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Review

Propeller Flaps: A Literature Review

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Abstract. *Background/Aim: Since their introduction in 1991, propeller flaps are increasingly used as a surgical approach to loss of substance. The aim of this study was to evaluate the indications and to verify the outcomes and the complication rates using this reconstructing technique through a literature review. Materials and Methods: A search on PubMed was performed using "propeller flap", "fasciocutaneous flap", "local flap" or "pedicled flap" as key words. We selected clinical studies using propeller flaps as a reconstructing technique. Results: We found 119 studies from 1991 to 2015. Overall, 1,315 propeller flaps were reported in 1,242 patients. Most frequent indications included loss of substance following tumor excision, repair of trauma-induced injuries, burn scar contractures, pressure sores and chronic infections. Complications were observed in 281/1242 patients (22.6%) occurring more frequently in the lower limbs (31.8%). Partial flap necrosis and venous congestion were the most frequent complications. The complications' rate was significantly higher in infants (<10 years old) and in the older population (>70 years old) but there was not a significant difference between the sexes. Trend of complication rate has not improved during the last years. Conclusion: Propeller flaps showed a great success rate with low morbidity, quick recovery, good aesthetic outcomes and reduced cost. The quality and volume of the transferred soft tissue, the scar orientation and the possibility of direct donor site closure should be considered in order to avoid complications. Indications for propeller flaps are small- or medium-sized defects located in a well-vascularized area with healthy surrounding tissues.*

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Key Words: Propeller flaps, perforator flap, surgical flaps, fasciocutaneous flap, island flaps, pedicled flap, local flaps, review.

The propeller flap represents a model of local perforator flap and, according to the Tokyo Consensus, can be defined as "an island flap that reaches the recipient sites through an axial rotation"(1).

Hyakusoku *et al.* first used the term 'propeller flap' in 1991, describing two subcutaneous pedicled island flaps, vascularized by a perforator artery in the center and rotated 90˚, for the reconstruction of skin scar contractures in burn patients (2).

With the improvement of knowledge on cutaneous vascular system, perforator flaps are increasingly used in clinical practice. In 2001, the Fifth International Course on Perforator Flaps, held in Gent, provided the "Consensus on Perforator Flap Terminology"(3) and, in 2009, the First Tokyo Meeting on Perforator and Propeller Flaps proposed a classification based on the perforator vessel supplying the flap (1).

Since several reconstructive options exist to cover loss of substance all over the body, the choice of the correct approach to any given defect should consider the specific, individual needs of the patient. The aim of this study was to evaluate the indications and to verify the outcomes and the complication rate of propeller flaps, as alternative to other types of surgical or clinical approaches.

Materials and Methods

A literature search of the PubMed database was performed using the key words ''propeller flap'', "fasciocutaneous flap", "local flap" or "pedicled flap". Additional articles were selected reviewing the citations of publications identified using these key words.

Inclusion criteria among these papers were:

- the paper was a case study, case report, clinical trial, open label prospective study, case series, retrospective study or letter to the editor;
- propeller flap was used as surgical therapy.

Exclusion criteria were:

- the paper did not provide sufficient details about the performed surgical procedure;
- the performed technique did not match the Tokyo Consensus classification (1);
- the paper was a review of literature.

We considered the database until April 2015. Both English and non-English language papers were included. Each article was tabulated as follows: author/s, year of the study, demographic data, vascular territory, number of propeller flaps, angle of rotation, indication, defect location, flap shape and size, follow-up time and complications. All kinds of propeller techniques were considered. The publications were screened manually and reviewed to identify reports on propeller flap techniques.

Results

Of the initial 162 studies yielded from our search, 160 were selected for the second stage and, after the screening of 132 full-text papers, 119 studies met the definitive inclusion criteria (Tables I and II).

Among the clinical studies included, 1315 propeller flaps were used in a total of 1,242 patients; 387 patients were female (31.16%), 675 patients were male (54.35%), while gender was not specified for 180 patients (14.49%). Mean age of the subjects was 45.9 years (age range=0-94, SD=25.26). Angle of rotation of the propeller flap was not specified in 268 flaps.

Etiology of tissue defect was not specified in 122 propeller flaps (9.3%). The most frequent etiologies were tumor excision (409 patients, 31.1%), trauma (376 patients, 28.6%), burn (106 patients, 8.1%), pressure sore (61 patients, 4.6%), osteomyelitis or osteitis (33 patients, 2.5%), peripheral arterial occlusive disease (25 patients, 1.9%), hidradenitis suppurativa (23 patients, 1.7%), scar correction (22 patients, 1.7%), infection (21 patients, 1.6%) and outcomes of previous surgeries (21 patients, 1.6%).

Vascular territory was not specified in 322 propeller flaps (24.5%). The most frequent origins of perforators were posterior tibial artery (PTA) in 272 flaps (20.7%), peroneal artery (PA) in 102 flaps (7.8%) and thoraco-dorsal artery (TDA) in 86 flaps (6.5%).

Defect location was not specified in 135 propeller flaps (10.3%). Anatomical sites of the propeller flaps were lower limb (503 flaps, 38.3%), trunk and perineum (385 flaps, 29.3%), upper limb (158 flaps, 12.0%) and head and neck (134 flaps, 10.2%).

Flap shape was not specified in 971 propeller flaps (73.8%); among the specified shapes (344, 26.2%), the elliptical shape was the most frequent (284 flaps, 82.6% of specified shapes).

Flap size was not specified in 648 propeller flaps (49.3%); mean size between the specified studies was 98 cm^2.

Mean follow-up was 15 months. Follow-up was not specified in 398 patients (30.3%). Among the total of 1,315 propeller flaps, 958 (72.8%) healed uneventfully. Overall, 548 complications occurred in 281/1242 patients (22.6%). The most frequent complications were partial flap necrosis (86 flaps, 6.54%), venous congestion (66 flaps, 5.0%), complete flap necrosis (35 flaps, 2.7%), dehiscence (28 flaps, 2.1%), hematoma/seroma (13 flaps, 1%), epidermolysis (12 flaps, 0.9%), wound infection (12 flaps, 0.9%), edema/lymphedema (11 flaps, 0.8%), loss of sensation/numbness/paraesthesia (9 flaps, 0.7%), osteomyelitis (5 flaps, 0.4%) and formation of a bursa / fistula (4 flaps, 0.3%).

Substitutive skin graft or another flap was needed in 31 flaps (2.4%), skin graft to close donor site was needed in 117 cases (8.9%), second operation was necessary in 68 patients (5.2%), 7 patients (0.5%) required amputation of the affected part of the body because of complications occurred following the surgical procedure. In 5 patients (0.4%), it was impossible to perform a propeller flap because a useful perforator artery was not found (4, 5).

Major complications' rate (partial flap necrosis, venous congestion and complete flap necrosis) was 14.2%.

Complications occurred most frequently in patients who underwent lower limb perforator flaps (160/497 patients, 31.8%; major complications' rate=20.7%). Patients who underwent perforator flaps on trunk and perineum reported a complication rate of 19.5% (75/324 patients, major complications' rate=11.2%). For patients who were operated on head and neck, the complication rate was 15.7% (21/134 patients, major complications' rate: 11.2%). A similar complication rate was observed in patients who underwent perforator flap on upper limb (25/156 patients, 15.9%, major complications' rate=14.6%).

Partial flap necrosis was the most frequent complication in lower (11.3% of flaps) and upper limb (8.9% of flaps) propeller flaps. Instead, venous congestion was the most frequent complication in head/neck (8.2% of flaps) and trunk/perineum (5.7% of flaps) propeller flaps.

Newborns and elderly patients showed a higher rate of complications (Figure 1).

No statistically significant difference in the distribution of the complications' rate according to sex was found, as well as during the last years (Table III).

Advantages-disadvantages of propeller flaps are summarized in Table IV.

Discussion

Basic concepts, guidelines, classification and principles of propeller flaps are well-described in the literature (28, 30, 116, 122, 123).

Relying on our results, propeller flaps were an appealing option when the defect to treat had small to medium size and was located in a well-vascularized area with healthy surrounding tissues. Lower limb district showed the highest complication rate, almost twice than the other areas, associated with the highest number of skin grafts or other flaps needed to close donor sites; therefore, propeller flaps showed better results when direct donor site closure was achievable without tension in the area.

Table I. *Data about propeller flaps, grouped depending on anatomical site*.

Anatomical region	Vascular territory	N° of pts	Demographic data	N° of flaps	Etiology	Defect location	Flap shape and size	Mean follow-up in months	Complications rate	Complications of flaps (number of flaps, percent of flaps)
Head & neck: 12 studies (6-17)	51 STA, 35 FACA, 23 DLA, 3 SLA, 3 TCA, 2 PAA, 2 SCA, 1 RAA, 8 Not specified	134	29 F and 64 M, 41 sex not specified; mean age= 70.2 yo	134	130 Tumor excision 2 trauma 1 venous insufficiency 1 nostril stenosis	79 nose 23 oral cavity 12 nasolabial and perinasal region 5 lower eyelid 5 Neck 4 ear 3 upper lip 2 lower lip 1 cheek 1 retroauricular region	126 shape not specified, 6 elliptical, 1 rectangular, 1 triangular; Mean size 17,2 cm^2	7	21 pts (15.7%)	Venous congestion (11, 8.2%) Partial flap necrosis (4, 3.0%) Trapdoor deformity (2, 1.5%) 2nd operation needed (1, 0.7%) Edema/lymphedema (1, 0.7%) Septicemia/ infection in other site (1, 0.7%) Flap bulkiness (1, 0.7%)
Upper limb: 23 studies	(2, 5, 6, 10, 13, 18-35) 33 RA, 27 UA, 17 RCA, 9 IOA, 7 BA, 7 UDA, 6 DMA, 4 AXA, 4 SUCA, 3 RRA, 3 RUA, 3 TAA, 2 DCA, 1 DBA, 32 Not specified	156	46 F and 95 M, 15 sex not specified; mean age= 41.9 yo	158	62 Burn 58 trauma 18 tumor excision 11 cyst/bursa 2 electrical injury 2 post snake bite defect 2 radiation induced ulcer 1 extravasations of radiographic contrast medium 1 pressure sore 1 scar correction	73 upper limb (not better specified) 39 Elbow 13 forearm 12 wrist/hand 11 hand finger 5 upper arm	104 shape not specified, 31 elliptical, 8 eight-limb-modified, 7 diamond-shaped 4 quadrilobed, 2 trilobed, 2 bilobed, 1 double-pedicled; Mean size 68,6 cm^2	14	25 pts (15.9%)	Partial flap necrosis (14, 8.9%) 2nd operation needed (10, 6.3%) Complete flap necrosis (6, 3.8%) Skin graft needed to close donor site (5, 3.2 %) Venous congestion (3, 1.9%) Substitutive skin graft or flap needed (1, 0.6%) Wound infection (1, 0.6%) Hematoma/seroma (1, 0.6%) Edema/lymphedema (1, 0.6%) Formation of a bursa/ fistula (1, 0.6%) Epidermolysis (1, 0.6%) Dehiscence (1, 0.6%) Donor site infection (1, 0.6%) Insufficient release of burn scar contracture (1, 0.6%)
Trunk and perineum: 52 studies (2, 4, 5, 10, 12, 19, 21, 31, 34, 36-76)	86 TDA, 58 IPA, 46 SGA, 16 SEA, 13 IGA, 13 LICA, 11 DICA, 11 ICA, 8 ITA, 7 PICA, 4 DIEA,	324	149 F and 120 M, 55 sex not specified; mean age= 50.0 yo	385	199 Tumor excision 49 pressure sore 33 burn 23 hidradenitis suppurativa 19 meningo-myelocele/ pseudome-ningocele	79 breast 72 axilla 58 back 38 vagina 24 sacrum 23 chest 18 gluteus 15 anus and perineum 13 ischium 10 torso	291 shape not specified, 65 elliptical, 8 quadrilobed, 7 trilobed, 7 multi-island, 2 bilobed, 2 L-shaped, 1 triangular, 1 rectangular,	16	75 pts (19.5%)	Venous congestion (22, 5.7%) Dehiscence (15, 3.9%) Partial flap necrosis (12, 3.1%) 2nd operation needed (12, 3.1%) Complete flap necrosis (9, 2.3%) Hematoma/seroma

Table I. *Continued*

Table I. *Continued*

Anatomical region	Vascular territory	N° of pts	Demographic data	N° of flaps	Etiology	Defect location	Flap shape and size	Mean follow-up in months	Complications rate	Complications of flaps (number of flaps, percent of flaps)
	4 DLICA, 3 TAA, 2 AICA, 2 LTA, 2 PNA, 2 DSEA, 1 CSA, 1 IMA, 1 LICA, 1 SCIA, 93 not specified				9 osteomyelitis/ osteitis 7 scar correction 4 radiation induced ulcer 3 trauma 3 dehiscence 3 cyst/bursa 2 closure of donor site of precedent flap 1 infection 1 electrical injury 1 fistula	10 trunk (not better specified) 6 abdomen 5 pelvic cavity 3 flank 2 shoulder 2 scapula 1 lateral thoracic region 1 supra-clavicolar region 1 groin	23 double-pedicled; Mean size 111,2 cm^2			(8, 2.1%) Loss of sensation/ numbness/ paraesthesia (7, 1.8%) Substitutive skin graft or flap needed (5, 1.3%) Skin graft needed to close donor site (3, 0.8%) Failure to find a useful perforator (3, 0.8%) Formation of a bursa/ fistula (2, 0.5%) Evacuation needed (2, 0.5%) Tension in donor site (1, 0.3%) Erythema (1, 0.3%) Cellulitis (1, 0.3%) Flap bulkiness (1, 0.3%) Recurrence of precedent disease (1, 0.3%) De-rotation of the pedicle needed (1, 0.3%) Insufficient release of burn scar contracture (1, 0.3%)
Lower limb: 48 studies (6, 10, 13, 24, 28, 34, 44, 45, 48, 77-115)	257 PTA, 102 PA, 13 DFA, 10 FA, 8 ATA, 8 DGA, 7 PDA, 6 MA, 5 LCFA, 2 DPA, 2 FDMA, 2 GA, 2 LMA, 2 SA, 2 SMGA, 1 LPCA, 1 MPA, 1 MSGA, 1 SLGA, 1 TA, 70 Not specified	497	136 F and 329 M, 32 sex not specified; mean age= 49.9 yo	503	210 trauma 62 tumor excision 25 PAOD 24 osteomyelitis/ osteitis 21 Complication of precedent surgery 21 infection 13 scar correction 10 pressure sore 10 closure of donor site of precedent flap 8 dehiscence 7 diabetic ulcer 6 burn 5 spokes 4 venous	210 distal third of leg 67 lower limb (not better specified) 61 Knee and upper leg, 56 foot 37 Achilles tendon 25 ankle 15 heel 10 fibula 7 malleolus 5 middle third of leg 4 tibia 4 trochanter	320 shape not specified, 178 elliptical, 3 round, 1 bilobed, 1 quadrilobed, 4 double-pedicled; Mean size 109,4 cm^2	23	160 pts (31.8%)	Skin graft needed to close donor site (110, 21.9%) Partial flap necrosis (57, 11.3%) 2nd operation needed (40, 8.0%) Venous congestion (30, 6.0%) Sostitutive skin graft or flap needed (20, 4.0%) Complete flap necrosis (17, 3.4%) Dehiscence (13, 2.6%) Epidermolysis (12, 2.4%) Wound infection (10, 2.0%) Edema/ lymphedema (9, 1.8%) Amputation needed

Table I. *Continued*

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Anatomical region	Vascular territory	N° of pts	Demographic data	N° of flaps	Etiology	Defect location	Flap shape and size	Mean follow-up in months	Complications rate	Complications of flaps (number of flaps, percent of flaps)
					insufficiency 4 electrical injury 2 neuropathy 1 frostbite 1 amputation					(7, 1.4%) Osteomyelitis (5, 1.0%) Hematoma/seroma (4, 0.8%) Loss of sensation/ numbness/paraesthesia (2, 0.4%) Failure to find a useful perforator (2, 0.4%) Donor site infection (1, 0.2%) Septicemia/infection in other site (1, 0.2%) Formation of a bursa / fistula (1, 0.2%) Hypertrophic keloid scar (1, 0.2%) Recurrence of precedent disease (1, 0.2%) Perforator accidentally cut (1, 0.2%) Necrosis of underlying organs (1, 0.2%) Tension in donor site (1, 0.2%)
Total 119 papers		1242	387 F and 675 M, 180 sex not specified; mean age= 45.9 yo	1315	409 tumor excision 376 trauma 106 burn 61 pressure sore 33 osteo-myelitis or osteitis 25 peripheral arterial occlusive disease 23 hidradenitis suppurativa 22 scar correction 21 infection 21 outcomes of previous surgeries	503 lower limb 385 trunk and perineum 158 upper limb 134 head and neck 135 not specified	971 shape not specified, 284 elliptical Mean size 98 cm^2	15	281 pts (22.6%)	Skin graft needed to close donor site (117, 8.9%) Partial flap necrosis (86, 6.5%) 2nd operation needed (68, 5.2%) Venous congestion (66, 5.0%) Complete flap necrosis (35, 2.7%) Sostitutive skin graft or flap needed (31, 2.4%) Dehiscence (28, 2.1%) Hematoma/seroma (13.1%) Epidermolysis (12, 0.9%) Wound infection (12, 0.9%) Edema/lymphedema (11, 0.8%) Loss of sensation/ numbness/paraesthesia (9, 0.7%) Osteomyelitis (5 flaps, 0.4%) Failure to find a useful

Table I. *Continued*

Table I. *Continued*

Anatomical region	Vascular territory	N° of pts	Demographic data	N° of flaps	Etiology	Defect location	Flap shape and size	Mean follow-up in months	Complications rate	Complications of flaps (number of flaps, percent of flaps)
										perforator (5, 0.4%) Formation of a bursa/ fistula (4, 0.3%) ension in donor site (3, 0.2%) Septicemia/infection in other site (2, 0.15%) Flap bulkiness (2, 0.15%) Recurrence of precedent disease (2, 0.15%) Evacuation needed (2, 0.15%) Trapdoor deformity (2, 0.15%) Erythema (1, 0.1%) Cellulitis (1, 0.1%) Donor site infection (1, 0.1%) Hypertrophic keloid scar (1, 0.1%) Perforator accidentally cut (1, 0.1%) De-rotation of the pedicle needed (1, 0.1%) Insufficient release of burn scar contracture (1, 0.1%) Necrosis of underlying organs (1, 0.1%)

AICA, Anterior intercostal artery; ALT, anterolateral thigh; ATA, anterior tibial artery; AXA, axillary artery; BA, brachial artery; CRA, collateral radial artery; CSA, circumflex scapular artery; d, days; DBA, deep brachial artery; DCA, dorsal carpal artery; DFA, deep femoral artery; DGA, descending genicular artery; DICA, dorsal intercostal artery; DIEA, deep inferior epigastric artery; DLA, deep lingual artery; DLICA, dorso-lateral intercostal artery; DMA, dorsal metacarpal artery; DPA, dorsalis pedis artery; DSEA, deep superior epigastric artery; F, female; FA, femoral artery; FACA, facial artery; FDMA, first dorsal metatarsal artery; GA, genicular artery; ho, hours old; HT, hospitalisation time; ICA, intercostal artery; IGA, inferior gluteal artery; IOA, anterior interosseous artery; IMA, internal mammary artery; IPA, internal pudendal artery; ITA, internal thoracic artery; LA, lumbar arteries; LCFA, lateral circumflex femoral artery; LICA, lateral intercostal artery; LMA, lateral malleolar artery; LNA, lateral nasal artery; LPCA, lateral popliteal cutaneous artery; LTA, lateral thoracic artery; M, male; MA, metatarsal artery; mo, months; MPA, medial plantar artery; MSGA, medial superior genicular artery; p. flaps, propeller flaps; PA, peroneal (fibular) artery; PAA, posterior auriculartery; PAOD, peripheral arterial obstructive disease; p.com., personal communication; PDA, plantar digital artery; PICA, posterior intercostal arteries; PNA, perineal artery; pt, patient; PTA, posterior tibial artery;, patients; RA, radial artery; RAA, retroauricular artery; RCA, radial collateral artery; RRA, recurrent radial artery; RUA, recurrent ulnar artery; SA, saphenous artery; SCA, superficial cervical artery; SCIA, superficial circumflex iliac artery; SEA, superiorepigastric artery; SGA, superior gluteal artery; SIEA, superficial inferior epigastric artery; SLA, superior labial artery; SLGA, superior lateral genicular artery; SMGA, superior medial genicular artery; STA, supratrochlear artery; SUCA, superior ulnar collateral artery; TA, tibial artery; TAA, thoraco-acromial artery; TCA, transverse cervical artery; TDA, thoraco-dorsal artery; UA, ulnar artery; UDA, ulnar digital artery; VAC, vacuum assisted closure; y, year/years; yo, years old.

On 1,315 propeller flaps, 35 (2.7%) were lost, whereas, in 31 cases (2.4%), a substitutive skin graft or another flap was needed. These values corroborate data found by Lazzeri *et al*. (123). We planned to match our results with other reconstructive techniques but, in literature, there are not many big-populated studies reporting analogous data.

In the head and neck district, we compared our results with the Zhang *et al*.'s experience (124) on microsurgical free flaps (Table V). Propeller flaps showed a higher success rate than microsurgery, although with a little higher complication rate. The lower flap loss rate could rely on reduced dimensions of the defects without the need of microvascular anastomosis.

Table II. *Overview of clinical studies on propeller flaps*.

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Hyakusoku H, (2)	2	2 M; 17 and 20 yo (mean= 18.5 yo)	Not specified	2	90˚	Burn scar contractures	Elbow and axilla	Subcutaneous pedicled flap with a pedicle in the centre	6-12	None
Murakami M, (5)	13	6 F and 7 M; age range=2-58 yo (mean= 34.7 yo)	Not specified	19	90˚	Burn scar contractures	13 Axilla, 6 elbow	7 trilobed, 12 quadrilobed	3-36	Insufficient release of contracture, resolved spontaneously after 3 years (1 pt)
Aslan G, (18)	7	4 F and 3 M; age range=7-25 yo (mean= 16.0 yo)	Not specified	7	90˚	Burn scar contractures	Elbow	Diamond shaped, based on the central subcutaneous pedicle designed along the long axis of the burn contracture	Up to 24	Skin graft needed to close donor site (2 pts)
Hallock GG, (4)	2	2 M; 41 and 53 yo (mean= 47 yo)	IGA	3	180˚	Pressure sore	1 Ischium, 1 trochanter	Not specified	12	Skin graft needed to close donor site (1 pt)
Hyakusoku H, (36)	2	1 F and 1 M; 17 and 42 yo (29.5 yo)	Not specified	2	90˚	Burn scar contractures	Axilla	Trilobed	24-36	None
Moscatiello F, (78)	6	1 F and 5 M; age range=43-72 yo (mean= 55.5 yo)	3 DGA, 2 SA,1 FA	6	180˚	3 Tumor excision, 2 unstable scar, 1 open fracture	Knee and upper leg	Width >10 cm	12-48	Partial flap necrosis, required 2nd operation (1 pt) Skin graft needed to close donor site (6 pts)
Hyakusoku H, (19)	2	1 F and 1 M; 18 and 53 yo (mean=35.5 yo)	1 SGA, 1 DBA	2	180˚	1 Pressure sore, 1 trauma	1 Sacrum, 1 elbow	Acentric perforator pedicled	Not specified	None
Jakubietz RG, (77)	8	1 F and 7 M; age range=45-86 yo (mean= 61.4 yo)	5 PA, 3 PTA	8	180˚	2 Open fracture, 2 osteomyelitis, 2 dehiscence, 1 unstable scar, 1 diabetic ulcer	1 Heel, 4 lateral malleolus, 3 Achilles tendon	Elliptical	6	Skin graft needed to close donor site (1 pt) Epidermolysis with venous congestion (2 pts) Partial flap necrosis, below-knee amputation needed (1 pt)
Pignatti M, (79)	6	1 F and 5 M; age range= 15-63 yo (mean=52.5 yo)	Not specified	6	2 90˚, 2 135˚, 2 180˚	5 Trauma, 1 infection of prosthesis	Leg and knee	1 Round, 1 two-bladed; 3 double pedicled; from 8x9 cm to 25x12 cm	Not specified	Partial flap necrosis of the flap (1 pt) Venous congestion, resolved spontaneously (2 pts)
Rad AN, (80)	1	M; 40 yo	PA	1	180˚	Tumor excision	Ankle	Elliptical, 22x8 cm	22	Skin graft needed to close donor site Loss of sensation in the sural nerve distribution
Rubino C, (81)	1	F; 78 yo	PA	1	180˚	Chronic osteomyelitis	Distal third of the fibula	16x6 cm	12	None
Xu Y, (38)	6	2 F and 4 M; age range=28-67 yo (mean= 51.3 yo)	SGA	7	90˚	Pressure sore	Sacrum	Multi-island design, from 12x16 cm to 25x30 cm	6-38 (mean 20,1)	Numbness in the donor site (6 pts)
Bravo FG, (6)	6	2 F and 4 M; age range=52-65 yo (mean=59.3 yo)	2 PTA, 2 RA, 1 TCA, 1 SGA	6	180˚	3 Pressure sore, 3 trauma	2 Distal lower extremity, 2 distal upper extremity,	4 elliptical, 1 triangular, 1 V-rectangular; from 4x12 cm	12	Dehiscence, required surgical revision (1 pt)

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
							1 cervical, 1 trochanter	to 12x22 cm		
Jakubietz RG, (37)	3	3 M, age range= 29-73 yo (mean= 56.3 yo)	2 SGA, 1 IGA	3	180˚	Pressure sore	2 Ischium, 1 sacrum	Elliptical; from 7x16 cm, to 9x18 cm	5-6	Dehiscence (1 pt) Hematoma, required drainage (1 pt)
Battiston B, (20)	1	M; 43 yo	2nd DMA	1	180˚	Trauma	Index finger	Elliptical; 8x1.5 cm	6	Partial flap necrosis
Kosutic D, (21)	1	M; 24 yo	TAA	1	180˚	Scar contracture	Upper arm, axilla and lateral thoracic region	Elliptical, based on two dominant perforators	Not specified	None
Jiga LP, (82)	5	4 F and 1 M; age range=59-79 yo (mean=71 yo)	5 PA, 1 PTA	6	Up to 180˚	PAOD	1 Medial leg, 1 lateral malleolus, 3 heel	From 4x7 cm to 8x31 cm	6	Complete flap necrosis, below-knee amputation needed (1 pt) Partial flap necrosis, skin graft needed (1 pt) Edema, resolved spontaneously (5 pts)
Woo KJ, (41)	1	M, 40 yo	DSEA	1	180˚	Tumor excision	Upper abdomen	Elliptical; 20x10 cm	Not specified	None
Rezende MR, (83)	21	5 F and 16 M; age range=19-80 yo (mean=40 yo)	9 FA, 10 PTA, 5 ATA	21	19 180˚, 2 120˚	Skin injuries (not specified)	4 Middle third of leg, 17 distal third of leg	From 3x6 cm to 9x15 cm	Not specified	Skin graft needed to close donor site (18 pts)
Sinna R, (40)	1	F; 57 yo	Not specified	2	90˚	Tumor excision	Perineum	L-shaped	2	None
Schaverien MV, (84)	100	25 F and 75 M; age range=9-90 yo (mean= 47.2 yo)	PTA	106	60˚-180˚ (mean 160˚)	63 Trauma, 15 chronic osteomyelitis, unstable scar, burn scar contractures	72 Lower third of the leg, 10 ankle, heel, foot	Elliptical	18	Complete flap necrosis, required 6 free muscle flap transfer and 3 below knee amputation (9 pts) Partial flap necrosis, all managed conservatively except one that needed an adipo-fascial transposition flap (12 pts) Osteomyelitis (5 pts) Dehiscence (9 pts) Wound infection (8 pts) Hematoma (4 pts)
Teo TC, (116)	130	Not s pecified	Not specified	130	90˚-180˚ (more than 2/3 180˚)	100 Trauma, tumor excision, chronic infection, pressure sore, chronic leg ulcer	Trunk, upper and lower limbs	The biggest 21x10 cm; the longest 31x5	Not specified	Complete flap necrosis, required another flap (3 pts)
Jakubietz RG, (117)	9	1 F and 8 M; age range=14-72 yo (mean= 56.1 yo)	3 PTA, 1 ATA, 3 PA	7	90˚-180˚	1 Trauma, 1 burn, 5 wound dehiscence	Achilles tendon	2 Local rotational flaps, 5 elliptical; from 4x7 cm to 5x24 cm	Not specified	Failure to find a useful perforator (2 pts) Skin graft needed to close donor site (4 pts) Partial flap necrosis (1 pt) Complete flap necrosis (1 pt)

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
										VAC Therapy needed (1 pt) Liposuction and flap thinning needed (1 pt); Epidermolysis (1 pt)
Schonauer F, (15)	3	Not specified	Not specified	3	Up to 120°	Tumor excision	Ear	Not specified	18	None
Karsidag S, (11)	6	1 F, 5 M; age range=54-73 yo (mean=63.8 yo)	LNA	6	90°-180°	Tumor excision	Nose	Elliptical; from 1.5x2 cm to 2x2.5 cm	Mean 18	Venous congestion, resolved in 24 hours (3 pts)
Korambayil PM, (39)	11	3 F and 8 M; age range= 22-50 yo (mean =36.6 yo)	8 SGA, 3 IGA	11	40°-180° (mean 97,3°)	9 Pressure sore, 2 pilonidal sinus	8 Sacrum, 3 ischium	From6x7 cm to 14x11 cm	Not specified	Wound dehiscence (1 pt) Complete flap necrosis (1 pt) Skin graft needed to close donor site (1 pt)
Ang GG, (42)	1	F; 50 yo	DIEA	1	180°	Tumor excision	Anterior abdomen	Triangular	Not specified	None
Lu TC, (90)	11	6 F and 5 M; age range=16-82 yo (mean=53.5 yo)	PA	11	up to 180°	10 Trauma, 1 tumor excision	Lower leg and foot	Elliptical; from 7.5x3 cm to 20x8 cm	2,5 to 5	Venous congestion (3 pts) Partial flap necrosis, skin graft needed (1 pt) Skin graft needed to close donor site (n° not specified)
Kneser U, (46)	1	F; 61 yo	TCA	1	180°	Tumor excision	Supraclavicular region	Elliptical; 16x7 cm	4	None
Bous A, (86)	2	1 F and 1 M; age range=62-78 yo (mean=70 yo)	PTA	2	180°	1 Trauma, 1 osteomyelitis	Tibia	Elliptical	Not specified	Skin graft needed to close donor site (1 pt)
Jakubietz RG, (45)	13	4 F and 9 M; age range=12-78 yo (mean= 52.5 yo)	Not specified	10	From 140° to 180° (mean 174°)	Pressure sore	7 sacrum, 5 ischium, 1 scapula	Elliptical; from 4x5 cm to 12x18 cm	From 3 to 16 (mean 11,5)	Failure to find a useful perforator (3 pts) Complete flap necrosis due to venous congestion, required local advanced flap (2 pts) Wound dehiscence with formation of a bursa (2 pts) Hematoma, required evacuation (1 pt)
Ignatiadis IA, (89)	6	1 F and 5 M; age range=35-58 yo (mean= 45.8 yo)	PTA	6	90°-180°	Achilles tendon Rupture	Achilles tendon	Not specified	From 18 to 84	Wound dehiscence (1 pt) Hypertrophic keloid scar (1 pt) Partial flap necrosis (1 pt)
Ayestaray B, (118)	3	3 M; age range= 37-53 yo (mean= 44.0 yo)	1 SGA, 1 CSA, 1 CRA	4	90°-180° (mean 135°)	1 Pilonidal cyst, 1 burn scar contracture, 1 open fracture	1 Sacrum, 1 axilla, 1 elbow	2 Elliptical, 1 bilobed; from 6x4 cm to 17x10 cm	Not specified	None

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Ono S, (48)	13	6 F and 7 M; age range= 15-63 yo (mean=38.5 yo)	7 ITA, 3 PTA, 2 PNA, 1 LTA, 1 SGA, 2 PA	16	90˚-180˚	5 Keloid, 2 burn scar contractures, 1 tumor excision, 1 pilonidal cyst, 4 ulcer	4 Chest, 1 axilla, 1 vulva, 1 buttocks, 1 lower leg, 1 ankle, 3 calcaneus	12 Elliptical, 3 bilobed, 1 quadrilobed; from 3.5x2 cm to 27x8 cm	Not specified	Skin graft needed to close donor site (2 pts) Partial flap necrosis (1 pt)
Hosny H, (22)	8	5 F and 3 M; age range= 18-44 yo (mean=28.7 yo)	Not specified	8	45˚	Burn scar contracture	5 Elbow, 3 first web space of the hand	Eight-limb modified propeller	6-18 (mean 12,5)	Venous congestion, resolved spontaneously (1 pt) Skin graft needed to close donor site (2 pts) Partial flap necrosis (1 pt)
Go JY, (43)	1	F; 57 yo	DIEA	1	180˚	Wound dehiscence after tumor excision	Antero-lateral chest wall	Elliptical	12	Seroma under the flap, evacuated and minimal debridement in the area of flap necrosis
Youn S, (17)	1	M; 50 yo	RAA	1	90˚	Trauma	Ear	Rectangular, 3x2.5 cm	Not specified	Venous congestion
Higueras Suñé MC, (44)	11	6 F and 5 M; age range= 40-85 yo (mean=64.1 yo)	2 IPA, 1 LCFA, 7 PA, 1 PTA	11	Not specified	3 Osteitis, 6 tumor excision, 2 trauma	2 Perineum, 1 knee, 4 distal third of leg, 2 malleolus, 2 Achilles tendon	Mean size 5.2x5.7 cm	Not specified	Skin graft needed to close donor site (7 pts) Partial flap necrosis, skin graft needed (3 pts)
Ono S, (23)	12	2 F, 10 M; age range=25-70 yo (mean= 49.1 yo)	1 SUCA, 1 RRA, 3 RCA, 1 BA, 3 UA, 3 RA	12	From 90˚ to 180˚ (mean 145,8˚)	4 Burn scar contracture, 3 trauma, 2 excision of olecranon bursa, 1 electrical burn, 1 radiation dermatitis, 1 olecranon implant exposure	6 Elbow, 6 wrist or hand	9 Elliptical, 1 quadrilobed, 2 bilobed; the smallest 8x4 cm; the largest 18.0x5.5 cm (mean size= 12.2x4.7 cm)	Not specified	Partial flap necrosis, required abdominal flap (1 pt) Skin graft needed to close donor site (1 pt)
Ziegler K, (50)	1	F; 46 yo	SEA	1	90˚	Tumor excision	Chest	Elliptical; 21x12 cm	3	Skin graft needed to close donor site
Tos P, (91)	22	11 F and 11 M; age range= 22-86 yo (mean=56.5 yo)	6 PA, 13 PTA, 1 GA, 1 LCFA, 1 DFA	22	From 80˚ to 180˚ (mean 142,3˚)	6 Tumor excision, 7 postsurgical wound defect, 5 trauma, 3 pressure sore, 1 chronic osteomyelitis	7 Achilles tendon, 1 thigh, 7 leg, 1 groin, 2 foot, 1 ankle, 2 heel, 1 knee	From 3x5 cm to 25x15 cm	6	Venous congestion (3 pts) Complete flap necrosis (2 pts) Secondary skin graft needed to treat complications (3 pts) Epidermolysis (5 pts) Transient edema (n˚ not specified) Prolonged (6 mo) leg edema with spontaneous resolution (1 pt)
Ogawa R, (47)	1	M; age not specified	Not	specified	1	135˚	Keloid	Breastbone	Elliptical	18 None

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Gobel F, (88)	3	1 F and 2 M, age range= 50-75 yo (mean=65 yo)	2 SMGA, 1 SLGA	3	180°	Not specified	Knee	Elliptical; from 8x4 cm to 18x9 cm	3	Perforator cut during a first incision, another flap needed (1 pt) Partial-flap necrosis, required debridement (1 pt) Venous congestion (1 pt)
D'Arpa S, (10)	85	20 F and 65 M; age range= 40-92 yo (mean=76 yo)	18 FACA, 11 STA, 2 PAA, 1 TCA, 1 LICA, 5 TDA, 1 AICA, 4 SEA, 1 PICA, 4 UA, 1 RA, 1 DMA, 1 LCFA, 1 SGA, 7 PTA, 4 PA	63	57 180°, 6 90° (mean 171,4°)	43 tumor excision, 4 benign lesions excision, 4 Port-A-Cath exposure, 1 pressure sore, 10 trauma, 1 sternotomy wound dehiscence	23 nose, 1 retro-auricular region, 2 neck, 3 upper lip, 1 cheek, 2 lower lip, 6 breast, 2 pre-sternal, 1 scapula, 2 axilla, 1 lower back, 5 forearm, 1 dorsal fifth finger of the hand, 1 groin, 1 sacrum, 11 lower third of the leg	From 0.5x0.7 cm to 24x12.5 cm	3	Partial flap necrosis (3 pt) Arterial insufficiency, de-rotation needed (1 pt) Complete flap necrosis (1 pt) Infection of the donor site (1 pt)
Unal C, (49)	12	12 M; age range =24-56 yo (mean= 44.4 yo)	8 SGA, 4 IGA	17	Not specified	Chronic suppurative-hidradenitis	Gluteus and perianum	Not specified	8-36 (mean 20)	Dehiscence (1 pt) Completeflap necrosis (1 pt)
Chang SM, (87)	1	M; 28 yo	TA	1	135°	Open Achilles tendon rupture with overlying skin flap necrosis	Leg	Elliptical	Not specified	None
Bajantri B, (85)	1	M; 22 yo	Not specified	1	Not specified	Trauma	Leg	Not specified	Not specified	Skin graft needed to close donor site
Oh TS, (53)	11	5 F and 6 M; age range= 18-69 yo (mean=49 yo)	5 PICA, 3 TDA, 3 LA	11	Up to 180°	10 Tumor excision, 1 pressure sore	10 Posterior trunk, 1 flank	Not specified	8,2	Venous congestion (5 pts)
Schmidt VJ, (57)	1	F; 16 h-old	SGA	1	160°	Meningo-myelocele	Lower back	Elliptical	28	None
Cordova A, (8)	15	5 F and 10 M; age range= 62-94 yo (mean=75 yo)	STA	15	180°	Tumor excision	Nose	Not specified	6	None
Kosutic D, (51)	1	M; 23 yo	CSA	1	160°	Burn scar contractures	Axilla	Elliptical	1	None
Mateev MA, (24)	25	6 F and 19 M; age range=8-61 yo (mean= 32.2 yo)	5 UA, 4 RA, 2 DCA, 2 DMA, 1 SUCA, 8 PTA or PA,	25	Up to 180°	Burn scar or trauma	7 Hand, 6 forearm, 1 arm, 9 distal part of leg, 1 proximal	Elliptical; from 4x3 cm to 21x6 cm	Not specified	Complete flap necrosis caused by venous congestion, free scapular flap needed (1 pt) Partial flap necrosis,

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
			2 LMA, 1 DPA				part of leg, 1 foot plantar surface			skin graft needed (2 pt) Wound infection (2 pt) Hematoma (1 pt)
Rüegg EM, (56)	1	F; 68 yo	IMA	1	180˚	Radio-necrosis	Breast	Dualperforator propeller; 20x12 cm	12	None
Ono S, (54)	2	Not specified	SCA + DICA	2	180˚	Burn scar contractures	Neck and axilla	Elliptical, supercharged; 30x8 cm and 32x10 cm	Not specified	None
Murakami M, (25)	2	2 M; 71 and 70 yo	RCA	2	180˚ and 120˚	1 Bursitis, 1 radiation-induced ulcer	Elbow	Elliptical; 13x5 cm and 9x6 cm	Not specified	None
Karki D, (94)	20	20 M; age range= 16-70 yo (mean=38.2 yo)	14 PTA, 6 PA	20	180˚	Trauma	Leg	Elliptical	Not specified	Venous congestion (2 pts) Wound dehiscence, skin graft needed (1 pt) Partial flap necrosis (1 pt)
Kim YJ, (12)	5	Sex not specified; age range= 58-79 yo (mean=70.4 yo)	Not specified	5	180˚	Tumor excision	Lower eyelid	Not specified	8	Venous congestion (2 pts)
Nguyen DT, (52)	1	M; 55 yo	ITA	1	100˚	Keloid excision	sternal	Not specified	12	Erythema along the wound-edge union
Georgescu AV, (92)	24	5 F and 19 M; age range= 39-81 yo (mean=69.1 yo)	15 PA, 9 PTA, 1 ATA	25	Not specified	19 PAOD, 4 venous insufficiency, 1 frostbite	12 Foot, 13 lower leg	From 8x3 cm to 31x12 cm	6-51 (mean 33,6)	Skin graft needed to close donor site (20 pts) Partial flap necrosis (6 pts) Complete flap necrosis, lower extremity amputation needed (1 pt)
Prasad V, (55)	1	M; 71 yo	7th PICA	1	180˚	Tumor excision	Mid back	Elliptical; 40x15 cm	15	Hematoma underthe flap
Hsu H, (93)	2	2 M; age range= 27-70 yo (mean=48.5 yo)	Not specified	2	180˚	1 Trauma, 1 tumor excision	1 Knee, 1 distal thigh	1 Elliptical; 1 22x7 cm	Not specified	None
Kim do Y, (119)	1	F; 70 yo	LTA	1	100˚	Radiation-induced ulcer	Anterior chest	Elliptical; 16x7 cm	6	None
Okada M, (120)	1	M; 34 yo	TAA	1	180˚	Tumor excision	Cervical region	Elliptical; 15x6 cm	18	None
Cheng A, (58)	1	M; 33 yo	DIEA	1	115˚	Trauma	Abdomen	Elliptical; 30x17 cm	Not specified	Abdominal wall cellulitis
Ayestaray B, (95)	1	M; 52 yo	SIEA	1	100˚	Pressure sore	Trochanter	15x20 cm	24	None
Wong CH, (97)	1	M; 47 yo	Not specified	1	180˚	Trauma	Knee	Not specified	6	Necrosis of the patella
Sharma M, (96)	10	2 F and 8 M; age range= 45-76 yo (mean=62 yo)	Not specified	10	180˚	Closure of donor site of precedent skin graft	Fibula	From 10x4 cm to 16x5 cm	6	Partial flap necrosis (1 pt) Complete flap necrosis, skin graft needed (1 pt)
Boucher F, (26)	1	M; 42 yo	BA	1	180˚	Tumor excision	Elbow	Elliptical	Not specified	None
Thomsen JB, (61)	15	15 F; age range= 38-71 yo	TDA	16	Not specified	Tumor excision	Breast	4 With 2 perforators	From 1 to 11	Complete flap necrosis due to

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
		(mean=54 yo)							(mean 5)	venous congestion (1 pt) Flap accidentally rotated the wrong way, 2nd operation needed (1 pt) Minor complications (3 pts)
Chaput B, (27)	1	M; 83 yo	RCA	1	180°	Fracture	Olecranon	Not specified	Not specified	Edema Venous insufficiency Complete flap necrosis
Iida T, (59)	2	2 M; 60 and 63 yo (mean=61.5 yo)	ICA	2	180°	Closure of donor site of precedent free flap	Flank	Not specified	6	Loss of sensation in the flap (1 pt)
Moon SH, (60)	13	5 F and 8 M; age range= 21-79 yo (mean=56.2 yo)	SGA	13	180°	2 Pseudo-meningocele, 9 pressure sore, 2 hardware exposure	Lower back	Elliptical; from 5x11 cm to 10x28	7-31 (mean 26)	Complete flap necrosis due to venous congestion (1 pt)
Yoon TH, (16)	10	2 F and 8 M; age range= 35-75 yo (mean=61 yo)	2 LNA, 3 SLA, 5 FACA	10	6 180°, 4 120° (mean 156°)	8 Tumor excision, 1 venous malformation, 1 nostril stenosis	Nose	from 1x1.5 cm to 3x6 cm	3-6 (mean 4,8)	Venous congestion (2 pts)
Chang SM, (98)	12	3 F and 9 M; age range= 12-65 yo (mean=43 yo)	5 PA, 7 PTA	12	180°	6 Trauma, 4 iatrogenic skin flap necrosis or infection, 1 tumor excision, 1 pressure sore	Foot and ankle	From 4x8 cm to 6x18 cm	6-24 (mean 13)	Wound dehiscence (1 pt) Partial flap necrosis (1 pt) Paraesthesia of lateral dorsal foot (1 pt)
Tremp M, (109)	1	M; 23 yo	Not specified	1	180°	Trauma	Heel	Bone propeller flap	28	Fistula
Chaput B, (29)	1	M; 43 yo	RCA	1	120°	Extravasation of radiographic contrast medium	Elbow	Not specified	3	None
Royer E, (107)	1	M; 39 yo	PTA	1	180°	Open fracture	Tibia	Elliptical; 16x8 cm	Not specified	Partial flap necrosis
Kneser U, (13)	10	4 F and 6 M; age range=29-71 yo (mean=53.4 yo)	2 TCA, 1 DICA, 1 TAA, 2 IGA, 2 DFA, 1 RCA, 1 BA	10	Up to 180°	5 Tumor excision, 3 pressure sore, 2 trauma	1 Neck, 1 shoulder, 2 back, 2 ischium, 2 upper arm, 2 proximal lower extremity	From 4.7x1.6 cm to 29x9 cm	6	Partial flap necrosis (2 pts) Wound infection (1 pt)
Innocenti M, (103)	5	5 M; age range =26-72 yo	Not specified	5	90°-180°	3 Trauma, 1 infection, 1 post-knee replacement surgery	Knee	Chimaeric gastrocnaemius flap	3	Septicemia, above-the-knee amputation needed (1 pt)
Patel KM, (106)	1	F; 52 yo	DIEA	1	Not specified	Tumor excision	Thigh	Not specified	12	None
Alharbi M, (62)	5	4 F and 1 M; age range= 27-39 yo (mean=31.4 yo)	BA and SUCA	6 specified	Not	Hidradenitis suppurativa	Axilla	From 8x8 cm to 11x7 cm	6-21 (mean 13)	Delayed healing (1 pt)
Yuste V, (70)	1	M; 27 ho	SGA	2	Not specified	Myelome-ningocele	Lower back	Not specified	Not specified	Venous congestion

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Wettstein R, (69)	9	4 F and 5 M; age range= 61-84 yo (mean=69 yo)	SEA	9	90˚	Osteomyelitis after sternotomy	Chest	Not specified	12	Complete flap necrosis due to wound dehiscence (3 pts) Seroma/hematoma (3 pts) 2nd operation needed (2 pts)
Dong KX, (100)	20	8 F and 12 M; age range=5-75 yo (mean=28 yo)	15 PA, 5 PTA	20	Not specified	5 Spokes, 4 infection, 11 trauma	Lower third of leg and foot	From 5x11 cm to 12x28 cm	1-18 (mean 13,5)	Skin graft needed to close donor site (8 pts) Venous congestion (1 pt)
KT R, (105)	15	4 F and 11 M; mean age=32 yo	7 PA, 2 SGA, 1 DPA, 2 DMA, 3 not specified	15	90˚	Not specified	Lower limb	Not specified	24	Partial flap necrosis (2 pts) Venous congestion (1 pt)
Hashimoto I, (66)	35	Sex not specified, age range=19-84 yo (mean=62 yo)	IPA	56	90-180˚ (mean 131˚)	Tumor excision	28 Vulvar skin, 9 buttock skin, 6 vagina, 6 anus, 5 pelvic cavity	Width from 4 to 7 cm (mean 5.6 cm), length from 8 to 18 cm (mean 13,9 cm)	12	Partial flap necrosis (4 pts) Wound dehiscence (5 pts) Flap bulkiness, 2nd operation needed (1 pt)
Innocenti M, (104)	74	30 F and 44 M; age range=14-87 yo (mean=54 yo)	41 PTA, 10 DFA, ATA, PA, LCFA MSGA, LPCA, MPA	66	Up to 180˚	27 Trauma, 18 tumor excision, 17 postoperative complications of orthopedic surgery	Knee, distal third of the leg, Achilles region	From 5x2 cm to 25x15 cm	12-84 (mean 36)	Venous congestion (11 pts) Partial flap necrosis (9 pts) Complete flap necrosis (1 pt) 2nd operation needed (10 pts) Skin graft needed to close donor site (32 pts)
Schannen AP, (108)	1	F; 51 yo	PTA	1	180˚	Fracture	Ankle	12x6 cm	4	None
Cinpolat A, (99)	6	1 F and 5 M; age range= 13-55 yo (mean=37.6 yo)	MA	6	5 90˚, 1 180˚ (mean 105˚)	4 Electrical injury, 2 Benign tumor excision	Foot	From 4x2 cm to 8x4 cm	Mean 4,2	Venous congestion (2 pts)
Lepivert JC, (68)	1	M; 54 yo	SEA	1	180˚	Tumor excision	Hypochon-drium	11x20 cm	Not specified	None
Cordova A, (7)	25	9 F and 19 M; age range=67-90 yo (mean= 79.5 yo)	STA	25	180˚	Tumor excision	Nose	Not specified	Not specified	Venous congestion (2 pts, p.com.) Partial flap necrosis (2 pt, p.com.) Flap bulkiness, 2nd operation needed (1 pt)
Cöloğlu H, (64)	7	2 F and 5 M; newborns	LA and DICA	14	Not specified	Myelome-ningocele	Thoraco-lumbar	Bilateral; from 7x4 cm to 9x7 cm	4-16 mo (mean 10 months)	Venous congestion (3 pts)
Wettstein R, (32)	9	9 M; age range=28-83 yo (mean=57 yo)	RCA	9	180˚	8 Bursitis, 1 pressure sore	Olecranon	Up to 14 x 5 cm	Not specified	Partial flap necrosis, 2nd operation needed (1 pt) Formation of a fistula after removal of the suture material (1 pt)

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Panse N, (30)	62	24 F and 38 M; age range=9-51 yo (mean=34 yo)	7 UDA, 9 IOA, 15 UA, 20RA, 3 RUA, 2 RRA, 3 BA, 4 AXA	63	From 90° to 180°	31 Trauma, 30 burn sequel, 2 post snake bite defects	Upper limb	Not specified	1-6	Complete flap necrosis (4 pts) Partial flap necrosis (4 pts) 2nd operation needed (7 pts)
Hallock GG, (101)	2	2 M; 31 and 45 yo (mean=38 yo)	FDMA	2	Not specified	1 Infected callus, 1 benign tumor	Toe	Elliptical; 2.5x8 cm and 1.6x5 cm	9 and 12	Recurrent callus (1 pt)
Valentin GA, (111)	7	1 F and 6 M; age range= 59-78 yo (mean=64.7 yo)	PDA	7	3 90°, 4 180° (mean 141°)	2 Neuropathy, 3 diabetic ulcer, 1 trauma, 1 diabetes mellitus + trauma	Plantar forefoot	Not specified	7-17 (mean 9,8)	Delayed healing (1 pt)
Zang M, (71)	1	F; 66 yo	BA	1	180°	Radiation ulcer	Chest wall	15x6 cm	1	Skin graft needed to reduce tension in donor site area
Rout DK, (31)	1	M; 25 yo	TAA	1	Not specified	High voltage electric burn	Shoulder and arm	Not specified	12	Venous congestion
Angrigiani C, (63)	17	17 F; age range=38-66 yo (mean=55.1 yo)	TDA	19	180°	Not specified	Breast	From 28x7 cm to 36x8 cm	4-48	Partial flap necrosis (2 pts) Wound dehiscence (2 pts)
Corradino B, (65)	1	F; 61 yo	Not specified	1	90°	Fistula with a cutaneous opening	Sternum	Elliptical; major transversal axis 9 cm	48	None
Artiaco S, (28)	21	8 F and 13 M; age range= 22-86 yo (mean=54.5 yo)	3 RA, 2 DMA, 2 SUCA, 7 PTA, 3 PA, 2 LCFA, 1 GA, 1 ATA	21	Not specified	9 Tumor excision, 7 trauma, 4 surgical wound complications, 1 chronic osteomyelitis	2 Elbow, 3 dorsal aspect of the hand, 2 hand finger; 3 thigh, 11 leg or ankle	From 1x5 cm to 7x8cm in the upper limb; from 10x3 cm to 25x15 cm in the lower limb.	Not specified	Epidermolysis, resolved spontaneously (4 pts) Partial flap necrosis (3 pts) Skin graft needed to close donor site (2 pts) ALT free flap needed (1 pt)
Horta R, (102)	1	M; 50 yo	PTA	1	90°	Open fracture	Tibia	2 Perforators	Not specified	Skin graft needed to close donor site
Zheng HP, (115)	5	Sex not specified, age range= 21-58 yo (mean=37 yo)	DGA	5	180°	1 Tumor excision, 4 trauma	3 Distal antero-medial thigh, 2 knee	From 6.0x7.1 cm to 11.0x 20.1 cm.	6-9 (mean 7,4)	Tension blister (1 pt)
Zang M, (33)	2	1 F and 1 M; 35 and 60 yo (mean=47.5 yo)	Not specified	2	180°	1 Nevi resection, 1 tumor excision	Elbow	Elliptical, 17x8 cm and 11x7 cm	15 and 18 (mean 16,5)	Venous congestion and excessive skin tension over the pedicle, released by removing several sutures (1 pt)
Vaienti L, (110)	8	8 M; age range=33-68 yo (mean=46 yo)	PTA	8	From 90° to 180° (mean 144°)	Soft-tissue infection	Achilles tendon	2 Round; from 5x4 cm to 18x5 cm	15-38 (mean 21)	Venous congestion (1 pt) Partial flap necrosis (1 pt) Skin graft needed to close donor site (4 pts)
Karki D, (67)	44	19 F and 25 M; mean age= 17.1 yo	Not specified	12	90°	Burn scar contractures	Axilla	Not specified	12	None

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Ruiz-Moya A, (14)	12	5 F and 7 M; age range= 53-82 yo (mean=70.2 yo)	FACA	12	120˚-180˚	Tumor excision	Nasolabial and perinasal region	From 3.5x3.2 cm to 5x2 cm	12-18 (mean 13,8)	Partial flap necrosis (1 pt) Venous congestion, spontaneously resolved (1 pt) Trapdoor deformity (2 pts) Malar lymphedema (1 pt)
Scaglioni MF, (75)	1	M; 65 yo	DSEA	1	90˚	Tumor excision	Upper abdomen	Elliptical; 15 x 6 cm	37	None
Ayestaray B, (72)	1	F; 60 yo	SGA	1	100˚	Tumor excision and radio-chemo-therapy	Posterior vaginal wall	8x26 cm	12	Small sinus formation at caudal part of the flap after complete healing
Sekiguchi H, (35)	1	M; 58 yo	BA	1	180˚	Trauma	Elbow	14,5x6 cm	11	None
Gunnarsson (34)	34	18 F and 16M; age range= 37-93 yo (mean=64.6 yo)	Not specified	34	22 90˚, 12 180˚ (mean 122˚)	26 tumor excision, 6 scar correction, 4 chronic wound or trauma	13 lower limb, 11 upper limb, 10 trunk	From 1,5x3 cm to 12x22 cm	Not specified	Partial flap necrosis (7 pts)
Acartürk TO, (112)	2	2 F; 23 and 45 yo (mean=34 yo)	PA	2	Not specified	Trauma	Calcaneus and Achilles tendon	12x6 cm and 14x6 cm	19	None
Kang JS, (113)	1	M; 45 yo	PTA	1	180˚	Pressure sore	Lower third of leg	Not specified	3	Skin graft needed to close donor site
Cordova A, (9)	23	8 F and 15 M; age range= 43-82 yo (mean=65 yo)	DLA	23	180˚	Tumor excision	Oral cavity	From 4.2x3.7 cm to 6.5x4.5 cm	12	Infection of the neck soft tissues (1 pt)
Park SW, (74)	18	8 F and 10 M; age range= 18-80 yo (mean=53.2 yo)	Not specified	26	90˚-180˚	13 Tumor excision, 1 infection, 2 wound dehiscence from previous surgery, 1 pressure sore, 1 burn	Back	Not specified	4-86 (17,3)	Venous congestion (7 pts)
Børsen-Koch M, (121)	38	38 F; age range=38-73 yo (mean age=53 yo)	TDA	43	150˚-160˚	Tumor excision	Breast	Not specified	7-26 (mean 12,5)	Hematoma (1 pt) Partial flap necrosis (8 pt) Venous congestion (1 pt)
Zang M, (76)	7	3 F and 4 M; age range= 19-52 yo (mean=34.9 yo)	4DLICA, 3 LICA, 1 DICA, 1 AICA, 1 DIEA, 1 SEA, 1 SCIA	12	5 180˚, 4 150˚	Tumor excision	2 Back, 2 chest, 1 abdomen, 2 lumbar	1 With 2 perforators; from 6x6 cm to 30x20 cm (mean 9.4x21.2 cm)	Not specified	Partial flap necrosis, required debridement and another flap (3 pts)
Brunetti B, (73)	9	6 F and 3 M; age range= 45-76 yo (mean=63.4 yo)	ICA	9	180˚	Tumor excision	Trunk	From 4x9 cm to 6x13 cm	3-24 (mean 15,7)	None

Table II. *Continued*

Table II. *Continued*

First Author, (Ref #)	N° of pts	Demographic Data	Vascular territory	N° of p. flaps	Angle of rotation	Indication	Defect location	Flap shape and size	Follow-up in months	Complications
Zhong W, (114)	15	4 F and 11 M; age range= 22-58 yo (mean=39 yo)	PTA	15	180˚	15 Trauma	Lower limb	From 8x4 cm to 17x8 cm	11-22 (mean 15,3)	Partial flap necrosis (2 pts) Infection (1 pt)

AICA, Anterior intercostal artery; ALT, anterolateral thigh; ATA, anterior tibial artery; AXA, axillary artery; BA, brachial artery; CRA, collateral radial artery; CSA, circumflex scapular artery; d, days; DBA, deep brachial artery; DCA, dorsal carpal artery; DFA, deep femoral artery; DGA, descending genicular artery; DICA, dorsal intercostal artery; DIEA, deep inferior epigastric artery; DLA, deep lingual artery; DLICA, dorso-lateral intercostal artery; DMA, dorsal metacarpal artery; DPA, dorsalis pedis artery; DSEA, deep superior epigastric artery; F, female; FA, femoral artery; FACA, facial artery; FDMA, first dorsal metatarsal artery; GA, genicular artery; ho, hours old; HT, hospitalisation time; ICA, intercostal artery; IGA, inferior gluteal artery; IOA, anterior interosseous artery; IMA, internal mammary artery; IPA, internal pudendal artery; ITA, internal thoracic artery; LA, lumbar arteries; LCFA, lateral circumflex femoral artery; LICA, lateral intercostal artery; LMA, lateral malleolar artery; LNA, lateral nasal artery; LPCA, lateral popliteal cutaneous artery; LTA, lateral thoracic artery; M, male; MA, metatarsal artery; mo, months; MPA, medial plantar artery; MSGA, medial superior genicular artery; p. flaps, propeller flaps; PA, peroneal (fibular) artery; PAA, posterior auricularartery; PAOD, peripheral arterial obstructive disease; p.com., personal communication; PDA, plantar digital artery; PICA, posterior intercostal arteries; PNA, perineal artery; pt, patient; PTA, posterior tibial artery; pts, patients; RA, radial artery; RAA, retroauricular artery; RCA, radial collateral artery; RRA, recurrent radial artery; RUA, recurrent ulnar artery; SA, saphenous artery; SCA, superficial cervical artery; SCIA, superficial circumflex iliac artery; SEA, superiorepigastric artery; SGA, superior gluteal artery; SIEA, superficial inferior epigastric artery; SLA, superior labial artery; SLGA, superior lateral genicular artery; SMGA, superior medial genicular artery; STA, supratrochlear artery; SUCA, superior ulnar collateral artery; TA, tibial artery; TAA, thoraco-acromial artery; TCA, transverse cervical artery; TDA, thoraco-dorsal artery; UA, ulnar artery; UDA, ulnar digital artery; VAC, vacuum assisted closure; y, year/years; yo, years old.

In 2014, De Blacam *et al*. (125) performed a literature review on the distally based sural flap (Table VI). Comparing our results on lower limb, distally based sural flap showed significantly lower complication rate and flap loss rate than propeller flaps. As reported by D'Arpa *et al*., "free flaps are still the gold-standard for large defects in lower limb, but propeller perforator flaps are an appealing option for small and medium defects", especially at the level of the lower leg and foot (122, 126). Our results match those by Nelson *et al*. who found a 5.5% total flap loss rate and an 11.6% partial loss rate in the lower limb (127). Schaverien *et al*., using the islanded posterior tibial artery perforator flap to reconstruct lower limb defects, identified cigarette smoking, diabetes and peripheral vascular disease as important risk factors for partial and complete flap failure. They found that the complete and partial flap failure rate was reduced from 8.5 to 2.5 % and from 12 to 5%, respectively (84), excluding, however, patients who were smokers or had diabetes or peripheral vascular disease.

In relation to functionality and aesthetics, propeller flaps showed good satisfaction rates among both patients and surgeons, especially for the ability to reconstruct in a single-stage procedure. Preserving the underlying muscle provides lower donor site morbidity, preservation of functionality and reduced hospitalization time. Korambayil *et al*. reported a high rate of loss of sensation using propeller flaps for sacral and ischial soft tissue reconstruction (39); in our review, we only found 9 cases (0.7%) reporting loss of sensation/numbness/paraesthesia.

Table III. *Trend of complication rate in the articles published from 2005 to April 2015.*

Year	N° of patients reported	N° of patients with complications	Complication rate
2005	13	1	7.7%
2006	11	0	0%
2007	16	4	25.0%
2008	14	10	71.4%
2009	11	4	36.4%
2010	315	72	22.8%
2011	172	38	22.1%
2012	115	24	20.9%
2013	77	18	23.4%
2014	386	93	24.1%
2015 (until April)	110	17	15.4%

In infants and elderly patients, we observed a higher complication rate that could rely on worsening vascularization, comorbidities and dehydration. During the last years, there was not a reduction of the complication rate despite the increasing use of this technique. However, this statement has to be verified in further studies due to the heterogeneity of the publications included in this study.

In fact, the limitation of this work is the lack of standardization of patients' data of the studies included. Moreover, the absence of comprehensive studies about other

Table IV. *Advantages and disadvantages of using propeller flaps as a reconstructive technique.*

Advantages of using propeller flaps as reconstructive technique	Disadvantages of using propeller flaps as reconstructive technique
Short operating and hospitalization time Single-stage procedure No microsurgical anastomosis required Preoperative detection of the best perforators assures good safety of perfusion No need of particular staff expertise or complex logistic setup Possibility of reconstructing "like with like": (donor site and recipient area are made of the same tissue) Great freedom in choosing design, shape and dimensions High mobility of the flap, allowing rotation up to 360˚ (180˚ clockwise and 180˚ counterclockwise) Theoretical application in all body areas, where a useful perforator can be found The rotation of the flap allows partial coverage of the donor site as the remaining part can be sutured directly most of the times No sacrifice of muscles, fascia, nerves, source vessels or any unnecessary tissue (except for complex reconstructions) with preservation of function	Inability to cover large skin defects Occurrence of tension in the donor site and torsion of the perforator artery State of the tissues surrounding the loss of substance and future need for secondary surgeries must be considered The perforator artery must be carefully skeletalized from the surrounding tissues, such as side branches or fibrous bands Preoperative investigation of vascularization is always indicated due to multiple anatomical variants of the perforator vessels: at least two suitable perforators should be detected, giving the surgeon an alternative plan in case of issue The identification of perforators by Doppler examination can lead to possible false-positive and false-negative results, especially in areas where source vessels have a superficial location, as in the lower limb The 180-degree rotation allows maximal coverage of the donor-site defect for this technique but is also related to a higher complication rate due to the risk of twisting or kinking the pedicle if not of a proper length Although rarely (in our series, 0.4%), sometimes a useful perforator artery cannot be identified

Table V. *Comparison between Zhang et al.'s experience (124) and our results.*

	Microsurgical free flaps for head and neck defects (Zhang *et al*. (124))	Propeller flaps
Population	4,640 flaps	12 articles on head and neck/171 flaps
Complications rate (minor plus major complications)	10.42%	15.7%
Success rate	91.9-98.2%	100%
Most frequent complication	Venous congestion	Venous congestion
Notes		In this area, no skin graft was needed to close donor site thanks to the small dimensions of the flaps (mean size=17.2 cm^2)

Table VI. *Comparison between De Blacam et al.'s review (125) and our results.*

	Distally based sural flap, as described by De Blacam *et al*. (125)	Propeller flaps
Population	61 papers/907 patients (pts)	48 articles on lower limb/613 pts
Most frequent involved areas	Heel, foot, ankle	Lower third of leg, knee, foot
Most common indications	Trauma, ulcers, open fractures	Trauma, tumor excision, peripheral arterial obstructive disease, osteomyelitis
Complications' rate	26.4%	31.8%
Flap loss rate	3.2%	4.0%
Notes	Venous insufficiency and increasing age were independent risk factors for complications	Donor site could not be closed directly in 21.9% of cases probably due to the large dimensions of the defect to treat and the paucity of local tissues available for reconstruction

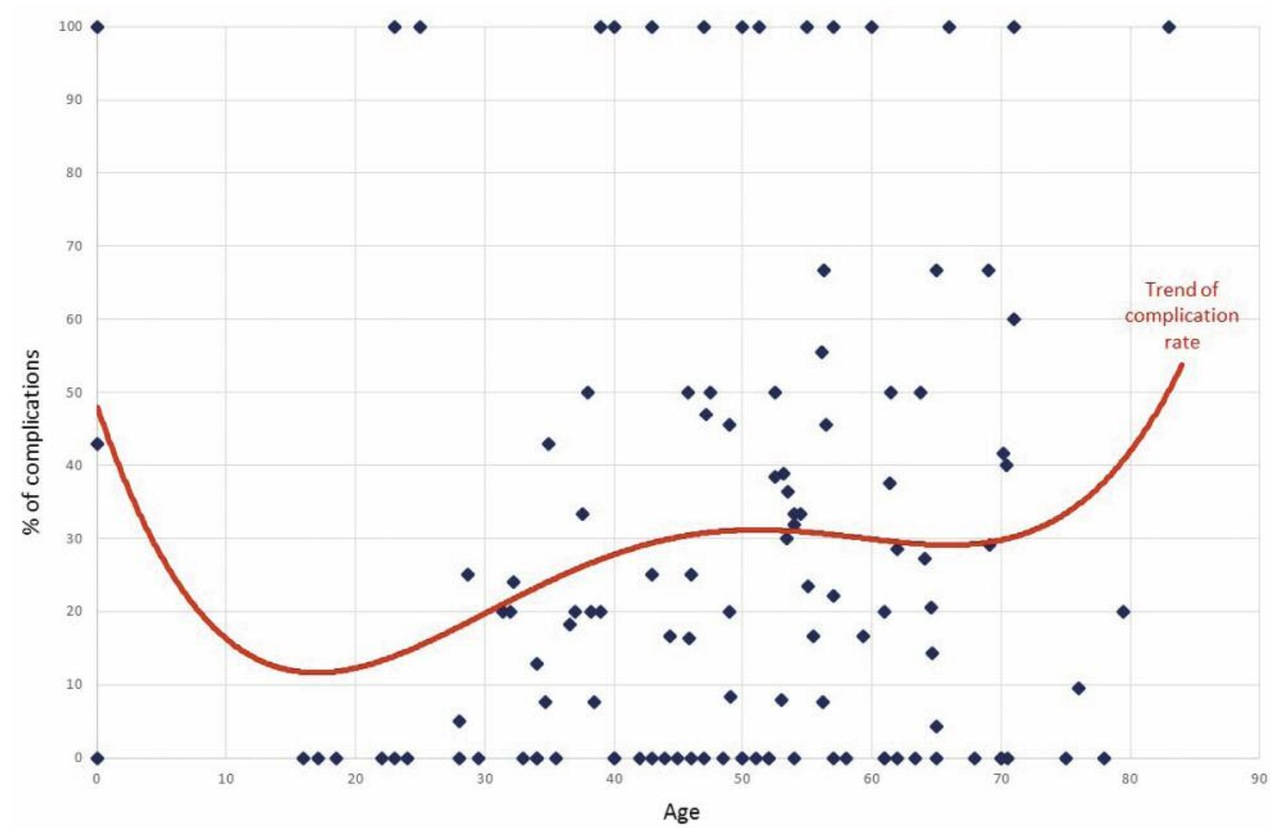

Figure 1. *Trend of complication rate according to age as it stems from the publications of the web-based search.*

techniques prevents us to perform a significant comparison of results.

Conclusion

Indications for propeller flaps are small- or medium-sized defects located in a well-vascularized area with healthy surrounding tissues. This reconstructive technique can be performed with a single-stage approach. More than vascularity and traditional length/width ratios, the most important factors to consider are the quality and volume of the soft tissue transferred, scar orientation and, above all, proper planning of the flap, in order to allow direct donor site closure without tension in the area.

When these indications were respected, propeller flaps showed great success rate with low morbidity, quick recovery, good aesthetic outcomes and reduced cost.

A comparison between the aesthetic results using propeller flaps and other reconstructive techniques has to be verified in further studies.

Conflicts of Interest

None.

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