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RESEARCH ARTICLE

VERSATILITY OF PERFORATOR-BASED PROPELLER FLAP IN RECONSTRUCTION OF VOLAR ASPECT OF DISTAL FOREARM, DISTAL LEG & ANKLE DEFECTS - A RETROSPECTIVE ANALYSIS

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Abstract

Background: The use of regional flaps based on perforator arteries is generating more interest in limb reconstruction surgery. The surgical approach allows for the restoration of soft tissue lesions using neighboring homologous tissues without the need for microvascular anastomosis. The aim of the study was to evaluate the clinical results of local perforator flaps in the treatment of complex lower limb and upper limb defects.

Materials and Methods: Fourteen patients (six upper limb and eight lower limb defects) underwent reconstruction using perforator-based flaps which were studied retrospectively during a three-year period. Donor sites were examined thoroughly and flaps selection was done using a handheld manual Doppler mapping preoperatively, to locate the perforator vessels and their flow. Thereby, perforator-based propeller flaps were raised and used for defect coverage based on their maximum arc of rotation.

Results:Postoperatively, all the flaps included in the study survived. Partial flap necrosis and venous congestion in the flap were reported in two patients following intervention. Donor site morbidity was minimal without any loss of function. Most of the patients were satisfied with the aesthetic outcome.

Conclusion: Perforator flaps using hand held Doppler are the most yielding, simple and safe flaps for the Reconstructive Surgeons. The need for the complicated microsurgical procedures can be avoided with the use of such locoregional propeller flaps which providedbetter aesthetic results with minimal donor site morbidity.

Introduction: -

Since the advent of innovative local flap models in recent years, the approach of treating soft tissue abnormalities in the upper and lowerextremities has altered and improved in cutaneous anatomical understanding. Numerous forms of perforator flaps that are currently used in clinical practice were developed owing to the subcutaneous and intramuscular vessels that originated from the major vascular axis of the limbs.[1-3]The Gent consensus flapstates that perforator flaps are made up of regions of cutaneous and subcutaneous tissue that are supplied with blood from perforator branches that arise from deep vascular axis and follow either an intramuscular (MCPF) or an intraseptal (SCPF) course.[4] The local perforator-based flap extends noticeably farther than the normal V-Y flap when providing

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coverage via V-Y advancement.[5] The local perforator-based flap is isolated and twisted around the perforator branch as a propeller in the pedicle torsion harvesting method for a maximum angle of 180 degrees.[6]According to the original concept, Hyakusokuet al. introduced propeller flap method to treat burn scar contractures.[7] The propeller flap's blades can be constructed using a "freestyle" method that follows the origin and orientation of the cutaneous paddle of the perforator vessels and differs in size depending on the faulty characteristic.[8] According to Georgescu et al., local flap technique can be classified as a microsurgical or non-microvascular flap even if it necessitates microsurgical dissection but not vascular suturing.[9] In contrast to microvascular flaps, vascular sutures can be avoided, and the pedicle can be skeletonized under loop magnification rather than always under a microscope. Deficit reconstruction produces the best outcomes from an aesthetic standpoint since the like-with-like reconstruction principle is respected by using donor-tissue regions close to the defect. All of these benefits help explain why local perforator flaps are increasingly used in reconstructive microsurgery of the upper and lower limbs in both simple and severe cases of substance loss. The biggest clinical trial to date was disclosed by Georgescu et al.for correcting substance deficiencies in the hands and forearms.[9]Reconstruction of the trunk, head, and perineal region has also been addressed in terms of clinical uses.[10,11] As far as the lower limb and upper limb are concerned, a single perforator vessel may nourish a sizable fasciocutaneous area, even in areas that are thought to be inaccessible or vulnerable to local flaps, such as the volar aspect of the distal forearm and wrist and the inferior third of the leg and ankle. According to Teo, the radial, ulnar, and posterior tibial arteries in the forearm and leg, respectively, are the sources of the primary perforators. The first two vessels and ulnar artery are the easier ones on which the flap can be based.[6] Propeller flaps elevated from the distal anteromedial side of the thigh and nourished by perforator branches of the saphenous, femoral, and descending genicular arteries can also be used to cover the peri patellar region.[12] As a result, the propeller flaps can be used in lower-limb and upper-limb reconstruction for a variety of clinical purposes, such as the repair of post-traumatic defects, the removal of cancer, and the healing of wounds that have dehisced following surgery, such as those caused by the treatment of fractures, knee replacement with a prosthetic implant and trauma/surgeries in and around the Tendo-Achilles region. The aim of this study was to evaluate clinical results of local perforator-based propeller flaps in treating complex lower-limb and upper limb defects. We present a retrospective analysis of propeller flaps performed in a group of patients affected by loss of substance of lower limb and upper limb operated in our departments.

Materials andMethods:-

The present case series involved 14 patients operated over a period of 3 years. All patients admitted underthe Burns and Plastic Surgery department, in a specialized tertiary care center, were included in the study. All patients gave their informed signed consent prior to being included in the study. The study was performed according to the institutional ethical guidelines. The study involved ten men and four women, with the mean age at the time of surgery ranged from 20-62 years. Etiology included eight post-surgical soft tissue loss with exposed bone in the lower extremity, involving Tendo-Achilles region (n=3), lower 1/3rd of leg (n=3), and medial malleolar region (n=2). Upper extremity defects involved post-surgical defects especially loss of substance in the volar aspect of wrist (n=3), post burn unstable scar over the wrist (n=2) and a single post traumatic defect over the wrist and distal forearm (n=1). None of the patients were lost to followup [Table 1].

Table 1:- Summarizes the detail characteristics, size and location of the defect for all the patients, the originating perforator artery on which the flap was raised and the postoperative complications.

Age	Sex	Etiology	Location of defect	Defect size (cm)	Perforator source vessel	Complication
56	M	Postsurgical	TA region	6 x 4	PAP	Nil
62	M	Postsurgical	TA region	6.5 x 4	PAP	Nil
38	M	Postsurgical	MM	5 x 4	PTAP	Nil
26	M	Postsurgical	Lower 1/3rd leg	7 x 5	PTAP	Flap Necrosis
34	M	Postsurgical	Lower 1/3rd leg	10 x 6.5	PTAP	Venous congestion
22	M	Postsurgical	MM	5 x 4	PTAP	Nil
24	F	Postsurgical	TA region	5 x 4	PAP	Nil
28	M	Postsurgical	Lower 1/3rd leg	6 x 4	PAP	Nil
20	F	Postsurgical	Wrist	5 x 4	UAP	Nil
23	F	Postsurgical	Wrist	6 x 5	UAP	Nil
30	F	Post-burn unstable Scar	Wrist	5 x 4	UAP	Nil

32	M	Postsurgical	Wrist	5 x 4	UAP	Nil
24	M	Trauma	Wrist	7 x 4	UAP	Nil
26	M	Post-burn scar	Wrist	6 x 4	UAP	Nil

M=Male, F=Female, cm = centimeters, PAP = Peroneal artery perforator, PTAP = posterior tibial artery perforator, UAP = Ulnar artery perforator, TA = Tendo Achilles, MM = Medial malleolus

Surgical technique:

A handheld ultrasound doppler scanner was utilized preoperatively to detect perforator arteries in the donor-site area.[13] At the locations where, perforating vessels emerge on the fascia, we drew a color Doppler duplex image on the skin. Based on this, the flap's design was determined by the location and size of the flap, the perforator vessel caliber, quality of Doppler sound signal, flap pattern and mobility, and the need to avoid placing too much tension on the propeller flap's border while suturing. An exploratory incision was made when the procedure was done in an emergency to locate a perforator artery suitable for harvesting a free-style perforator flap. Magnification loupes (2.5-4.5X) and microsurgical tools were used during procedures, along with a cautious blunt dissection. To clearly see, an exploratory incision was performed, typically using a sub fascial technique to identify the vessels that perforate. Prior to flap harvesting, perforator arteries were chosen based on vessel size and proximity to the defect. The perforator artery's site of emergence from muscle or fascia served as the focal point for the flap's design, which centers the movement of the propeller blades. The features of the lesion and the donor site determined whether to include fascia in the flap especially in case of bone exposure. The vascular pedicle was preserved with special care during the dissection process taking care to dissect out the adjoining tissue in order to avoid kinking of the pedicle during rotation. At least 1.5 cm of the perforator branch was isolated from the pedicle during dissection, and pedicle traction was carefully avoided throughout flap harvesting and positioning. In order to encourage microcirculation recovery, perfusion was tested prior to flap rotation by waiting a few minutes and irrigating the skin paddle with lukewarm saline solution. After propeller rotation, the small skin paddle assisted in the closure of the biggest portion of the donor site. Direct closure of the donor site without tension edge of the flap was attempted wherever possible. In all patients, skin grafts were required to cover the secondary defect, as direct closure was not possible. Ten days of immobilization was advised following surgery. At the end of the surgical intervention, carefully placed drains were then put in place. Typically, drains were removed after 24 hours. The limb was kept elevated and bandaged gently to prevent compression over the flap. In order to regulate skin tone and temperature without removing the bandage, a window like small opening was created in order to monitor the flap status [Figures 1-2].

Figure 1:- Ulnar artery perforator-based propeller flap used in the reconstruction of forearm and wrist defect**.** (A) Preop, (B) perforator dissected, (C) flap raised, (D) flap propelled into the defect, (E) flap inset, (F) 1 month postop.

Figure 2:- Posterior tibial artery perforator-based flap used in the reconstruction of lower 1/3rd leg defectwithexposed tibia. (A) Preop defect, (B) doppler marking of perforator, (C) intra-op isolation of perforator, (D) correlation with preop marked perforator, (E) Flap raised, (F) Flap propelled into the defect, (G) Flap inset, (H) 1 month postop.

Results:-

All the fourteen flaps that were studied, survived well post operatively with lesser complications and donor site morbidity. Out of these fourteen patients, eight patientsunderwent distal leg reconstruction and six patients were planned for reconstruction over the volar aspect of wrist. Donor site could not be closed primarily therefore split thickness split grafting was performed in all the patients. None of the patients reported any functional loss, but reported minimal scarring, pain and itching at the donor sites especially over the thighs where the grafts were harvested. From the fourteen participants, only two patients had major complications, one patient with tip necrosis of flap which required debridement and re-in setting of flap later on, and another with immediate post-operative venous congestion, which got relieved with removal of sutures. No total flap loss was reported in the series. The advantage of such flaps was noticed by theircolor and contour matching thereby, produced a better aesthetic outcome. At the end of the procedure, carefully placed drains were then used. Three patients had temporary venous congestion of the flap as minor complications which required only observation and no further intervention. Sometimes the affected limb displayed transient edema. Prolonged leg edema (six months) with spontaneous resolution was observed in patient with a large propeller flap coverage over Achilles tendon region, which disappeared in six months with the use of compressive stockings, and good functional and aesthetic result was obtained.

The precision of doppler signals were found to be accurate during mapping, which otherwise helped in perforator selection. Flap mobilitydepended upon the perforator dissection, the extension to where it can reach, and the arc of

rotation. Sometimes, reaching up to the source vessel helped in further mobilization of the flap. Both clockwise and anticlockwise rotation movement up to 180^0 was planned depending on the reach of the flap to cover the defect. The rotation was planned in such a manner not to impair the flap's viability. Flap design was outlined based on the size and shape of the defect. Maximum defect size of 10.5 x 6.5 cm^2 and minimum of 5 x 4 cm^2 defect was reconstructed using different perforator-based propeller flaps. The surgery time ranged between 3 to 5 hours for all the cases. The stay in the hospital ranged from 10-15 days depending on the patient and flap's condition. Six patients who had undergone upper limb reconstruction were advised for early mobilization, whereas those who had undergone lower limb reconstruction (n=8), were advised for delayed mobilization. Each patient was followed up at regular intervals up to 6 to 12 months. The functionality, color match, sensory and motor functions were checked in every visit with photographic documentation.

Discussion:-

Propeller perforator-based local flaps in carefully chosen cases, fulfilled these criteria. For both simple and complex upperand lower-limb abnormalities, the optimum reconstruction strategy should replace like-to-like tissue, minimal donor-site morbidity, retain primary circulatory trunks, and reduce operating and hospitalization time. Improved understanding of the arterial basis of flap perfusion has facilitated the development of propeller flaps in reconstructive microsurgery, and anatomical studies on lower limb and upper limb vascularization provided the basis for local perforator flap design in treating forearm and leg defect.[1,2, 12-15] The harvesting of delicate skin flaps is possible thanks to the sub dermic vascular network's exceptional richness. Due to the expansion of possible vascular regions that move to the flap's peripheral border, a single perforator vessel that is positioned eccentrically in reference to a skin paddle may be able to sustain a significant amount of skin. The increase in blood pressure that occurs in the perforator artery following the closure of the subcutaneous and intramuscular branches during flap harvesting promotes the process of vascular adoption. Propeller flaps' adaptability, which allows them to be chosen on the perforator artery based on the type of defect and harvested either in free or local form, is one of its key characteristics. Because it is a local flap, the perforator-based cutaneous paddle may fill the defect directly or by twisting the vascular pedicle. Toe has painstakingly and step-by-step explained the ideas for lower limb and upper limb restoration with perforator local flap.[6] This author also emphasized the significance of these flaps in protecting the heel, Achilles tendon, and lateral malleolar tissues. Alternative non-perforator local flaps are typically not effective in treating defects in these anatomical regions, despite the fact that they are frequently minor. The ideal quality of tissues transferred for defect regeneration significantly improves the valve of perforator local flaps. Contrarily, it has recently been discovered that the presence of tendons and the inadequate length of the perforator in the lower part of the leg and the ankle region may prevent flap transposition.[16]In the past three years, a number of clinical investigations have reported on the use of propeller flaps and their outcomes in 35 of 59 patients who underwent perforator flap surgery for abnormalities resulting from oncological surgery, trauma, and unstable scars. In four propeller flaps performed on patients who were either heavy smokers (three) or diabetic (one), they reported four unidentified flap losses and discovered partial necrosis with secondary healing.[17]Eight patients with abnormalities in the malleolar region were treated by Jaskubietz et al. using 180-propeller flaps based on perforators from the tibial and peroneal arteries.[18] Additionally, a partial flap loss was observed in this case series and was handled by skin grafting. Leg edema that was just temporary was seen in all subjects. Finally, Pignatti et al. identified six patients who had abnormalities in their Achilles tendon, tibia, and knee.[19]In other instances, a momentary venous congestion was seen and dissipated on its own. In the subsequent two case series, there was no evidence of flap necrosis. [20,21]Our study's primary limitations were that it was retrospective and that it comprised a variety of upper and lower limb sites. No additional surgical treatment was necessary because all patients recovered. The aesthetic outcome was generally excellent, and patients were completely satisfied. Postoperative compilations were observed in one of 12 patients with partial flap tip necrosis. There have been instances of transient leg edema with huge propeller flaps. Because like-to-like tissues were used, the propeller perforator-based local flaps used in the repair of very small loss-of-substance cases produced minimal donor-site morbidity and produced good aesthetic results. There was no specific medical care needed, and the operation took less time. The failure of the flap, which could result in substantial loss of tissue and an amount more than the area of the previously corrected defect, is a potential risk of this operation. This unfortunate occurrence confirms the need for adequate microsurgical expertise and specialized dissection training before carrying out this challenging technique. For body parts where, local reconstructive treatments are not an option, perforator flaps may be a useful alternative to free flaps. The positive outcomes for lower-limb and upper-limb reconstruction documented in the literature and our own experience are encouraging. We think this approach should be considered as one of the potential reconstructive options when the defect's characteristics allow for treatment using propeller-based local flaps. However, when it comes to sophisticated reconstruction involving composite or functional flaps, large cutaneous areas are still best covered

using free flaps. The use of microsurgery may be crucial in the treatment of orthopedic and trauma patients, and expertise in microsurgical procedures is becoming more and more important. In reality, microsurgery aids in the treatment of complex trauma in emergency scenarios and may enable the design of reconstructive surgeries, limb-salvage operations, post-oncological resections, and post-burn contracture operations.

Conclusion:-

The evolvement of local perforator-based propeller flaps, have made it easier to plan a soft tissue defect reconstruction based on its free style nature, simple, safe and reliability of the perforators. Even though, free flaps yield better aesthetic outcome in comparison to pedicled flaps, yet greater freedom of flap selection can be planned out skillfully based on its free style nature. In addition, functional loss, and donor site complications can be avoided easily. Therefore, in many emergency and non-emergency situations, perforator-based propeller flaps can be planned using a simple handheld doppler device.

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Conflicts of interest

None declared.

Declaration of patient consent

All informed and duly signed consent forms have been obtained from each patient prior to surgery. The article does not reveal the patient's identity, phone number, address, or any other personal details which was non-relevant to the article. The patients had given consent regarding his/her/their pictures to be published in the article.

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