respectively. Even when the dominant perforator arises from the brachial artery or radial recurrent artery, adequate perforators from the radial artery exist, making the transfer of the BR as either a muscle or musculocutaneous free flap possible. Additionally, the forearm skin paddle is perfused by septal perforators arising distal to the muscular branches. This arrangement on a single vascular pedicle allows the BR muscle and the fasciocutaneous segment to be oriented independently of each other.

The FDS is responsible for flexion of the four fingers at the distal interphalangeal joints, the metacarpophalangeal joints, and the proximal interphalangeal joints, as well as flexion of the wrist. The FDS consists of a radial, ulnar, and humeral head. It arises proximally in the forearm from both the medial epicondyle and the radius. This broad muscle separates the superficial and the deep muscles of the flexor compartment and narrows in the distal forearm giving rise to the four tendons noted above. The incorporation of the FDS into an RFFF has not been described in the literature. Studies have shown that the FDS involves at least two angiosomes. The FDS receives its blood supply from both the ulnar and radial artery, and therefore perforating branches from the radial artery are consistently present. There is, however, no anatomical study that examines the blood supply of the FDS in the context of its harvest with the radial forearm flap. In the case presented here, the radial slip of the FDS muscle was in close proximity to the forearm skin paddle, and therefore optimal for defect coverage by the interposition of the well-vascularized muscle layer over the exposed vertebrae. The patient did not show any functional finger impairment at 6 weeks postoperatively. Additionally, although wrist flexion was initially limited to 40°, the patient achieved a normal ROM by 12 weeks postoperatively. This is consistent with the outcomes of Gasse et al, who reported a case series of six patients in which a rotational FDS flap was harvested for the treatment of median nerve neuroma. The authors reported no ROM deficits during active or passive finger flexion. Though not utilized in this case, the flexor carpi radialis (FCR) muscle can also be incorporated into the radial forearm free flap. The composite radial forearm/FCR flap was not a viable option for our patient because the FCR muscle is located relatively proximal in the forearm, at too great a distance from the distal radial forearm skin paddle. Its position is comparable to the BR muscle.
relative to the fasciocutaneous paddle. According to Sukkar et al, a potential drawback to the FCR/RFF flap is the possibility of donor site morbidity including loss of wrist strength and stabilization.\textsuperscript{31} However, three of four patients in their study underwent postoperative grip strength testing and demonstrated no differences between the operated and the nonoperated arms. Of note, hand surgeons have used the entire FCR for the reconstruction of the basal joint of the thumb and report that patient wrist strength returns nearly to baseline by 6 months postoperatively.\textsuperscript{32} Furthermore, at 1 year postoperatively, patients did not experience either impaired wrist motion or reduced wrist flexion strength.\textsuperscript{32}

This case demonstrates a unique radiation-induced soft tissue destruction of the entire posterior pharyngeal wall spanning the nasopharynx to the hypopharynx following re-irradiation. Restoration of this complex defect was successfully accomplished with a novel composite radial forearm free flap, including the unique combination of the brachioradialis and flexor digitorum superficialis muscles. Additionally, our case highlights the benefits of incorporating muscle flaps into a hostile wound bed.

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CONFLICT OF INTEREST
The authors declare no potential conflict of interest.

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