Contemporary role of pectoralis major regional flaps in head and neck surgery

Attuale ruolo dei lembi di grande pettorale nella chirurgia della testa e del collo

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SUMMARY

Countless disadvantages of the "old" pectoralis major have been listed while the amazing versatility of the free flap armamentarium gives the opportunity to suit the defect deriving from virtually every ablative head and neck surgery with a tailored reconstruction. Nevertheless, pectoralis major is still the "workhorse" for head and neck reconstruction in developing countries thanks to its ease of harvest, and minimal requirements in term of instrumentation. Furthermore, even in facilities with a high volume of reconstructions by free flaps, a certain number of pectoralis major flaps is still raised every year. The history, present role and current indications of the most widely head and neck reconstructive procedure ever has been reviewed.

KEY WORDS: Pectoralis major • Head and neck reconstruction • Regional flaps • Myocutaneous flaps • Fasciocutaneous flaps

RIASSUNTO

Mediante i lembi liberi microlascolari è ad oggi possibile una ricostruzione "su misura" virtualmente di ogni difetto nel distretto testa e collo. I vantaggi delle innumerevoli possibilità ricostruttive offerte dai lembi liberi rispetto al "vecchio" lembo peduncolato di grande pettorale sono ben noti. Tuttavia il lembo di grande pettorale è tuttoggi il workhorse per la ricostruzione della regione testa e collo nei paesi in via di sviluppo, grazie alla relativa semplicità dal punto di vista tecnico, ed al minimo strumentario chirurgico richiesto. Inoltre, anche nelle strutture con un alto volume di procedure ricostruttive mediante lembi liberi, viene sempre indicata in una quota di casi una ricostruzione con lembo di grande pettorale. Nel presente lavoro vengono prese in esame la storia, il ruolo e le attuali indicazioni della procedura ricostruttiva più utilizzata nel testa e collo.

PAROLE CHIAVE: *Grande pettorale • Ricostruzione testa e collo • Lembi regionali • Lembi mio cutanei • Lembi fasciocutanei*

History of the pectoralis major

Evolution of the technique

Pectoralis major myocutaneous (PMMC) flap, based on the thoracoacromial artery, whose first description is commonly attributed to Ariyan in 1979 who exhaustively described the technique and its anatomical basis [1], was however reported in 1977 by at least two authors [2][3]. It has been considered for decades the workhorse for head and neck reconstruction, and is still often mentioned as a reliable and easy-to-raise flap [4]. Since then, an impressive number of modifications to the original technique have been proposed over the years, with different goals:

• to reconstruct different types of defects;
• to increase mobility of the flap itself;
• to reduce donor site morbidity.

All these modifications and technical refinements have been ultimately aimed at widening the indications for pectoralis major reconstruction.

Since 1984, a variant of the flap called pectoralis major myofascial (PMMF) flap, without the skin paddle overlying the muscle, and intended to reduce the thickness and bulkiness of the original flap, has been described and increasingly used mainly for the reconstruction of hypo/oropharyngeal defects [5-9]. Obviously, while PMMC is more suitable for reconstruction involving skin defects, the PMMF variant better complies with mucosal defects as it is covered early by a substantially normal mucosal layer [10].

Between the 1980s and the 1990s other major variants of the PM flap that incorporated a bony component, potentially very useful for combined mandibular reconstructions, have been described, including a vascularised section of the fifth rib [11][12] or a non-vascularised section of

the iliac crest [13] [14]. A third variant of the osteomyocutaneous flap that included a segment of the outer table of the sternum, sterno-costal joint and rib was reported by Jones and Sommerland who used it for the reconstruction of the zygoma, temporo-mandibular joint and hemi-mandible [15]. Maruyama et al. described the transfer of the flap through a midline section of the clavicle [3], a technique that has since been more extensively studied and refined in cadaver models by Freeman et al. who reported a lengthening of the pedicle within the range of 0.5 to 6.5 cm [16]. The section of the clavicle is the only way to guarantee greater length and a wider range of movement to the flap: in 2001, Kerawala et al. showed that the subclavicular route was both feasible and safe [17], although later other authors exposed some reservations about the effective advantages offered by this solution [18]. Shortly after the report of their first experience with the PMMC, Maruyama et al. proposed a dynamic variant in which the transfer of the flap was combined with selective neuro-anastomoses to provide dynamic muscle action [19]. Aesthetical concerns about PMMC in women led to describe "female-friendly" variants with modifications in the harvesting site (as the inframammary paddle described by Ariyan [20]) or in the shape of the skin paddle (as the crescentic skin paddle raised medially to the nipple described by Crosher [21]).

Since 1980, some authors have reported double paddle variants of the flap for reconstruction of defects involving two separate areas [22-24], which required the preservation of both the thoracoacromial artery and the lateral thoracic arteries, and allowed preservation of the nipple area complex [25] [26]. With the same aim, many authors have described combinations of the pectoralis major myofascial flap with latissimus dorsi [27], deltopectoral flap both in combination [28] or assembled in a bilobed flap version [29] [30], and with free flaps such as radial forearm flap, fibula flap and anterolateral thigh flap [31-33]. In 1981, Sharzer et al. reported a parasternal paddle that crossed the midline reaching the contralateral internal mammary perforators [34], and during the same year Dennis and Kashima described a "Janus flap" variant used to repair defects that required two skin surfaces (i.e. cervical oesophagus and pharynx) [35]. Later, in the same year, Strawberry et al. described reconstruction with a bilateral PMMC [36]. A tubed version of the flap was described by Neifeld et al. in 1983, representing a great advance in oesophageal reconstruction [37]. With an eye towards function sparing, in 1985 Morain et al. proposed a medially based segmental transfer of a single intercostal portion of the pectoralis major muscle supplied by a single perforating branch of the internal thoracic artery [38]. The same year Lawson described a PMMF flap covered with amnion to prevent partial necrosis in diabetic and elderly patients [39]. Katsantonis tried to solve the problem related to function in total glossectomy reconstruction by describing an animal model of neurotisation of PMMC by the hypoglossal nerve [40]. In 1988, in an effort to find

new ways to reduce thickness, even liposuction of the flap was proposed [41], although this technique, like many others, was most likely never actually employed.

Wei et al., in 1984, described a technique to harvest a muscle-free, longer, and much more movable pedicle by transecting the pectoralis major muscle along its horizontal fibres above the emergence of the thoracoacromial artery [42]. Further modifications of this variant have been recently described [43] [44], as it remains the most widely used trick, with less risk for the pedicle and patient, to increase the mobility of the flap and reduce undesired bulk in the neck.

It was 1993 when a pectoralis major free flap made its first appearance in the literature, and described by Gateley et al. in a case report that showed a composite variant based on the thoracoacromial artery [45]. Chaturvedi et al. have proposed both a sub-mammary approach for women and a flap harvested exclusively through the skin paddle incision [46] [47]. An endoscopic assisted technique to harvest the pedicle was proposed by Turkmen and Perks in 2005 [48]. Other innovations involved vascularisation of the flap, which was originally based only on the thoracoacromial artery. In 2006, a technique that preserved the lateral thoracic artery was published [49] and three years later Rikimaru et al. described another way to improve vascularisation and avoid possible complications related to circulation by including the third intercostal perforating branch of the internal thoracic artery [50]. The most widely used technique for closure of the donor site is undoubtedly primary closure. Nevertheless, it may be difficult or impossible to achieve when particularly wide skin pads are harvested to accomplish a proper reconstruction, and several authors have described alternative closure techniques for these cases [51-54].

Evolution of indications

In its long history, the pectoralis major flap has seen alternating indications. Since the beginning of the 1980s, until the end of the 1990s, the indications for pectoralis major flaps have progressively broadened, made possible by the unprecedented reconstructive possibilities they offered, which were further increased by the above cited technical refinements. Therefore, many head and neck surgeons worldwide have been trained in these techniques, which became the most widely used reconstructive procedure in the head and neck region to date, the so-called "workhorse of head and neck reconstruction". This reconstructive potential also contributed to enlarging the indications for ablative surgery itself, in cases in which the limitation was related to the possibility to close the defect (i.e. extensive pharyngeal or skin involvement), making many more head and neck malignancies operable.

The preponderance of pectoralis major flaps as a reconstructive option in the head and neck was progressively called into question in the beginning of the XXI century,

and pectoralis major is no longer the first option, at least in developed countries, and is often replaced by a wide choice of free flaps that can suit virtually every defect in the head and neck region. Accordingly, reconstruction is no longer an issue for ablative surgery in the head and neck. Nevertheless, many pectoralis major flaps are still harvested, and while its indications have changed and are less extensive, it still remains a very useful tool in several clinical situations.

In 1979, before the development of the techniques that would have pushed this flap to its theoretical limits, Ariyan described his experience with the reconstruction after exenteratio orbitae [55] and temporal bone resection [56]. Primary reconstruction of oropharyngeal, hypopharyngeal (including the base of the tongue), pharyngolaryngeal and oral cavity defects (including full thickness cheek defects, hemi- and total glossectomy) after highly invasive oncological surgery [3 5-9 35 57-59]; carotid artery protection after radical neck dissection or repair of an orocutaneous, tracheoesophageal and pharyngocutaneous fistula [28 60-62]; stomal recurrence after laryngectomy [63]; management of osteoradionecrosis of the mandible [64]; and salvage of necrotic wounds of the pharynx and neck [65] were among the first indications to be proposed.

The original technique, compared with late variants, allowed only limited mobility of the skin paddle. With the introduction of variants with longer pedicles [16 44 66], tubed [37], split and combined with other flaps [22 23], greater mobility and the possibility to reconstruct larger defects have been achieved, allowing broadening of the indications for reconstruction of nasopharyngeal defects, the anterior skull base [67] and the cervical oesophagus, as well as all skin defects located as far as the forehead [68] and extremely wide as midfacial reconstructions [69]. In the 1980s, variants of the flap were also proposed for treatment of facial palsy [70], septic and necrotic wounds [71] and reconstruction of mediastinal trachea [72].

During 1990s, while free flaps were strongly gaining momentum and direct comparisons between free and pedicled flaps were starting to appear in the literature [73-75], the main indications for pectoralis major flaps partially changed in favour of salvage operations. Reconstruction after free flap failure is still one of the major indications for pectoralis major flaps due to the high failure rate of second free tissue transfers [76-79]. During the last 10 years, many authors have reported on their experience with this flap, which underlined a shift in the type of subsite reconstructed, with less reconstruction of oral cavity defects over the years, and more hypopharyngeal and oropharyngeal reconstructions [80-82]. While the superiority of free flaps over pedicled flaps for tongue and mandibular reconstructions due to functional and esthetical advantages was clearly demonstrated [83-87], due to a higher total failure rate of free flaps other authors tended to still consider the pectoralis major an option when a bone reconstruction is

not needed [88], especially in patients with poor overall conditions or in case of unsuccessful microsurgical flaps [89]. Other applications that are still valid include management of carotid artery exposure [90], cervical skin defects, dead space filler, infections [78], vessel depleted necks [91], mandible reconstruction when a free flap is not advisable, by rolling the PMMF on a metal plate [88 92 93], pharyngocutaneous fistula [94], closure after total laryngectomies to prevent fistula [95] and reconstruction of full thickness defects of the cheek [96].

The above described evolutions in the indications for pedicled pectoralis reconstruction refers mainly to developed countries, and to settings where patients have access to free flap reconstruction, even though it is noted that the majority of the world population is not in the same condition. In developing densely populated countries, such as India, pectoralis major flaps remain the workhorse for head and neck reconstruction with all of their original indications [97].

Currently adopted techniques

Among the main considerations for currently recommending a pectoralis major reconstruction in a free flap facility in developed countries are shorter operating time, ease of harvest and favourable early and late morbidity profile. For these reasons, the above described complex variants, with multiple paddles, with bone, with a higher rate of failure and/or of donor site complications, or simply with longer operative time, are only seldom raised.

In general, we believe that two main variants: PMMF and PMMC, are by far the most employed techniques. Even if every surgeon has his own way and little tricks for raising a pectoralis major flap, at present most surgeons, to increase the flap mobility while reducing at the same time the bulk in the neck and over the clavicle, prefer the "island" technique described by Wei [42], with successive modifications [43 44], rather than more complex and invasive steps such as cutting the clavicle or passing the flap below the clavicle itself [98] since this increases operative time, morbidity, complications and even causes vascular/pedicle issues for the flap itself. In the same way and for similar reasons, most surgeons in the current literature transfer the flap to the head and neck region through a supraclavicular subplatysmal tunnel, without any incision of the skin overlying the clavicle (which would compromise the vascular supply of a deltopectoral flap (or of its propeller variant internal mammary perforator flap). The only technical differences between the two variants are that the PMMF is harvested without skin, with consequent changes in skin incision and aesthetic outcomes of the donor site, and in operative time (which is even shorter).

Relative advantages and indications
The two variants, even if very similar in terms of the har-

vesting technique, show many relevant differences for reconstructive potential, postoperative rearrangements and results with clear relative advantages and disadvantages that have an impact on their indications. The PMMC flap was described first and is probably still the most employed variant worldwide. Its advantages lay mostly in the short operative time, ease of harvest, potentially large amount of well-vascularised tissue, relatively low morbidity on the donor site and, most of all, great versatility, as it can close virtually every defect in the head and neck region. The disadvantages and limits should be assessed in comparison with the other reconstructive options available, mainly free flaps, but also the PMMF variant.

Comparison with free flaps, which offer on the whole a huge spectrum of reconstructive options, and are in most situations the gold standard for long-term functional and aesthetic results, which is probably the key issue when evaluating the present role of pectoralis major flaps and will be discussed in detail below.

The skin of the PMMC is not 100% reliable, especially if it is not over the muscle and/or if the skin island is too small. In fact, the vascular supply to the skin comes from musculocutaneous perforators from the pectoralis branches of the thoracoacromial artery, and partial skin losses are relatively frequent (from 5 to 30%) in all series as the perforating vessels are usually not looked for. At any rate, in general, when a skin defect is created, the PMMC variant is always preferable (Figs. 1, 2). The PMMC can be used for mucosal resurfacing with good results as well (Fig. 3).

PMMF, in comparison with PMMC, is characterised by an even faster harvest, a wider and more pliable myofascial surface (potentially the entire surface of the pectoralis major muscle) for the closure of the defect. It is thinner, is not covered by hair and is usually resurfaced by the mucosa which normally covers the resected area, whose borders with native mucosa are not usually recognisable in few weeks after insetting (Fig. 4). The shape of the area closed by muscle fascia can be arbitrarily chosen in this case by the surgeon by applying a stitch along the desired suture line.

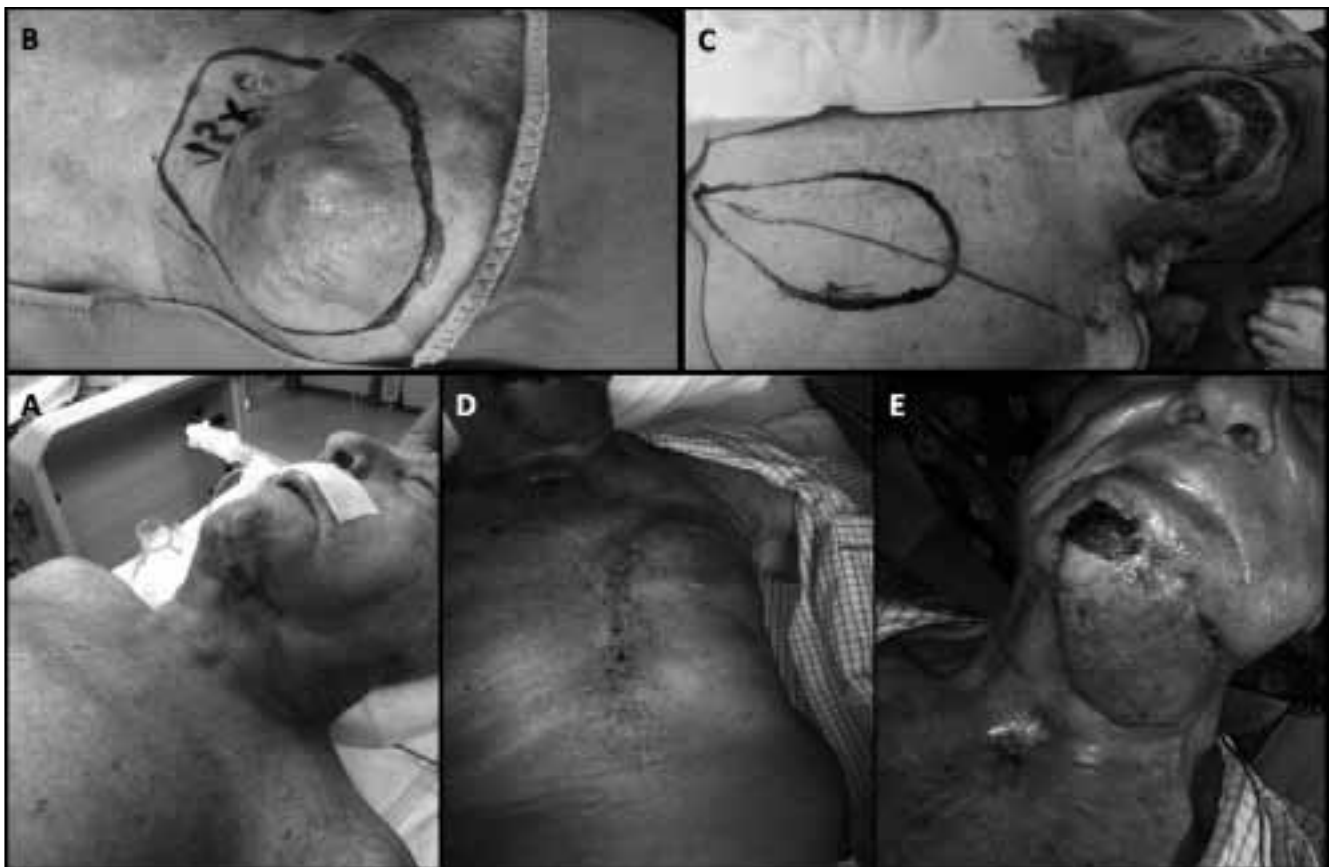The reduced thickness and the coverage with normal, not

Fig. 1. A second neck submandibular recurrence with skin invasion (A, B) of a cutaneous SCC in a 92-year-old patient, was treated with a revision of the neck dissection and a wide skin excision (C). The large defect (B, C) was closed with a PMMC flap with a large (15 cm major axis) skin paddle (C, E), partially lying beyond the inferior limit of the pectoralis major muscle (C). For this reason a small distal part of the skin paddle (C), not vascularised enough by muscolocutaneous perforators, has undergone partial necrosis (E). Despite the large dimensions of the skin paddle, a primary closure of the donor site was successfully performed without any complication (D).
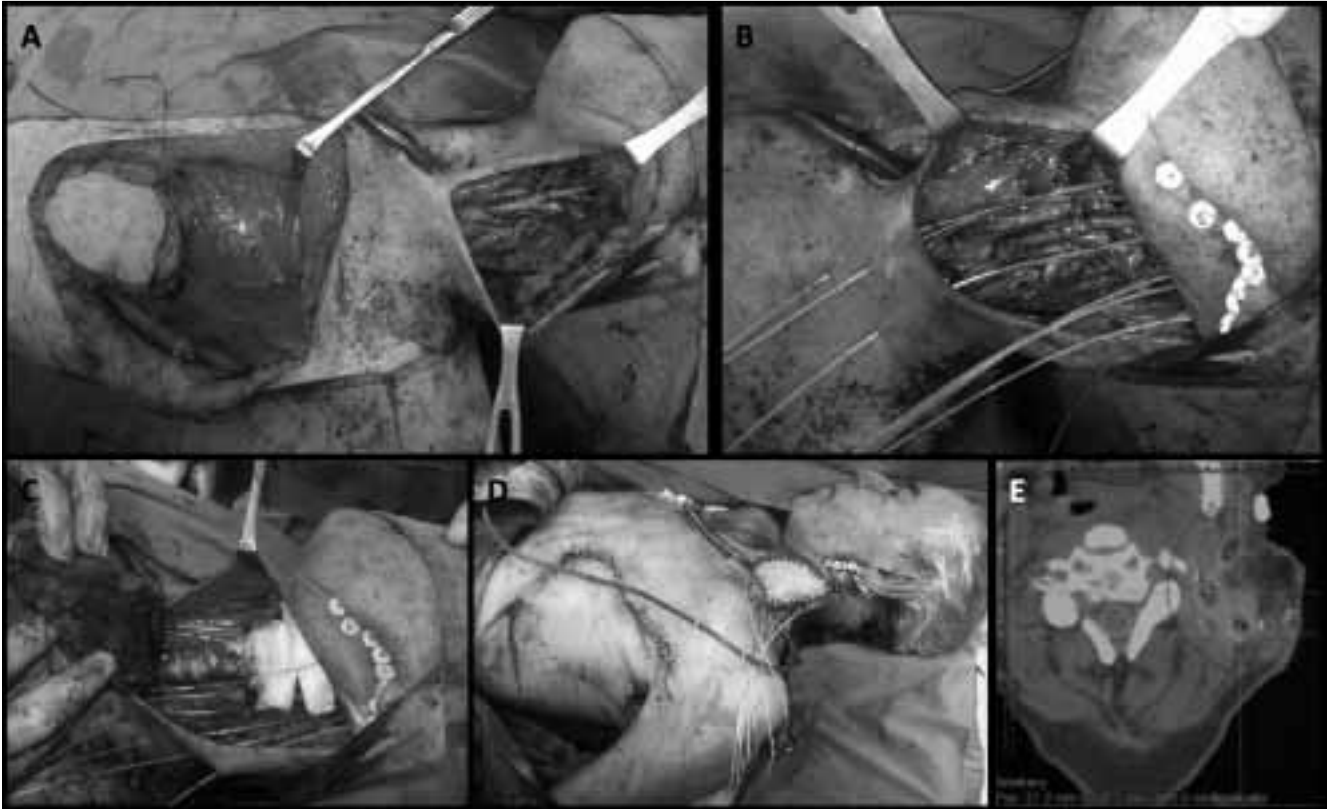
Fig. 2. A neck recurrence in a patient previously treated with salvage total laryngectomy and neck dissection for a persistent laryngeal cancer after radiochemotherapy, and salvaged again by radical neck dissection (A, B). A pectoralis major myocutaneous flap was raised (A, C, D) to fill the dead space, protect the carotid axis and allow a safe re-irradiation by HDR brachytherapy through the plastic tubes placed during the operation (B, C, D). With this precaution, most of the adjuvant dose is given to the previously non-irradiated pectoralis muscle as shown in the axial image of the treatment plan (E).
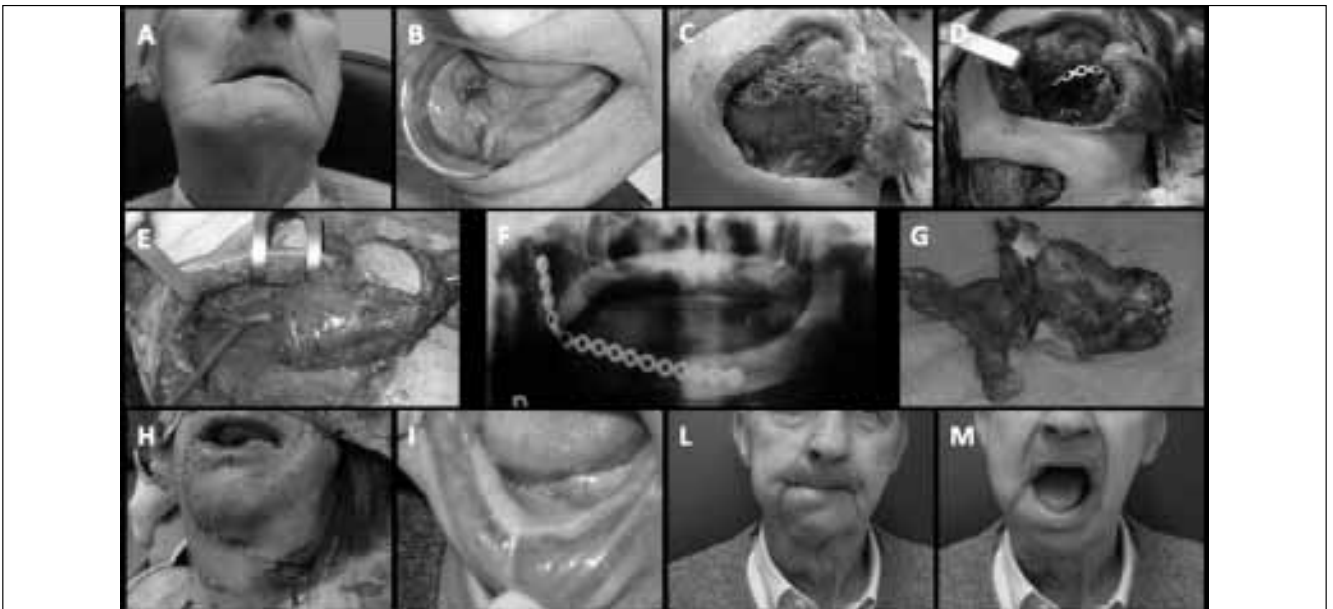

Fig. 3. (A,B) 75 ys old patient with gum scc invading bone and skin. (C)Wide demolition including skin and mandible was performed. The patient was not suitable for microsurgical recostruction. (D) A titanium plate was inserted in order to reconstruct the mandibular profile. (E,F)Pedicled pectoralis flap was harvested and wrapped on the plate. (H, I, L, M)The coutaneous portion of the flap was used to reconstruct the gum and the skin defect was reconstructed with rotation local flap.
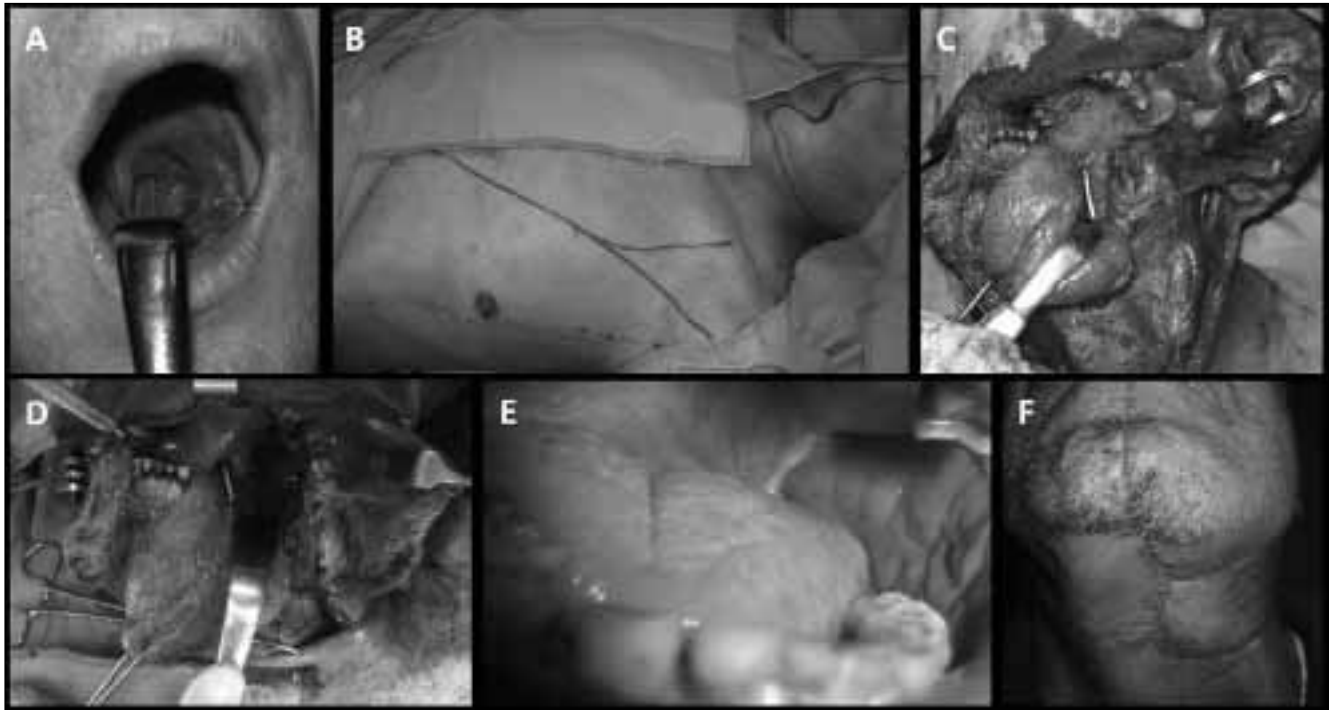
Fig. 4. The local recurrence after radiochemotherapy of a SCC of the left posterior faucial pillar (A,C) was salvaged by a partial pharyngectomy through a transmandibular approach (C, D). The defect was restored through a PMMF flap (B, D), with complete re-epithelialisation and acceptable aesthetic results (E, F). The patient was able to feed with a normal diet at 3 weeks after the salvage surgery and did not report dysphagia.

hairy, mucosa are undoubtedly a relevant argument supporting the use of PMMF in reconstructions of the oro- and hypopharynx (Figs. 4, 5), as the bulk and the hair of the PMMC variant (and also most free flaps) can cause a functional impairment and complaints from patients. On the other hand, one of the main issues considering the functional results of pectoralis major reconstructions, also deriving in pedicled flaps from muscle denervation, is muscle fibrosis and consequent retraction. This is much more evident in the PMMF variant in which it involves the surface of the defect: in pharyngeal defects involving a wide angle of the circumference in the axial plane, it is associated with a high rate of long-term dysphagia, stricture and dependence on PEG [99] [100] even in our personal experience (Fig. 5).

On the other hand, the wide pliable myofascial surface can be very useful to be rolled around a reconstruction plate in case of a segmental mandibular defect (Fig. 3). Even in these cases, if no skin area is resected, PMMF may be an alternative to PMMC [93] [97] [101] [102]. Considering that most free bony tissue transfers, characterised by relevant donor site morbidity, surgical complexity and duration and complications, are not followed by restoration of dentition through osteointegrated implants, they remain a undeniably valuable option for reconstruction of mandibular defects, especially if lateral, with less aesthetic and functional issues [102].

Salvage total laryngectomies after irradiation are characterised by a high rate of fistulas [103]; in these cases, pectoralis major flaps may work as dead space fillers, bring well-vascularised tissue in the irradiated field, reinforce the pharyngeal suture and have been demonstrated to markedly reduce the risk of this complication. For this reason, in post- radiation laryngectomies several authors propose to electively reinforce the suture line and the pharyngeal wall with a pectoralis major [95] [104] [105]. If a skin island is not needed for a skin defect, better results have been shown with a thin, well vascularised PMMF [95]. For the same reason, many authors use the pectoralis major to protect the carotid axis after a salvage radical neck dissection following radiotherapy failure [8] [78] [106]. At the same time, the well vascularised muscular tissue fills the dead space, and the vascular supply reduces post-irradiation neck fibrosis. If a PMMC is raised, its well vascularised skin reduces the tension and retraction of the suture line and later of the scar (Fig. 2). The inset of the PMMC flap in vessel depleted necks after salvage neck dissection has allowed us in some cases to place plastic tubes to administer further adjuvant perioperative brachytherapy (Fig. 2).

The protective and trophic effect of pectoralis muscle on neck vessels and tissues is an advantage in all cases after radiotherapy and neck dissection, even if the reconstructed defect is in the pharynx, oral cavity, or
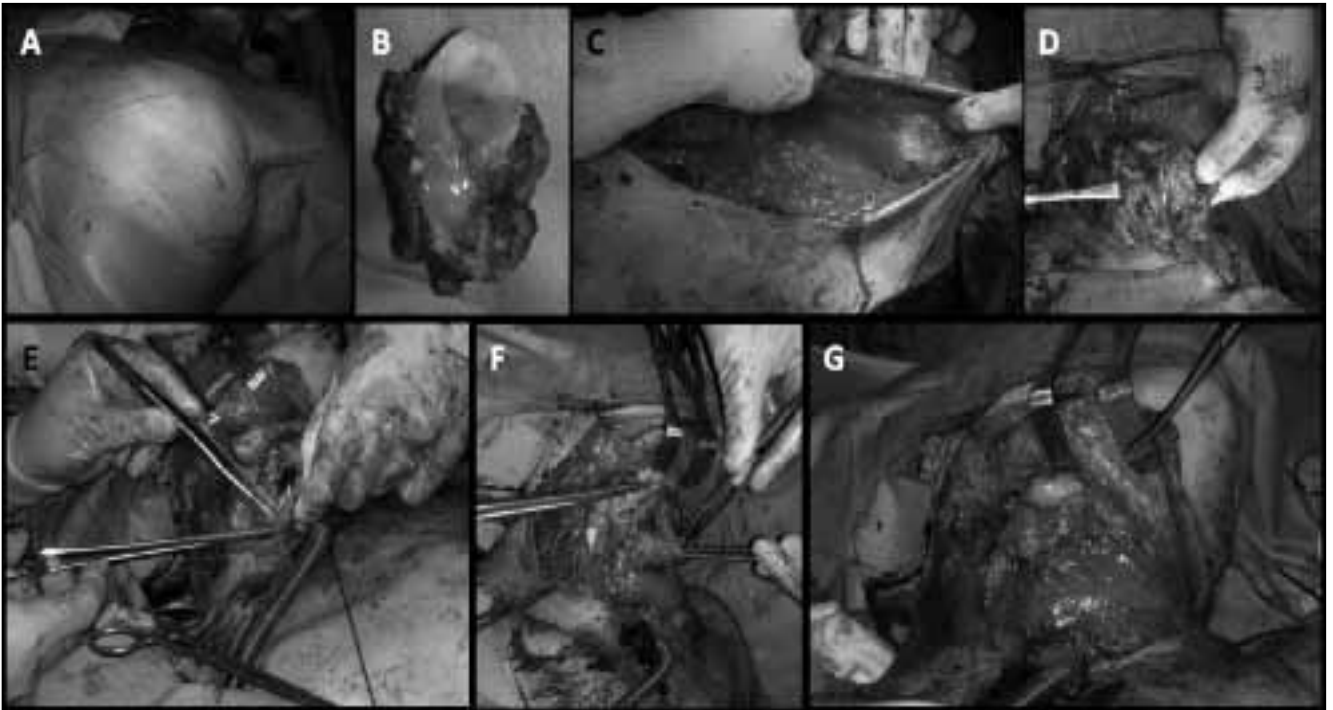
Fig. 5. Local recurrence after radiochemotherapy of a hypopharyngeal postcricoid SCC was salvaged by total laryngectomy and subtotal pharyngectomy (B). The pharyngeal tube was restored suturing the superficial fascia of a PMMF flap (A, C) to the residual posterior hypopharyngeal mucosa (D, E, F, G). The portion of the hypopharyngeal circumference restored with the procedure was more than 50% (D) and the patient, after the recovery of a normal swallowing without complications, showed progressive dysphagia after 4 months. A recurrent hypopharyngeal stricture was diagnosed, and after two endoscopic dilatations a gastrostomy tube was placed endoscopically (PEG).

other head and neck sites: in fact, the humeral end of the raised muscle always tends to remain in the neck (Figs. 1-5). Many free flap surgeons use both the variants of the pectoralis flap in combination with free tissue transfer, based upon these considerations and with similar indications, also for coverage and protection of microanastomosis [83] [115].

Complications and morbidity

PMMC and PMMF are both related to some complications that have partially changed both in type and frequency, thanks to evolution of the technique. The very first report of complications in 42 cases of reconstruction with PMMC [57] did not show any major necrosis, while minor necrosis was present in three cases (7%). appeared later report documented a wider range of complications including those involving the donor site, such as chest wall haematoma and infections, the reconstructed areas, including fistula and neck abscess, or the flap itself with partial and total necrosis [108].

Later, in 1983, two interesting and larger reports provided deeper insight into the actual complication rates. Mehrhof et al. [109], describing their experience on 67 patients treated with 73 PMMC, reported a complication rate of 54%. Major complications were total flap necrosis (4%) and partial flap necrosis (12%). The vast

majority were minor complications that did not require second procedures for correction: orocutaneous fistulas (16.5%), suture line dehiscence (12%), neck wound complications (11%), donor site complication (1.3%) and sequelae related to mandibular replacement (not a complication of the flap itself but related to a metal device used by the authors to restore mandibular continuity in 10 patients included in this series) (11%). In the same year, Ossoff et al. [110], while reporting an overall complication rate similar to those previously reported, warned other authors about the insidious possibility of a delayed detection of recurrence hidden by the flap itself, which occurred three times in their experience (86 patients, 95 PMMC). In 1984, Donegan et al. reported another rare complication, namely osteomyelitis of the rib in the donor area of the PMMF [111]. Even if unusual, this complication gave rise to a number of publications discussing its treatment, with the use of a vertical rectus abdominis myocutaneous flap proposed by Nagarjuna et al. being the latest [112]. Other reported complications include exposure of the plate covered by the flap in reconstructions of the mandible [91] and cervical contracture leading to severe functional impairment [113]. Cervical contracture has been specifically addressed by some authors by secondary myectomy and subclavicular route [17] [114], but a certain amount of contracture is unavoidable, deriving from the

fibrotic retraction of the denervated muscle, even in the "island" technique.

In 1990, an interesting report on 168 cases of PMMC and PMMF performed at MD Anderson Cancer Center in Texas by Kroll et al. was published [115] in which the rate of overall complications was 63%, but with a flap loss rate of only 2.4%, with a relatively higher complication rate in smokers and patients with larger tumours. Later, in the same year, Shah reported his experience [116] which consisted of 211 patients treated with PMMC. Similar to that seen at MD Anderson, he reported an overall complication rate of 63%. On the other hand, despite the apparently high complication rate, he reported only 2 cases in which a second flap was required (1%), and 33 cases in which reoperation was required to resolve complications. Such a low rate of major complications was substantially confirmed in the 1990s by other authors [117]. A correlation between complications and some variables was also shown, namely: age over 70 years, female sex, overweight, albumin less than 4 g/dl, oral cavity reconstruction after total glossectomy and systemic disease. Some of these correlations had been previously reported by Kroll et al. and later by other authors with the adjunct of prior chemotherapy and secondary reconstructions [117-119]. The higher rate of flap necrosis seen in women by those authors was attributed to the interposition of breast tissue between muscle and the skin paddle. In fact, the authors noted that only PMMC were involved by this phenomena, while in their series PMMF had the same complication rates between men and women [115]. Both Shah and later Keidan et al. outlined the absence of a significant correlation between prior radiation therapy and complication rates [120].

Starting from 2000, reports in literature from both wealthy and poor-developing countries, substantially confirm a slight drop in complications, with very few to no total flap losses recorded and an overall complication rate around 20–50% as seen in many papers published during this period [7 91 113 119 121 122]. At present such complications rates are probably even lower, at least in developed countries. A rare complication of PMMC with very few reports in literature published in the last 15 years is metastasis at the flap donor site, for which some possible mechanisms have been proposed based on anatomical and physiological considerations [123].

Comparison with free flaps

Since the development of reconstructive techniques involving free flaps [124], we participated in a lively debate on the advantages and disadvantages of both pedicled and free flap techniques applied to head and neck sites. In an attempt to summarise the data from the literature, it should be kept in mind that pectoralis major is often confronted to different types of free flaps and in different types of reconstructions, thus making it impossible to make any general statements. Each type of reconstruction would ideally require a separate discussion to come to definitive conclusions. During the last 30 years, the three main topics of discussion have been functional results, morbidity and costs of the two techniques. In all these areas, when comparing free flap with pectoralis major patients, several biases can be seen, the most important being in our opinion that in the free flap era many patients were recommended pedicled flaps when they are in poor general conditions, with the preference for an option with short operative time, technical ease and low morbidity. As a result, radically different groups, at least in terms of comorbidities, are often compared. For this reasons, we believe that comorbidity, or at least age, should be considered and matched in every attempt at comparison.

Functional results

Each subsite would ideally deserve a separate discussion, even if not all the papers in the literature analytically evaluate the functional differences according site and size of the defect. Paradoxically, despite the amount of publications evaluating reconstructive techniques in the head and neck, there is still a lack of evidence-based data about the functional differences between free and pedicled flaps, and no definitive conclusions can be made at present. Actually, the concept of function in head and neck cancer patients is controversial and consensus about the objective evaluation of functional results is lacking. The most used tools are questionnaires, which are not specific and sensitive in evaluating the functional aspects addressed by the different reconstructive techniques. Nonetheless, a few investigations give some clues with which to initiate definite functional comparison site by site.

An impressive series was presented by Hsing et al. in 2011 [125]. They reported their experience with 491 patients treated for oral cavity cancer, 100 of which completed a quality of life questionnaire. They found no significant difference in overall quality of life between patients treated with PMMC versus free flaps, nor did they find differences in the domains regarding pain, appearance, activity, recreation, swallowing, chewing, taste, saliva, or anxiety. Nevertheless, they reported significant differences between the free flap and PMMC flap groups in speech, shoulder mobility and mood domains with better outcomes for the free flap group.

Xiao et al., also focusing specifically on oral cavity cancer and analysing two groups, one characterised by reconstruction performed with an anterolateral tight (ALT) flap and the other by PMMC, found no significant differences between groups for pain, activity, recreation, swallowing, chewing, speech, taste, saliva, or mood and anxiety domains. However, significant differences were seen between the PMMC and ALT groups for the shoulder and

appearance domains, and a higher emotional impact left by the scar and the aesthetic appearance left by PMMC [126]. A similar study with similar results was presented in 2014 by Zhang et al., with the only difference being slightly worse speech outcome for patients treated by ALT [127].

O'Neill et al., in 2010, published an interesting comparison between radial forearm free flaps and PMMC in reconstruction of oral and oropharyngeal defects [128]. In their report, they outlined that while no differences in deformity, diet, or socialisation were found, only 22.2% of patients reconstructed with PMMC were satisfied with their speech compared with 53.1% of patients reconstructed with RFFF. Deganello et al. noted a difference in diet with all PMMC in their series able to feed only by soft or liquid diet postoperatively [99,129].

As free flaps show a predisposition to better performance in functional outcomes [86], many authors have tried to close the gap by developing variants of the PMMC/PMMF meant to improve functional results, such as the dynamic variant [19] and attempts of neurotisation of the flap with the hypoglossal nerve [40]. These complex techniques, however, are associated with loss of the renowned advantages of pectoralis flaps in terms of ease and speed.

Morbidity

Pectoralis major has a rate of complications that is not to be underestimated, and the rate of overall complications raised some concerns in the past. An interesting comparison of complications rate between the free tissue transfer option and the PMMC were made by Mallet et al. in 2009 [130] who analysed the results of 70 consecutive patients treated alternatively with both techniques (25 FTT and 45 PMMC). They outlined a similar rate of postoperative complications and the same duration of use of tracheostomy tube and feeding tube. Similar results, prone to a substantially similar morbidity of free flaps and PMMF/PMMC, have been reported by other groups [125,131], some of which also highlighted a similar failure rate [78]. O'Neill, reporting on a series of 114 patients treated alternatively with PMMC or radial forearm free flap (RFFF) reported that the only significant differences in complications were suture dehiscence, which were more frequent in PMMC, and atelectasis, which was more frequent in RFFF; major flap complications, leading to another surgery, were more frequent in the RFFF group [128].

In a similar study, de Bree et al. reported a higher rate of medical complications, flap failures and admissions to intensive care units in the radial forearm group, but more overall surgical complications (partial flap necrosis, dehiscence, wound abscesses and fistula) with PMMC [132], as seen in other studies [73,133], thus leading to a longer postoperative hospitalisation for treatment of complications.

Costs

In the last years, in light of spending reviews and rationalisations of resources, especially in Italy, the costs of reconstructive procedures must be taken into account. The main factors contributing to the increase in costs, in our experience, are the time spent in the hospital postoperatively (heavily influenced by the complication rate), time spent in the operating room and number of surgeons required. PMMC is often recognised as a faster technique considering operating time [125,126,129-132,134-136], and most reports outline that free flap surgery requires more surgeons at the same time [129,130,137]. In many departments, FFT in the head and neck are performed by two teams at the same time, thus reducing the operative time, but not the overall costs. Data regarding discharge time after surgery seems to be uniform in the literature with most authors outlining a similar if not shorter time needed after a procedure involving free flaps [128-132]. Nevertheless, when it comes to costs estimated in single experiences, data are rather conflicting. Some authors reported higher costs with free flaps [91,129,134,136,138], while others have documented that overall costs for PMMC are either higher [115,132] or not significantly different [131,139]. In particular, Funk et al. hypothesised that although surgical costs were higher for free flaps, postoperative hospitalisation due to treatment of complications, which is higher in PMMC, balanced the costs and abolished any economic advantages [139].

While a generally acceptable, definitive statement about respective costs is probably not possible at present, according to the literature we can at least definitely accept that, even with highly significant differences between various reports, the time spent in the operating room for reconstruction with a pedicled flap is undeniably shorter. Importantly, as outlined by de Bree et al. [132], most studies on costs have selection biases, and do not consider differences in age and comorbidity, thus probably complicating any possible evaluation on discharge time and complication rates.

Notably, in settings where resource constraints are a matter of fact, along with the lack of available technologies and expertise, such as in developing countries, extensive use of pectoralis major at the expense of free flaps remains a reality [91,97,138].

Our experience

Our 20-year clinical experience in pectoralis major reconstructions at the main big facilities in Italy performing a high volume of free flap procedures is shown in Table I. Virtually every defect in the head and neck region has been addressed, with a very low rate of complications (less than 5% of patients experienced any kind of procedure-related sequelae). Such complication rate is lower than what reported in most paper in the literature, nevertheless in our opinion it reflects the state of the art as for pectoralis major reconstruction and appears the main general argument supporting the use of pectoralis major regional flaps in most cases. The 274 cases (Table I) have

Table I. Descriptive statistics of the main variables concerning patients, primary sites and defects.

Characteristic	N = 274
Age at diagnosis	
Median	70
Range	29-92
Sex [N (%)]	
Male	199 (72.6%)
Female	75 (27.4%)
Variant (PMMC vs. PMMF) [N (%)]	
PMMC	237 (86.5%)
PMMF	37 (13.5%)
Primary site [N (%)]	
Larynx and Hypopharynx	21 (7.7%)
Mandible	19 (7%)
Oropharynx	85 (31%)
Skin	5 (1.8%)
Occult primary	1 (0.3%)
Oral cavity	143 (52.2%)
Retromolar	56 (20.4%)
Tongue	87 (31.8%)
Hystotype	**N (%)**
SCC	255 (93%)
Salivary histotypes	17 (6.2%)
Malignant ameloblastoma	1 (0.4%)
Osteosarcoma	1 (0.4%)
Type of defect	
Mucosa	141 (51.5%)
Mucosa+bone	112 (40.9%)
Mucosa+skin	11 (4%)
Skin	10 (3.6%)
Previous treatments for HNSCC	
None	209 (76.3%)
Radio+chemotherapy	48 (17.5%)
Surgery	3 (1.1%)
Surgery+ radio+chemotherapy	14 (5.1%)
Adjuvant /perioperative treatments	
None	154 (56.2%)
Radiotherapy	102 (37.2%)
Brachytherapy	4 (1.5%)
Radio+chemotherapy	14 (5.1%)
Timing	
Immediate	265 (96.7%)
Delayed	9 (3.3%)
(management of radiotherapy sequelae)	
Early and late complications of the procedure	
Partial skin necrosis	8 (2.9%)
Total necrosis	2 (0.7%)
Donor site dehiscence	2 (0.7%)
Late hypopharyngeal stricture/ gastrostomy	1 (0.4%)
Death	1 (0.4%)
None	261 (95.3%)

been operated along 20 years, in this long period several changes in the use and indications for pectoralis major reconstructions have been occurred, mostly reflecting the above cited literature evidences. In fact the number of pectoralis major flaps raised per year has on the whole decreased, and in particular it is now only seldom used for tongue and skin defect. The median age of the patient has increased together with their comorbidities. Interestingly, in recent years pectoralis major inset has been also useful for allow safe further irradiation by brachytherapy in a few cases, by protecting neck vessels and bringing non-previously irradiated tissue (Fig. 2).

Conclusions

We are definitely in the era of free flap surgery. In developed countries, in excellence centres, and in patients with good general conditions, the amazing versatility of the free flap armamentarium gives the opportunity to suit the defect deriving from virtually every ablative head and neck surgery with a tailored reconstruction. Such possibilities, even in the absence of definitive evidence-based data on better functional outcomes compared with pectoralis major flaps, make free tissue transfer the standard for head and neck reconstruction. Countless disadvantages of the "old" pectoralis major have been listed, such as flap thickness, functional and cosmetic defects, excessive bulk in obese or muscular patients, poor reliability of the skin in PMMC, difficulty in obtaining reliable bone tissue and long-term fibrotic muscle retraction.

Nevertheless, even in facilities with a high volume of reconstructions by free flaps, a certain number of pectoralis major flaps is still raised every year in the head and neck. The easier indication is reconstruction after a free flap failure due to the high failure rate of second free tissue transfers [76][77]. Other indications, which are much more common, are probably controversial, and therefore more interesting to discuss. They can be driven by the setting in which patients are cured, by clinical status and comorbidities of patients and perhaps, in very selected cases, by the type of the defect.

The healthcare system and the facilities in which patients are cured are also key considerations in determining epidemiology and death rates for cancer worldwide. Raising a pectoralis major just requires a knife, forceps and retractors as surgical instrumentation, few hours of operative time, shorter training time and less surgical skills. Mainly for these reasons in developing countries such as India the pectoralis major remains the workhorse for head and neck reconstruction [97]. Nevertheless, in forthcoming years, the public discussion about health system resources and spending reviews may bring these arguments to many Western countries in recession. As previously outlined, another reason why pectoralis major can still be indicated is related to patient conditions, which may require ease of

harvest and shorter operative times (and therefore, especially in the elderly, a lower perioperative complication rate).

Finally, there are some situations in which pectoralis major still appears as a valuable option even in facilities performing free flaps and for patients in good general conditions [78]. One such situation is prevention of pharyngocutaneous fistula in case of salvage total laryngectomies after irradiation. In these cases, several authors have proposed to electively reinforce the suture line and pharyngeal wall with a PMMF [95 104 105]. In the same way, PMMF/PMMC can be used to protect the carotid axis after salvage radical neck dissection following radiotherapy failure [8 78 106], and in these cases a further adjuvant perioperative brachytherapy can be safely administered (Fig. 2). Lastly, recent reports stress [7 80 99 100 140] the utility of pectoralis major flaps for reconstruction of pharyngeal defects. In case of circumferential defects, long-term stricture due to muscle fibrotic retraction is probably frequent (Fig. 5), but in lateral defects (less than 50% of pharyngeal circumference) the reduced thickness and coverage with normal, not hairy, mucosa are relevant advantages supporting the use of PMMF (Fig. 4). In case of a segmental lateral mandibular defect, if restoration of dentition is not planned, a PMMC or PMMF rolled around a reconstruction plate may be a valid option characterised by low morbidity [93 97 101 102].

References

[1]   Ariyan S. *The pectoralis major myocutaneous flap. A versatile flap for reconstruction in the head and neck.* Plast Reconstr Surg 1979;63:73-81.

[2]   Brown RG, Fleming WH, Jurkiewicz MJ. *An island flap of the pectoralis major muscle.* Br J Plast Surg 1977;30:161-5.

[3]   Maruyama Y, Fujino T, Aoyagi F, et al. *One stage reconstruction of oral cavity by use of pectoralis major myocutaneous island flap.* Keio J Med 1978;27:47-52.

[4]   El-Marakby HH. *The reliability of pectoralis major myocutaneous flap in head and neck reconstruction.* J Egypt Natl Canc Inst 2006;18:41-50.

[5]   Robertson MS, Robinson JM. *Pharyngoesophageal reconstruction. Is a skin-lined pharynx necessary?* Arch Otolaryngol 1985;111:375-376.

[6]   Phillips JG, Postlethwaite K, Peckitt N. *The pectoralis major muscle flap without skin in intra-oral reconstruction.* Br J Oral Maxillofac Surg 1988;26:479-85.

[7]   Montemari G, Rocco A, Galla S, et al. *Hypopharynx reconstruction with pectoralis major myofascial flap: our experience in 45 cases.* Acta Otorhinolaryngol Ital 2012;32:93-7.

[8]   Shindo ML, Costantino PD, Friedman CD, et al. *The pectoralis major myofascial flap for intraoral and pharyngeal reconstruction.* Arch Otolaryngol Head Neck Surg 1992;118:707-11.

[9]   Righi PD, Weisberger EC, Slakes SR, et al. *The pectoralis major myofascial flap: clinical applications in head and neck reconstruction.* Am J Otolaryngol 1998;19:96-101.

[10]   Johnson MA, Langdon JD. *Is skin necessary for intraoral reconstruction with myocutaneous flaps?* Br J Oral Maxillofac Surg 1990;28:299-301.

[11]   Cuono CB, Ariyan S. *Immediate reconstruction of a composite mandibular defect with a regional osteomusculocutaneous flap.* Plast Reconstr Surg 1980;65:477-84.

[12]   Green MF, Gibson JR, Bryson JR, et al. *A one-stage correction of mandibular defects using a split sternum pectoralis major osteo-musculocutaneous transfer.* Br J Plast Surg 1981;34:11-6.

[13]   Bell MS, Barron PT. *The rib-pectoralis major osteomyocutaneous flap.* Ann Plast Surg 1981;6:347-353.

[14]   Phillips JG, Falconer DT, Postlethwaite K, et al. *Pectoralis major muscle flap with bone graft in intra-oral reconstruction.* Br J Oral Maxillofac Surg 1990;28:160-3.

[15]   Jones NF, Sommerlad BC. *Reconstruction of the zygoma, temporo-mandibular joint and mandible using a compound pectoralis major osteo-muscular flap.* Br J Plast Surg 1983;36:491-7.

[16]   Freeman MS, Thomas JR, Zipper JA. *Clavicular division technique. A new approach for lengthening the pectoralis flap.* Arch Otolaryngol Head Neck Surg 1989;115:224-7.

[17]   Kerawala CJ, Sun J, Zhang ZY, et al. *The pectoralis major myocutaneous flap: Is the subclavicular route safe?* Head Neck 2001;23:879-84.

[18]   Vanni CM, Pinto FR, de Matos LL, et al. *The subclavicular versus the supraclavicular route for pectoralis major myocutaneous flap: a cadaveric anatomic study.* Eur Arch Otorhinolaryngol 2010;267:1141-6.

[19]   Maruyama Y, Nakajima H, Fujino T. *A dynamic reconstruction of a facial defect with a pectoralis major myocutaneous flap.* Br J Plast Surg 1980;33:145-9.

[20]   Ariyan S. *The donor site of the pectoralis major myocutaneous flap.* Plast Reconstr Surg 1980;66:165-6.

[21]   Crosher R, Llewelyn J, Mitchell R. *A modification of the pectoralis major myocutaneous flap that reduces the defect at the donor site.* Ann R Coll Surg Engl 1995;77:389-91.

[22]   Morain WD, Geurkink NA. *Split pectoralis major myocutaneous flap.* Ann Plast Surg 1980;5:358-61.

[23]   Freeman JL, Gullane PJ, Rotstein LM. *The double paddle pectoralis major myocutaneous flap.* J Otolaryngol 1985;14:237-40.

[24]   Ord RA, Avery BS. *Side-by-side double paddle pectoralis major flap for cheek defects.* Br J Oral Maxillofac Surg 1989;27:177-85.

[25]   Freeman JL, Walker EP, Wilson JS, et al. *The vascular anatomy of the pectoralis major myocutaneous flap.* Br J Plast Surg 1981;34:3-10.

[26]   Espinosa MH, Phillip JA, Khatri VP, et al. *Double skin island pectoralis major myocutaneous flap with nipple-areola complex preservation: a case report.* Head Neck 1992;14:488-91.

[27]   Maruyama Y, Nakajima H, Fujino T. *One-stage reconstruction of a esophagostome with a latissimus dorsi myocutaneous flap and a pectoralis major myocutaneous flap (case report).* Acta Chir Plast 1980;22:80-5.

[28]   Maisel RH, Liston SL. *Combined pectoralis major myocutaneous flap with medially based deltopectoral flap for closure of large pharyngocutaneous fistulas.* Ann Otol Rhinol Laryngol 1982;91:98-100.

29 Meyer R, Kelly TP, Abul Failat AS. *Single bilobed flap for use in head and neck reconstruction*. Ann Plast Surg 1981;6:203-6.

30 Weaver AW, Vandenberg HJ, Atkinson DP, et al. *Modified bilobular ("gemini") pectoralis major myocutaneous flap*. Am J Surg 1982;144:482-8.

31 Harii K, Iwaya T, Kawaguchi N. *Combination myocutaneous flap and microvascular free flap*. Plast Reconstr Surg 1981;68:700-11.

32 Chen HC, Demirkan F, Wei FC, et al. *Free fibula osteoseptocutaneous-pedicled pectoralis major myocutaneous flap combination in reconstruction of extensive composite mandibular defects*. Plast Reconstr Surg 1999;103:839-45.

33 Choi JO, Choi G, Chae SW, et al. *Combined use of pectoralis major myocutaneous and free radial forearm flaps for reconstruction of through-and-through defects from excision of head and neck cancers*. J Otolaryngol 1999;28:332-6.

34 Sharzer LA, Kalisman M, Silver CE, et al. *The parasternal paddle: a modification of the pectoralis major myocutaneous flap*. Plast Reconstr Surg 1981;67:753-62

35 Dennis D, Kashima H. *Introduction of the Janus flap. A modified pectoralis major myocutaneous flap for cervical esophageal and pharyngeal reconstruction*. Arch Otolaryngol 1981;107:431-5.

36 Strawberry CW, de Fries HO, Deeb ZE. *Reconstruction of the hypopharynx and cervical esophagus with bilateral pectoralis major myocutaneous flaps*. Head Neck Surg 1981;4:161-4.

37 Neifeld JP, Merritt WA, Theogaraj SD, et al. *Tubed pectoralis major musculocutaneous flaps for cervical esophageal replacement*. Ann Plast Surg 1983;11:24-30.

38 Morain WD, Colen LB, Hutchings JC. *The segmental pectoralis major muscle flap: a function-preserving procedure*. Plast Reconstr Surg 1985;75:825-30.

39 Lawson VG. *Pectoralis major muscle flap with amnion in oral cavity reconstruction*. Aust N Z J Surg 1986;56:163-6.

40 Katsantonis GP. N*eurotization of pectoralis major myocutaneous flap by the hypoglossal nerve in tongue reconstruction: clinical and experimental observations*. Laryngoscope 1988;98:1313-23.

41 Cueva R, Thomas JR, Davidson TM. *Liposuction to debulk the pectoralis major myocutaneous flap*. Am J Otolaryngol 1988;9:106-10.

42 Wei WI, Lam KH, Wong J. *The true pectoralis major myocutaneous island flap: an anatomical study*. Br J Plast Surg. 1984;37:568-73.

43 Kasler M, Banhidy FG, Trizna Z. *Experience with the modified pectoralis major myocutaneous flap*. Arch Otolaryngol Head Neck Surg 1992;118:931-932.

44 Palmer JH, Batchelor AG. *The functional pectoralis major musculocutaneous island flap in head and neck reconstruction*. Plast Reconstr Surg 1990;85:363-7.

45 Gateley DR, Moss AL, Blenkinsopp P. *Reconstruction of the anterior lower third of the face using a composite pectoralis major free flap*. J R Soc Med 1993;86:731-2.

46 Chaturvedi P, Prabhudesai SG, Kanitkar G, et al. *Sub-mammary approach for pectoralis major myocutaneous flap in females*. J Surg Oncol 2003;84:255-6.

47 Chaturvedi P, Pathak KA, Pai PS, et al. *A novel technique of raising a pectoralis major myocutaneous flap through the skin paddle incision alone*. J Surg Oncol 2004;86:105-6.

48 Turkmen A, Perks AG. *Endoscopic assisted harvest of the pedicled pectoralis major muscle flap*. Br J Plast Surg 2005;58:170-4.

49 Po-Wing YA. *Preservation of lateral thoracic artery to improve vascular supply of distal skin without compromising pedicle length in harvesting pectoralis major myocutaneous flap*. J Plast Reconstr Aesthet Surg 2006;59:1433-5.

50 Rikimaru H, Kiyokawa K, Watanabe K, et al. *New method of preparing a pectoralis major myocutaneous flap with a skin paddle that includes the third intercostal perforating branch of the internal thoracic artery*. Plast Reconstr Surg 2009;123:1220-8.

51 Belt PJ, Emmett J. *Local transposition flap repair of the pectoralis major myocutaneous flap donor site*. Plast Reconstr Surg 2004;114:732-7.

52 Chan YW, Ng RW, Yuen AP. *Lateral thoracic flap for donor site repair of pectoralis major myocutaneous flap*. J Plast Reconstr Aesthet Surg 2009;62:1004-7.

53 Kruse AL, Luebbers HT, Gratz KW, et al. *A new method for closure of large donor side defects after raising the pectoralis major flap*. Oral Maxillofac Surg 2011;15:251-2.

54 Benech A, Arcuri F, Poglio G, et al. *Vacuum-assisted closure therapy in reconstructive surgery*. Acta Otorhinolaryngol Ital 2012;32:192-7.

55 Ariyan S. *Further experiences with the pectoralis major myocutaneous flap for the immediate repair of defects from excisions of head and neck cancers*. Plast Reconstr Surg 1979;64:605-12.

56 Arlyan S, Cuono CB. *Use of the pectoralis major myocutaneous flap for reconstruction of large cervical, facial or cranial defects*. Am J Surg 1980;140:503-6.

57 Biller HF, Krespi YP, Lawson W, et al. *A one-stage flap reconstruction following resection for stomal recurrence*. Otolaryngol Head Neck Surg 1980;88:357-60.

58 Theogaraj SD, Merritt WH, Acharya G, et al. *The pectoralis major musculocutaneous island flap in single-stage reconstruction of the pharyngoesophageal region*. Plast Reconstr Surg 1980;65:267-6.

59 Evans PH, Das Gupta AR. *The use of the pectoralis major myocutaneous flap for one-stage reconstruction of the base of the tongue*. J Laryngol Otol 1981;95:809-16.

60 Withers EH, Franklin JD, Madden JJ Jr, et al. *Pectoralis major musculocutaneous flap: a new flap in head and neck reconstruction*. Am J Surg 1979;138:537-43.

61 Lee YT. *Carotid artery protection by pectoralis major muscle flap*. Am J Surg 1980;140:464.

62 Siu KF, Wei WI, Lam KH, et al. *Use of the pectoralis major muscle flap for repair of a tracheoesophageal fistula*. Am J Surg 1985;150:617-9.

63 Sisson GA, Goldman ME. *Pectoral myocutaneous island flap for reconstruction of stomal recurrence*. Arch Otolaryngol 1981;107:446-9.

64 Baker SR. *Management of osteoradionecrosis of the mandible with myocutaneous flaps*. J Surg Oncol 1983;24:282-9.

65 Price JC, Davis RK, Koltai PJ. *The pectoralis myocutaneous flap for salvage of necrotic wounds.* Laryngoscope 1985;95:146-50.

66 Krespi YP, Sisson GA. *Reconstruction after total or subtotal glossectomy.* Am J Surg 1983;146:488-92.

67 Sasaki CT, Ariyan S, Spencer D, et al. *Pectoralis major myocutaneous reconstruction of the anterior skull base.* Laryngoscope 1985;95:162-6.

68 Deganello A, Gitti G, Struijs B, et al *Palliative combined treatment for unresectable cutaneous basosquamous cell carcinoma of the head and neck.* Acta Otorhinolaryngol Ital 2013;33:353-6.

69 Morgan RF, Sargent LA, Hoopes JE. *Midfacial and total nasal reconstruction with bilateral pectoralis major myocutaneous flaps.* Plast Reconstr Surg 1984;73:824-6.

70 Milroy BC, Korula P. *Vascularized innervated transfer of the clavicular head of the pectoralis major muscle in established facial paralysis.* Ann Plast Surg 1988;20:75-81.

71 Joseph CA, Fayman MS, Kadwa MA, Gregor RT. *The pectoralis major flap for reconstruction of septic wounds.* S Afr J Surg 1988;26:107-9.

72 Fleischer A, Khafif R. *Reconstruction of the mediastinal trachea with a tubed pectoralis major myocutaneous flap.* Plast Reconstr Surg 1989;84:342-6.

73 Schusterman MA, Kroll SS, Weber RS, et al. *Intraoral soft tissue reconstruction after cancer ablation: a comparison of the pectoralis major flap and the free radial forearm flap.* Am J Surg 1991;162:397-9.

74 Kroll SS, Reece GP, Miller MJ, et al. *Comparison of the rectus abdominis free flap with the pectoralis major myocutaneous flap for reconstructions in the head and neck.* Am J Surg 1992;164:615-8.

75 Cordeiro PG, Hidalgo DA. *Soft tissue coverage of mandibular reconstruction plates.* Head Neck 1994;16:112-115.

76 Wei FC, Demirkan F, Chen HC, et al. *The outcome of failed free flaps in head and neck and extremity reconstruction: what is next in the reconstructive ladder?* Plast Reconstr Surg 2001;108:1154-60.

77 Bozikov K, Arnez ZM. *Factors predicting free flap complications in head and neck reconstruction.* J Plast Reconstr Aesthet Surg 2006;59:737-42.

78 Schneider DS, Wu V, Wax MK. *Indications for pedicled pectoralis major flap in a free tissue transfer practice.* Head Neck 2012;34:1106-10.

79 Colletti G, Autelitano L, Tewfik K, et al. *Autonomized flaps in secondary head and neck reconstructions.* Acta Otorhinolaryngol Ital 2012;32:329-35.

80 Spriano G, Piantanida R, Pellini R. *Hypopharyngeal reconstruction using pectoralis major myocutaneous flap and prevertebral fascia.* Laryngoscope 2001;111:544-7.

81 Saussez S, Cuno A, Urbain F, et al. *Reconstruction of circumferential oro- and hypopharyngeal defects with U-shaped pectoralis major myocutaneous flap.* Otolaryngol Head Neck Surg 2006;134:823-9.

82 Liu HL, Chan JY, Wei WI. *The changing role of pectoralis major flap in head and neck reconstruction.* Eur Arch Otorhinolaryngol 2010;267:1759-63.

83 Talesnik A, Markowitz B, Calcaterra T, et al. *Cost and outcome of osteocutaneous free-tissue transfer versus pedicled soft-tissue reconstruction for composite mandibular defects.* Plast Reconstr Surg 1996;97:1167-78.

84 Giordano L, Bondi S, Ferrario F, et al. *Radial forearm free flap surgery: a modified skin- closure technique improving donor-site aesthetic appearance.* Acta Otorhinolaryngol Ital 2012;32:158-63.

85 Pellini R, Mercante G, Spriano G. *Step-by-step mandibular reconstruction with free fibula flap modelling.* Acta Otorhinolaryngol Ital 2012;32:405-9.

86 Tarsitano A, Vietti MV, Cipriani R, et al. *Functional results of microvascular reconstruction after hemiglossectomy: free anterolateral thigh flap versus free forearm flap.* Acta Otorhinolaryngol Ital 2013;33:374-9.

87 Baj A, Beltramini GA, Demarchi M, et al. *Extended-pedicle peroneal artery perforator flap in intraoral reconstruction.* Acta Otorhinolaryngol Ital 2013;33:282-5.

88 IJsselstein CB, Hovius SE, ten Have BL, et al. *Is the pectoralis myocutaneous flap in intraoral and oropharyngeal reconstruction outdated?* Am J Surg 1996;172:259-62.

89 Croce A, Moretti A, D'Agostino L, et al. *Continuing validity of pectoralis major muscle flap 25 years after its first application.* Acta Otorhinolaryngol Ital 2003;23:297-304.

90 Leemans CR, Balm AJ, Gregor RT, et al. *Management of carotid artery exposure with pectoralis major myofascial flap transfer and split-thickness skin coverage.* J Laryngol Otol 1995;109:1176-80.

91 Kekatpure VD, Trivedi NP, Manjula BV, et al. *Pectoralis major flap for head and neck reconstruction in era of free flaps.* Int J Oral Maxillofac Surg 2012;41:453-7.

92 Kiyokawa K, Tai Y, Inoue Y, et al. *Reliable, minimally invasive oromandibular reconstruction using metal plate rolled with pectoralis major myocutaneous flap.* J Craniofac Surg 2001;12:326-36.

93 Salvatori P, Motto E, Paradisi S, et al. *Oromandibular reconstruction using titanium plate and pectoralis major myocutaneous flap.* Acta Otorhinolaryngol Ital 2007;27:227-32.

94 Cordova A, Corradino B, Pirrello R, et al. *Surgical treatment of pharyngostomes in irradiated patients. Our experience with musculocutaneous pectoralis major flap and hyperbaric oxygen therapy.* Acta Otolaryngol 2005;125:759-64.

95 Gilbert MR, Sturm JJ, Gooding WE, et al. *Pectoralis major myofascial onlay and myocutaneous flaps and pharyngocutaneous fistula in salvage laryngectomy.* Laryngoscope 2014;124:2680-6..

96 Bhola N, Jadhav A, Borle R, et al. *Is there still a role for bilobed/bipaddled pectoralis major myocutaneous flap for single-stage immediate reconstruction of post ablative oncologic full-thickness defects of the cheek?* Oral Maxillofac Surg 2014 Aug 17 [Epub ahead of print].

97 Gadre KS, Gadre P, Sane VD, et al. *Pectoralis major myocutaneous flap--still a workhorse for maxillofacial reconstruction in developing countries.* J Oral Maxillofac Surg 2013;71:2005.

98 Vartanian JG, Carvalho AL, Carvalho SM, et al. *Pectoralis major and other myofascial/myocutaneous flaps in head and neck cancer reconstruction: experience with 437 cases at a single institution.* Head Neck 2004;26:1018-23.

99 Mura F, Bertino G, Occhini A, et al. *Advanced carcinoma of the hypopharynx: functional results after circumferen-*

tial pharyngolaryngectomy with flap reconstruction. Acta Otorhinolaryngol Ital 2012;32:154-7.

100 Mura F, Bertino G, Occhini A, et al. *Surgical treatment of hypopharyngeal cancer: a review of the literature and proposal for a decisional flow-chart.* Acta Otorhinolaryngol Ital 2013;33:299-306.

101 Wada T, Nakatani K, Hiraishi Y, et al. *Usefulness of myofascial flap without skin in contemporary oral and maxillofacial reconstruction.* J Oral Maxillofac Surg 2011;69:1815-25.

102 Deleyiannis FW, Rogers C, Lee E, et al. *Reconstruction of the lateral mandibulectomy defect: management based on prognosis and location and volume of soft tissue resection.* Laryngoscope 2006;116:2071-80.

103 Galli J, Valenza V, Parrilla C, et al. *Pharyngocutaneous fistula onset after total laryngectomy: scintigraphic analysis.* Acta Otorhinolaryngol Ital 2009;29:242-4.

104 Oosthuizen JC, Leonard DS, Kinsella JB. *The role of pectoralis major myofascial flap in salvage laryngectomy: a single surgeon experience.* Acta Otolaryngol 2012;132:1002-5.

105 Righini C, Lequeux T, Cuisnier O, et al. *The pectoralis myofascial flap in pharyngolaryngeal surgery after radiotherapy.* Eur Arch Otorhinolaryngol 2005;262:357-61.

106 McLean JN, Carlson GW, Losken A. *The pectoralis major myocutaneous flap revisited: a reliable technique for head and neck reconstruction.* Ann Plast Surg 2010;64:570-3.

107 Blackwell KE, Buchbinder D, Biller HF, et al. *Reconstruction of massive defects in the head and neck: the role of simultaneous distant and regional flaps.* Head Neck 1997;19:620-8.

108 Maisel RH, Liston SL, Adams GL. *Complications of pectoralis myocutaneous flaps.* Laryngoscope 1983;93:928-30.

109 Mehrhof AI, Jr., Rosenstock A, Neifeld JP, et al. *The pectoralis major myocutaneous flap in head and neck reconstruction. Analysis of complications.* Am J Surg 1983;146:478-82.

110 Ossoff RH, Wurster CF, Berktold RE, et al. *Complications after pectoralis major myocutaneous flap reconstruction of head and neck defects.* Arch Otolaryngol 1983;109:812-4.

111 Donegan JO, Gluckman JL. *An unusual complication of the pectoralis major myocutaneous flap.* Head Neck Surg 1984;6:982-3.

112 Nagarjuna M, Patil BR, Nagraj N, et al. *Use of superiorly based vertical rectus abdominis myocutaneous flap for the correction of costal osteomyelitis at the pectoralis major myocutaneous flap donor site.* J Oral Maxillofac Surg 2013;71:e132-6.

113 Liu R, Gullane P, Brown D, et al. *Pectoralis major myocutaneous pedicled flap in head and neck reconstruction: retrospective review of indications and results in 244 consecutive cases at the Toronto General Hospital.* J Otolaryngol 2001;30:34-40.

114 van Rossen ME, Verduijn PV, Mureau MA. *Survival of pedicled pectoralis major flap after secondary myectomy of muscle pedicle including transection of thoracoacromial vessels: does the flap remain dependent on its dominant pedicle?* J Plast Reconstr Aesthet Surg 2011;64:323-8.

115 Kroll SS, Goepfert H, Jones M, et al. *Analysis of complications in 168 pectoralis major myocutaneous flaps used for head and neck reconstruction.* Ann Plast Surg 1990;25:93-7.

116 Shah JP, Haribhakti V, Loree TR, et al. *Complications of the pectoralis major myocutaneous flap in head and neck reconstruction.* Am J Surg 1990;160:352-5.

117 Mehta S, Sarkar S, Kavarana N, et al. *Complications of the pectoralis major myocutaneous flap in the oral cavity: a prospective evaluation of 220 cases.* Plast Reconstr Surg 1996;98:31-7.

118 Castelli ML, Pecorari G, Succo G, et al. *Pectoralis major myocutaneous flap: analysis of complications in difficult patients.* Eur Arch Otorhinolaryngol 2001;258:542-5.

119 You YS, Chung CH, Chang YJ, et al. *Analysis of 120 pectoralis major flaps for head and neck reconstruction.* Arch Plast Surg 2012;39:522-7.

120 Keidan RD, Kusiak JF. *Complications following reconstruction with the pectoralis major myocutaneous flap: the effect of prior radiation therapy.* Laryngoscope 1992;102:521-4.

121 Avery CM, Gandhi N, Peel D, et al. *Indications and outcomes for 100 patients managed with a pectoralis major flap within a UK maxillofacial unit.* Int J Oral Maxillofac Surg 2014;43:546-54.

122 Jena A, Patnayak R, Sharan R, et al. *Outcomes of pectoralis major myocutaneous flap in female patients for oral cavity defect reconstruction.* J Oral Maxillofac Surg 2014;72:222-31.

123 Bansal R, Patel TS, Bhullar C, et al. *Metastases to the donor site of the pectoralis major myocutaneous flap following reconstructive surgery: a rare complication.* Plast Reconstr Surg 2004;114:1965-6.

124 Seidenberg B, Rosenak SS, Hurwitt ES, et al. *Immediate reconstruction of the cervical esophagus by a revascularized isolated jejunal segment.* Ann Surg 1959;149:162-71.

125 Hsing CY, Wong YK, Wang CP, et al. *Comparison between free flap and pectoralis major pedicled flap for reconstruction in oral cavity cancer patients - a quality of life analysis.* Oral Oncol 2011;47:522-7.

126 Xiao Y, Zhu J, Cai X, et al. *Comparison between anterolateral thigh perforator free flaps and pectoralis major pedicled flap for reconstruction in oral cancer patients -a quality of life analysis.* Med Oral Patol Oral Cir Bucal 2013;18:e856-61.

127 Zhang X, Li MJ, Fang QG, et al. *A comparison between the pectoralis major myocutaneous flap and the free anterolateral thigh perforator flap for reconstruction in head and neck cancer patients: assessment of the quality of life.* J Craniofac Surg 2014;25:868-71.

128 O'Neill JP, Shine N, Eadie PA, et al. *Free tissue transfer versus pedicled flap reconstruction of head and neck malignancy defects.* Ir J Med Sci 2010;179:337-43.

129 Deganello A, Gitti G, Parrinello G, et al. *Cost analysis in oral cavity and oropharyngeal reconstructions with microvascular and pedicled flaps.* Acta Otorhinolaryngol Ital 2013;33:380-7.

130 Mallet Y, El BS, Penel N, et al. *The free vascularized flap and the pectoralis major pedicled flap options: comparative results of reconstruction of the tongue.* Oral Oncol 2009;45:1028-31.

131 Smeele LE, Goldstein D, Tsai V, et al. *Morbidity and cost differences between free flap reconstruction and pedicled flap reconstruction in oral and oropharyngeal cancer: Matched control study.* J Otolaryngol 2006;35:102-7.

132 de Bree R, Reith R, Quak JJ, et al. *Free radial forearm flap versus pectoralis major myocutaneous flap reconstruction of*

oral and oropharyngeal defects: a cost analysis. Clin Otolaryngol 2007;32:275-2.

[133] Chepeha DB, Annich G, Pynnonen MA, et al. *Pectoralis major myocutaneous flap vs revascularized free tissue transfer: complications, gastrostomy tube dependence, and hospitalization.* Arch Otolaryngol Head Neck Surg 2004;130:181-6.

[134] Tsue TT, Desyatnikova SS, Deleyiannis FW, et al. *Comparison of cost and function in reconstruction of the posterior oral cavity and oropharynx. Free vs pedicled soft tissue transfer.* Arch Otolaryngol Head Neck Surg 1997;123:731-7.

[135] Petruzzelli GJ, Brockenbrough JM, Vandevender D, et al. *The influence of reconstructive modality on cost of care in head and neck oncologic surgery.* Arch Otolaryngol Head Neck Surg 2002;128:1377-80.

[136] McCrory AL, Magnuson JS. *Free tissue transfer versus pedicled flap in head and neck reconstruction.* Laryngoscope 2002;112:2161-5.

[137] Rosenthal E, Carroll W, Dobbs M, et al. *Simplifying head and neck microvascular reconstruction. Head Neck.* 2004;26:930-6.

[138] Metgudmath RB, Metgudmath AR, Metgudmath VV, et al. *Versatility of pectoralis major myocutaneous flap in onco-surgery and its role in developing countries.* Indian J Otolaryngol Head Neck Surg 2013;65:80-4.

[139] Funk GF, Karnell LH, Whitehead S, et al. *Free tissue transfer versus pedicled flap cost in head and neck cancer.* Otolaryngol Head Neck Surg 2002;127:205-12.

[140] van der Putten L, Spasiano R, de BR, et al. *Flap reconstruction of the hypopharynx: a defect orientated approach.* Acta Otorhinolaryngol Ital 2012;32:288-96.

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