Journal of Experimental and Clinical Medicine
http://dergipark.ulakbim.gov.tr/omujecm

Clinical Research

J. Exp. Clin. Med., 2016; 33(4): 199-204
doi: 10.5835/jecm.omu.33.04.004

Pharyngoesophageal reconstruction with the radial forearm free flap

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ARTICLE INFO

Article History
Received 19 / 06 / 2016
Accepted 12 / 08 / 2016

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Keywords:
Oesophagectomy
Oesophagus reconstruction
Pharyngoesophageal reconstruction
Radial forearm free flap

ABSTRACT

Due to its unique structure, oesophageal defects are of the hardest to reconstruct. Since local flap options and their success are limited free tissue transfers are considered the treatment of choice for reconstruction of partial or circumferential defects left by cervical oesophagectomy. While free jejunum flaps are regarded as the most appropriate solution, its donor site morbidity and increased risk associated with its harvest tend the surgeons to prefer a skin flap instead. This study presents our experience with the radial forearm free flap for oesophageal reconstruction along with a detailed description of the techniques utilized and an 11 patient case series. This flap technique is a single stage solution for reconstruction of oesophageal defects yielded by malignant tumour ablation, and it has distinct advantages such as consistent flap anatomy, straightforward dissection technique, long and wide vascular pedicle, and thin and pliable skin paddle. We believe that with good knowledge of flap anatomy and pertinent execution of microsurgical techniques, free radial forearm flap is an effective and reliable option for post-ablative oesophageal reconstruction in the elderly patients. Also, thanks to the pliable skin paddle and long vascular pedicle, radial forearm flap is one of the most frequently preferred skin flaps for oesophageal reconstruction.

1. Introduction

Ablation of malignant hypopharyngeal tumours yield circumferential or partial oesophageal defects. Due to the uniqueness and complexity of the structure involved, reconstruction of these defects are one of the most challenging tasks. While the use of local (cervical, submental or supaclavicular) or regional (pectoralis major, deltopectoral, thoracodorsal) flaps have been reported, increased knowledge and availability of microsurgical techniques highlighted free tissue transfers as the treatment of choice for all patients expect those who are clearly contraindicated (Harii et al., 1985; Anthony et al., 1994; Güler et al., 1998; Taylor and Haughey, 2002; Stile et al., 2006; Oki et al. 2010;

Piazza et al., 2012; Welkoborsky et al., 2013; Amin et al., 2014; Nagel and Hayden, 2014; Mohammad et al., 2015; Yin et al., 2015; Shen et al. 2016). The primary objective of oesophagus reconstruction is restoring the water-tight continuity of the oesophagus as anatomically as possible while obviating strictures and dysphagia (Taylor and Haughey, 2002; Welkoborsky et al., 2013; Nagel and Hayden, 2014). While gastric pull up appears to be a suitable non-microsurgical way of re-establishing anatomic continuity, jejunum, radial forearm and anterolateral thigh flaps are also used with varying degrees of success (Harii et al., 1985; Anthony et al., 1994; Güler et al., 1998; Taylor and Haughey, 2002; Kim Evans et al., 2010; Elfeky et al., 2015).

Radial forearm flap (RFF) has a long vascular pedicle, matching calibre with recipient vessels in the neck and thin and pliable skin paddle in which is amenable to tailoring. In this article, our experience with the RFF for oesophageal reconstruction is presented along with technical highlights and an 11 patient case series.

2. Materials and methods

Eleven patients who had undergone laryngopharyngectomy between the years 2013 and 2016, and their defects subsequently reconstructed via free RFF were included in this study. The average age of the patients were 66 years (58-81). Nine of the patients were male (81.8%) and two of them were female (18.1%). Five of the defects were circumferential and 6 of them were partial. All partial defects were caused by oesophageal infiltration of epidermoid carcinoma of the larynx. Of the 5 circumferential defects, two were caused by infiltration of the carcinoma of the larynx and three were primary oesophageal carcinomas. The average length of oesophageal defects was 10 cm.

Surgical technique

Prior to surgery, Allen test is performed on the patient to ensure that ulnar artery will suffice to sustain the hand once the radial artery will be harvested along with the flap. After tumour ablation (Fig. 1A, B), the patient's neck is extended to 30^0 and distance between the hypoharynx and distal stump of the oesophagus is measured to yield the true length of the defect (Fig. 2A). Afterwards, the oesophagus is stretched by 3 and 9 o'clock positions at the each end of the proximal and distal stumps to give the assumed diameters of the proximal and distal ends of the flap. From these measurements, the trapezoid shaped skin paddle of the flap is outlined on paper, with the upper and lower edges being the distal and proximal ends respectively, and the height of the trapezoid being the length of the defect. Afterwards, the template is cut out and fitted to the defect to confirm pertinent match of shape and size (Fig. 2B). Once satisfied with the design, the

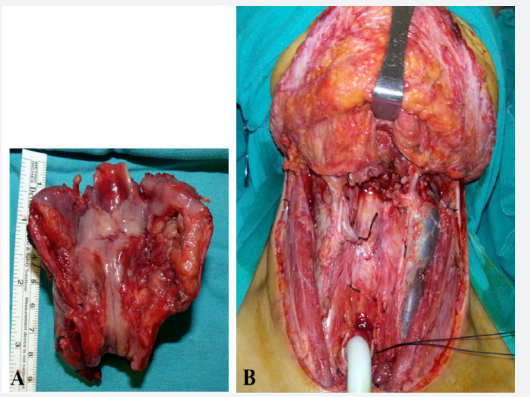

Fig. 1. A: Total Laryngopharyngectomy specimen excised; **B:** Post-ablative defect

template is laid on the forearm and flap is marked over the course of the radial artery (Fig. 3A). At this point, an additional, 2 cm wide skin island is marked distal to the main skin paddle to be used for postoperative monitoring. Working as two teams is advised, a great deal of time can be gained if one team prepares the recipient vessels while the other harvests the flap. Donor limb is exsanguinated and RFF is harvested as described in the literature. The reader is advised to clip or ligate the small vessels emerging from the radial artery rather than cauterizing them to decrease the risk of postoperative bleeding. To obviate size discrepancy with the recipient vessels, radial artery is dissected up to the brachial artery and concomitant veins are dissected up to the cephalic vein (Fig. 3B). Flap is not detached from its blood supply before the recipient vessels are located and their adequate blood supply is confirmed. In the neck region, usual recipient arteries are facial, superior thyroid and lingual arteries and common recipient veins are branches of the internal jugular vein and distal end of the external jugular vein.

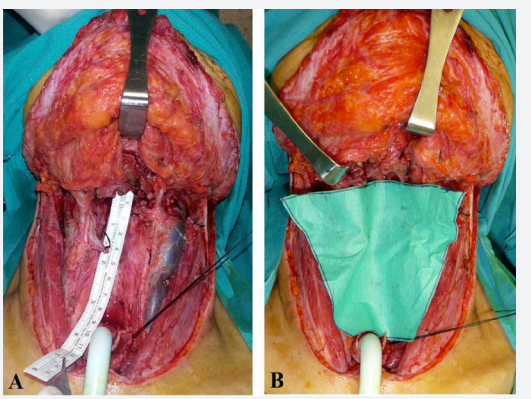

Fig. 2. A: Oesophageal defect measured with the neck in mild extension; **B:** Flap template outlined on sterile gauze wrapping

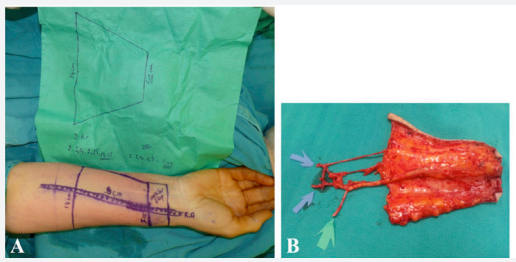

Fig. 3. A: RFF marked on the nondominant forearm using the cut out template; **B:** RFF harvested (Thick and thin arrows indicate radial artery and concomitant veins, respectively)

In circumferential defects, the trapezoidal flap is laid on the prevertebral fascia with its epithelial surface facing up and its base aligned against the cranial oesophageal stump. First proximal (Fig. 4A) and distal (Fig. 4B, 5A) circular anastomoses are carried out. Afterwards, lateral sides of the flap are approximated ventrally. The skin extension on the distal part is fashioned to an island flap and left on the skin surface (Fig. 5B).

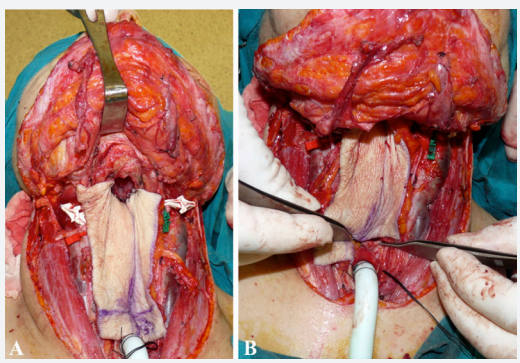

Fig. 4. A: Flap inset for circumferential defect (see text); **B:** Monitor flap is islanded distal to the main flap with its subcutaneous and fascial connection preserved

In partial defects, a longitudinal strip of the oesophagus is left on the paravertebral fascia (Fig. 6A, B). The size of the flap is calculated as described earlier, however the width of the remnant mural strip is deducted from the elapsed width of the proximal and distal ends. This time, flap inset is began with the skin side facing down against the remnant mural epithelium and flap is secured in a proximal to distal fashion; with proximal coaptation carried out first, followed by the sides and finally the distal coaptation. (Fig. 7A-C).

For suturation, 3/0 and 4/0 PLGA sutures are used. 3/0 vertical mattress sutures were placed 5-7 mm apart and 4/0 simple interrupted sutures were placed between them. Once the flap is tubed, a nasogastric

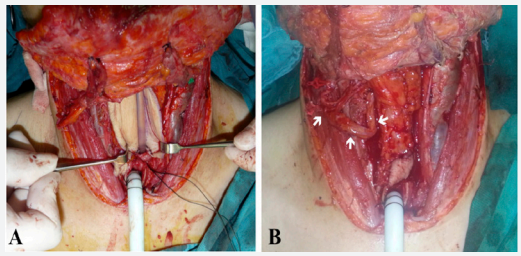

Fig. 5. A: Coaptation of the flap to the oesophageal stump; **B:** Approximation of the lateral sides of the flap, forming the ventral suture line. Monitor flap is left on the tubed flap (arrows indicate the course of the vascular pedicle)

tube is introduced. Then, muco-cutaneous suturations are complete, an additional layer of sutures is placed corresponding to the subfascial plane of the flap, to evert the coaptation and prevent fistulisation. After the flap is inset, microvascular anastomoses are commenced. We prefer simple interrupted anastomosis technique using 8/0 and 9/0 polypropylene sutures with the initial stay sutures placed 180^0 apart. Once the clamps are released, bleeders on the flap are meticulously cauterized. Suction drains are placed under apron flaps and they are loosely sutured in a safe distance away from anastomoses and pedicle. The neck flaps are returned to their anatomical locations. The monitor flap is surfaced either between apron flaps or through an incision made on its overlying skin and sutured in place (Fig. 7D). Postoperative flap monitoring can be directly done via bleach-refill or pin-prick tests made on this flap. Keeping the patient's head in neutral position will avoid tension on the vascular pedicle. After 24 hours postoperatively, enteral nutrition is started from the NG tube. Oral ingestion of liquid and regular diet is allowed at the 10^{th} day and first month, respectively.

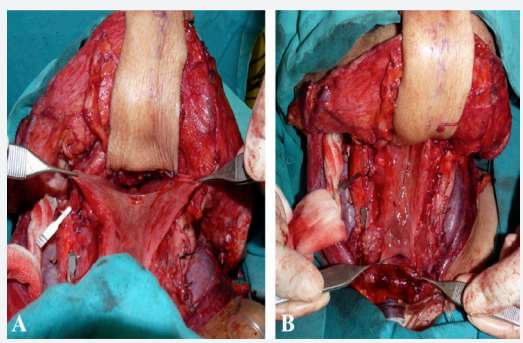

Fig. 6. A: RFF inset to a partial defect (see text); **B:** Distal oesophageal stump

3. Results

The average surface areas of the trapezoidal flaps used for partial (n=6) and circumferential (n=5) defects

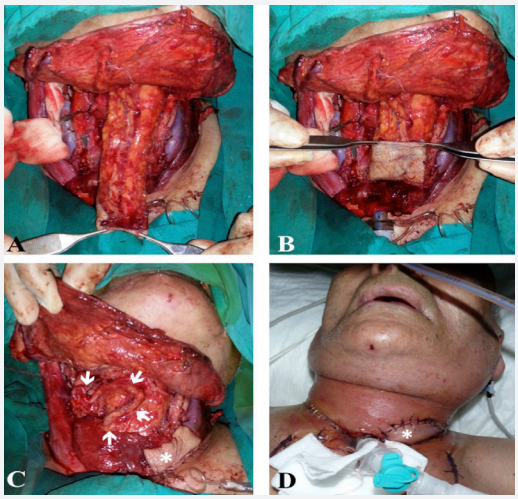

Fig. 7. A: Coaptation of the lateral sides of the flap along the length of the oesophageal strip; **B:** Monitor flap flipped outwardly over the distal stump. **C:** Monitor flap inset to the skin surface after anastomoses are completed (arrows indicate the contorted course of the pedicle, asterisk indicates the monitor flap); **D:** Apron flaps closed with the monitor flap (indicated by asterisk) in place (see text)

were 65.56 cm^2 and 105.05 cm^2, respectively. Average pedicle length was 10 cm. Total flap necrosis developed in three patients due to anastomotic problems in two and leakage associate complications in one of them. Salvage procedures were undertaken via single stage pectoralis major myocutaneous flap in two of the cases and two-staged deltopectoral skin flap in one. The last patient is lost due to opportunistic fungal infections. None of the remaining patients developed fistulisation. Five of the patients underwent endoscopy at the 3rd month follow up and none of them displayed any stricture formation. Five patients received radiotherapy and none of them manifested any oesophagus-related symptoms or complaints. Average patient follow up was 23.4 months. Patient data is summarized in Table 1.

4. Discussion

The objective of pharyngoesophageal reconstruction is restoring continuity of cervical oesophagus which conforms functional deglutition while avoiding odynophagia, dysphagia and stricture formation (Güler et al., 1998; Taylor and Haughey, 2002; Stile et al., 2006; Kim Evans et al., 2010). While free jejunum transfer is regarded as the ideal reconstruction method, risks associated with its harvest are daunting factors of their use, especially for the elderly patients. In that case, less morbid and technically less challenging cutaneous flaps are resorted to (Kim et al., 2008; Welkoborsky et al., 2013; Nagel and Hayden, 2014; Tornero et al., 2014; Mohammad et al., 2015). A well recognized workhorse flap, RFF was first used for reconstruction of hypopharingeal and oesophageal defects by Harii et al and is of use ever since (Harii et al., 1985; Taylor and Haughey, 2002). It's straightforward dissection, thin and pliable skin paddle, reliable circulation pattern and long pedicle make it a more favourable flap than other fasciocutaneous flaps (Harii et al., 1985; Anthony et al., 1994; Güler et al., 1998; Taylor and Haughey, 2002; Stile et al., 2006; Piazza et al., 2012; Nagel and Hayden, 2014; Tornero et al., 2014). Also, free fasciocutaneous flaps respond better to speech therapy following tracheooesophageal puncture than free

Table 1. Data summary of the patients in whom free RFF procedure is undertaken

Patient no	Gender	Age	Esophageal defect	Trapezoidal Flap dimensions (cm) (proximal width / length / distal width			Complication (salvage procedure)	Pedicle length (cm)	Follow up (month)
1	M	68	Partial	9	9	4.5	-	10.5	36
2	M	66	Partial	6	9.5	4	Total necrosis, PMMCF	9.5	18
3	M	60	Circumferential	12	14	7	-	7	24
4	M	58	Circumferential	10	11	7	-	10	20
5	F	56	Circumferential	14	12	10	Total necrosis, PMMCF	11	30
6	M	73	Partial	8	9.5	4.5	-	11.5	24
7	M	74	Partial	9	10	7	-	10.5	18
8	M	81	Circumferential	10	9	6	Total necrosis, PMMCF	10	Deceased
9	M	59	Partial	11	9	7	-	11	24
10	M	68	Partial	9	9	6	-	10.5	22
11	F	64	Circumferential	14	9	5.5	-	9	18
Mean		66		10.1	10	6.2		10	23.4

PMMCF: Pectoralis major myocutaneous flap; **DPF:** Deltopectoral flap

jejunum flaps. (Dodd et al., 2010). Likewise, in partial resections which a posterior strip of the oesophagus is preserved, visceral flaps are not suitable and require removal of the posterior strip for their successful use. On the other hand, skin flaps accommodate both partial and circumferential defects (Dodd et al., 2010).

The most important concern regarding the use of cutaneous flaps for oesophagus reconstruction is the stricture formed at the mucocutaneous junctions (Ho et al., 2012). In their study comparing the efficacy of RFF, ALT flap and jejunum flap for oesophageal reconstruction, Tan et al reported no significant difference between methods with regard to fistula formation. However, stricture formation was significantly less with jejunum flaps (Tan et al., 2015). In their study in which they presented a 45 patient series in whom partial or total oesophageal reconstruction was undertaken due to corrosive substance ingestion, they compared long the term results (average 24 years postoperatively) of pedicled colon, free jejunum and RFF flaps. They have reported multiple strictures, segmental narrowing and irregular surface in RFFs and almost normal appearance in intestinal flaps. However, unlike ours, their patient population was consisted of young patients with non-neoplastic etiology. They also noted that they prefer cutaneous flaps for the elderly tumour patients and recommend bowel flaps for young patients with long life expectancy. (Imaizumi et al., 2015). In the literature, interdigitating the tubed flap and recipient oesophageal rims after making series of Z-plasty like incisions on them has been suggested as a preventative measure against stricture formation (Cho et al., 2002; Yu et al., 2010; Fujiwara et al., 2011; Ho et al., 2012).

Regardless of the flap used, free flap monitoring is a concern in oesophageal reconstruction, for the flap is totally immersed under the skin integument. RFF has the advantage of having a wide calibre pedicle the patency of which can easily be checked by Doppler under the apron flaps. Also, its vascularity allows an individual skin paddle to be fashioned as a monitor distal to the main flap and sutured to the skin surface. (Cho et al., 2002; Ferguson and Yu, 2009; Tornero et al., 2014). This advantage can further be utilized when there's an additional cervical skin defect other than the oesophageal flap (Piazza et al., 2012; Tornero et al., 2014).

Salivary fistula formation occurs, as high as 67%, in fasciocutaneous oesophageal reconstructions, significantly higher than encountered in bowel flaps (Taylor and Haughey, 2002; Stile et al., 2006). Allowing inversion of the epithelial margin while tubing the flap is the major factor facilitating fistulisation. We believe that our technique combining vertical mattress and simple interrupted suturing, and reinforcement sutures placed at the subfascial plane helps the epithelial margin evert into the lumen. While leaving the vertical suture line of the tubed flap posteriorly, against the prevertebral fascia has been advised, (Ho et al., 2012) we believe that this will expose the suture line to the stagnant salivary secretions in the reclined patient and thus facilitate fistulisation. Therefore, in our series we placed the vertical suture line anteriorly. The use of additional measures such as Montgomery salivary bypass stent has been advised to further obviate fistulisation, (Varvares et al., 2000) however, we believe that application of a nasogastric catheter and abstinence of oral intake for 10 days is enough for reestablishment of water-tight epithelial continuity. Afterwards, we order liquid diet for another month before allowing regular diet.

It has been reported that RFF tolerates postoperative radiotherapy significantly better than bowel flaps (Piazza et al., 2012). Five of our patients received adjucant radiotherapy postoperatively and none of them developed any radiotherapy-associated complicaitons. In obese patients, most of the other pedicled or free cutaneous flaps such as pectoralis major or ALT and visceral flaps such as jejunum or colon flaps are contraindicated due to increased donor site associated complication risks (Welkoborsky et al., 2013; Nagel and Hayden, 2014). Likewise, in the female population, the viability of the skin flap is ambiguous. In such scenarios, RFF emerges as the most dependable option. Also in respect to restoration of deglutition and vocation, RFF has superior functional outcomes (Piazza et al., 2012). Nevertheless, PMMC flap is still regarded as the salvage procedure of choice when free flap surgery is not feasible or a reconstructive attempt has failed (Kim Evans et al., 2010; Piazza et al., 2012; Nagel and Hayden, 2014; Yin et al., 2015). Likewise, our series have two patients in whom PMMC flap has been successfully used after free flaps have failed. In another patient in whom free flap has failed, our staged reconstruction attempt using deltopectoral flap has been interrupted by the demise of the patient due to an opportunistic nosocomial fungal infection in the early postoperative period. While a frequently mentioned but seldom justified concern regarding the use of RFF is vascular problems associated with the sacrifice of a major artery supplying the hand (ref needed). However, tendency to develop such complications can easily be spotted by a simple Allen test and neither in our series presented in this work, nor other patients who underwent RFF surgery for other reconstructions, we encountered no vascular donor site complications or other problems in which vascular compromise can be incriminated.

RFF is a single stage solution for reconstruction of oesophageal defects yielded by malignant tumour ablation, and it has distinct advantages such as consistent flap anatomy, straightforward dissection

technique, long and wide vascular pedicle, and thin and pliable skin paddle. It does not require laparotomy like bowel flaps or gastric pull up procedure and its donor site morbidity is well tolerated. We believe that with good knowledge of flap anatomy and pertinent execution of microsurgical techniques, free RFF is an effective and reliable option for post-ablative oesophageal reconstruction in the elderly patients.

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