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Review Article

Reverse dorsal metacarpal artery flap: a review

Erick Hidrogo Ordaz[1]*, Ezequiel Salcedo Ignacio Ayala[1], Luis Fernando Bustamante Sánchez[1], Luis Carlos Dávila Kutugata[1], José Enrique Santiesteban Inzunza[1], Iberia Maria Ossa Nájera[2], Pablo Alberto Mendoza Sánchez[3], Hector Ulises Quiroga Jiménez[4], Rogelio Romero Vázquez[5]

[1]Department of Surgery, ISSSTE Hospital General Dr. Francisco Galindo Chávez, Torreón, Coahuila, México
[2]Department of Surgery, Hospital General De Reynosa, Reynosa, Tamaulipas, México
[3]Department of Surgery, Hospital General Dr. Miguel Silva, Morelia, Michoacán, México
[4]Faculty of Medicine, Universidad Autónoma De Nuevo León, Monterrey, Nuevo León, México
[5]Department of Surgery, Hospital General, Rio Bravo, Tamaulipas, Mexico

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***Correspondence:**
Dr. Erick Hidrogo Ordaz,
E-mail: dr.erickhidrogo@gmail.com

ABSTRACT

Deep soft tissue injuries around the thumb can significantly impair hand function if not managed appropriately. Various surgical options exist for treating these complex lesions, including microsurgical flaps, local flaps, and distant pedicled flaps. The dorsal metacarpal artery (DMCA) family of flaps belongs to the latter category. These versatile flaps can be designed as racquet-shaped, island, or bilobed flaps, utilizing the first DMCA alone or in combination with the second DMCA. In this review, we explore the surgical anatomy, techniques, and clinical applications of reversal DMCA flap (RDMA).

Keywords: RDMA, DMCA flap, Dorsal digital flap, Dorsal branch of the digital artery

INTRODUCTION

Digital tip injuries with bone and tendon commitment, are lesions of difficult coverage which over time have been treated with advance flaps, free flaps, or two-stroke surgeries that limit the mobility of the limb.

DMCA-based flaps are an important resource when it comes to reconstructing digital injuries. The flaps have evolved in recent years in the practice of hand surgery. They are versatile and can be used as simple advance flaps, transposition flaps or island flaps. Over the years and with the development of the DMCA-based flap technique, it has been possible to cover lesions both on the palmar and dorsal surfaces of the thumb, as well as on the proximal palm and on the almost entire dorsal surfaces of the fingers especially in lesions with bone and tendon exposure, a method to cover distal and complete digital lesions was also developed with the extended RDMA. The development of the DMCA, RDMA and extended RDMA, have revolutionized the management of these lesions in expert hands with minimal morbidity at the donor site with exceptional functional and aesthetic results.[1]

HISTORICAL REVIEW

Defects of the soft tissues of the fingers with involvement of the bone and tendon have been an important factor in the need for the development of coverage techniques in this area. The first flaps of the hand and some other parts of the body raised the principles of the based on the random supply of blood, in addition to using simple flaps of rotation, advancement and transposition, which decreased their success rate, increased their complications and increased morbidity in the injured area as in the

donor area. The vascular anatomy and the sources of blood supply in the flaps of the hands have been studied more thoroughly over time. Simple flaps without a described irrigation, or at random, continue to help in digital injury coverage mainly in small or superficial lesions; mainly because they are limited by the amount of stance, they have limitations with respect to the early mobilization of the limb, sometimes, they are flaps that require multiple surgeries to be performed.[1] The second metacarpal artery was initially described in 1928 by Adachi in Japan.[2] Lister described a flap likely based on this artery in the 1950s, which he called an axial flag flap from the dorsum of the hand.[3] Earley and Milner performed a cadaver study that confirmed the anatomy of the second DMCA and helped to outline and popularize the second DMCA flap.[4] Constant distal perforators from the common palmar digital arteries between the metacarpal necks that anastomose with the DMCA were originally described by Foucher and Braun in 1979.[5]

In 1990 and Muruyama raised the principles of how the skin on the back of the hand could advance taking advantage of the vasculaturs of the DMCA.[6] Although the use of RDMA to make flaps of the back of the hand to cover digital injuries was planned by Maruyama and Quaba, it took many years to fully exploit the RDMA-based flaps.[6] Beldame et al showed communication between dorsal metacarpal arteries and palmar digital arteries in their anatomical studies. In the same study, they detected plexiform communications especially in the distal juncture.[7]

In 1997, Santa-Comba and colleagues described the use of the RDMA as an osteocutaneous flap. This technique enabled the reconstruction of proximal phalangeal defects involving missing soft tissue, extensor tendon, and bone with a single flap.[8]

A variety of RDMA has also been described for distal defect coverage, the extended RDMA, changing the pivot point of the flap to the proximal phalanx using the connections between the dorsal metacarpal and the palmar digital arterial systems at the level, to reach distal defects and even for nail coverage.[9]

INDICATIONS FOR REVERSAL METACARPAL ARTERY FLAP

The flaps with reverse irrigation are mainly indicated in the closure of deep lesions with bone or tendon exposure at the level of the first proximal phalanx of the finger in which the coverage is planned, so its first indication would be in lesions of the proximal phalanx, since the anastomoses of the DMCA at the level of the proximal head of the first phalanx with the adjacent metacarpal artery or the digital artery, allows us to use this area as a good pivot point with a distal range limitation (Figure 3). For digital tip distal injuries, the proximal phalanx of the finger in which the coverage is planned is used as a pivot point, which increases the range of distal coverage, by the extended RDMA (Figure 4). This type of flaps, due to their versatility, can be planned in different ways, extensions and coverage sites, they are mainly based on the distal connections between the palmary metacarpal arteries and the dorsal metacarpal arteries and/or the digital artery. Due to the consistency of the connection between the distal dorsal metacarpal arteries and the palmary metacarpal arteries, they can be designed on the second, third and fourth intermetacarpal spaces based on the second, third and fourth dorsal metacarpal arteries, respectively.

SURGICAL ANATOMY AND TECHNIQUE

The second, third and fourth DMCA come from the perforating branch of the deep palmar arch. At the bases of the proximal phalanxes of the two adjacent fingers, the DMCA branches into two dorsal digital arteries (Figure 1).[10] The arterial pattern of the dorsum of the hand is both complex and variable. In most cases, the second DMCA lies in a line connecting the anatomic snuffbox to the second web. The artery arises from the dorsal carpal arch and runs above the fascia of the interosseous muscle deep to the extensor tendons of the index finger. The artery and its paired small venae combatants run distally on the fascia in the second intermetacarpal space, extending several branches to the adjacent metacarpal bones, interosseous muscle, and the overlying skin. One or more perforating vessels linking the DMCA to the palmar digital artery are frequently found between the second and third metacarpal heads. As it approaches the second web the DMCA runs superficially to enter the fat pad.[11] The dorsal branches of the digital artery present an orderly and consistent distribution and location. These branches allow us to create the DMCA flaps (Figure 2).[12]

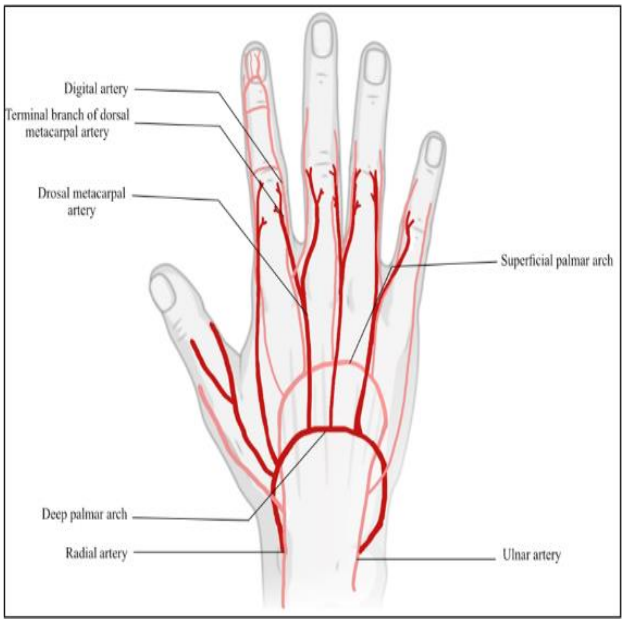

Figure 1: Irrigation of the dorsal hand.
Dorsal irrigation in red (deep) and palmar irrigation in pink (superficial). Created with BioRender.com.

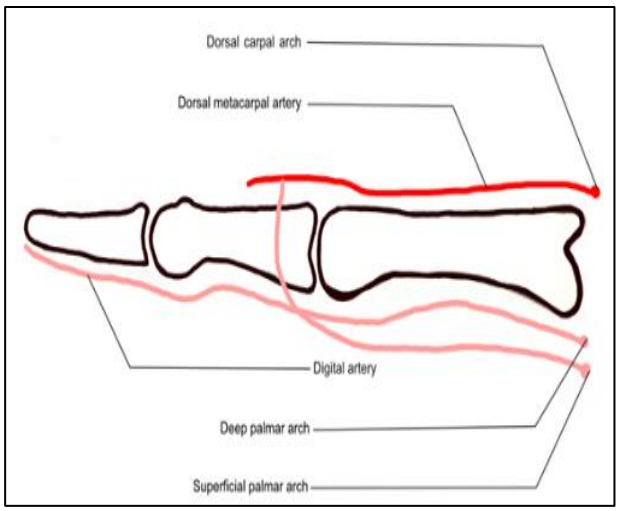

Figure 2: Lateral view of dorsal branches of digital artery.
Dorsal-red, palmar-pink, created with BioRender.com.

The operation is performed under axillary block with the aid of tourniquet control. The flap is designed on the back of the hand, in the non-adjacent site between the midpoint of the phalanx and the proximal third of the proximal phalanx. The size of the flap is designed between 10 and 15% larger than the defect (Figure 3).[13]

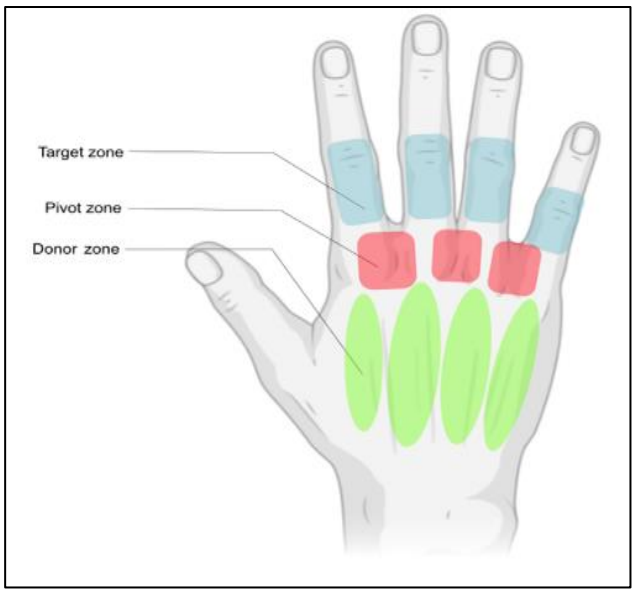

Figure 3: RDMA planning.
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The flap is designed in the intermetacarpal spaces as an ellipse centered on the DMCA. The flap rises from proximal to distal. The DMCA is linked in the proximal margin of the flap, and then the flap rises in the interosseous fascial plane. The dorsal digital artery that was derived from DMCA is identified and dissected with surrounding subcutaneous tissue 1 cm wide. The pivot point of the flap is located at the midpoint of the proximal phalanx, where the proximal dorsal branch of the digital artery is anastomose with the dorsal digital artery (Figure 2). To avoid compression after the transfer of the flap, a strip of skin 3 mm wide is harvested with the pedicle. The flap is transferred to the defect through an open tunnel. Hemostasis is achieved and the primary closure of the defect is performed at the donor site in all patients. The intermediate skin between the flap and the defect is incised to accommodate the pedicle. Then, the flap is transferred to the defect and sutured. The insertion is stress-free and the twisting of the pedicle is excluded. The hand is immobilized in a neutral position with a flight splint. We make sure that the strict lifting of the hand has been carried out for at least 7 days after the operation in all patients. The flap is regularly monitored to detect vascular involvement. If venous congestion is observed, sutures are removed to decongest the flap and the patient is monitored for a longer period of time in hospitalization.[13,14]

The most distal level defects cannot be covered with conventional RDMA flaps. For this reason, extended RDMA flap is used. The pivot point of extended RDMA, defined in 1997, is the middle of the proximal phalanx, where the DMCA and palmar common digital artery are anasotmosed.[15] The study of Shen et al stated that there is no significant difference between the classical RDMA flap and the extended in terms of complications. While the complication rate is 14% in classical RDMA flaps, it is 17% in extended RDMA flaps (Figure 4).[16]

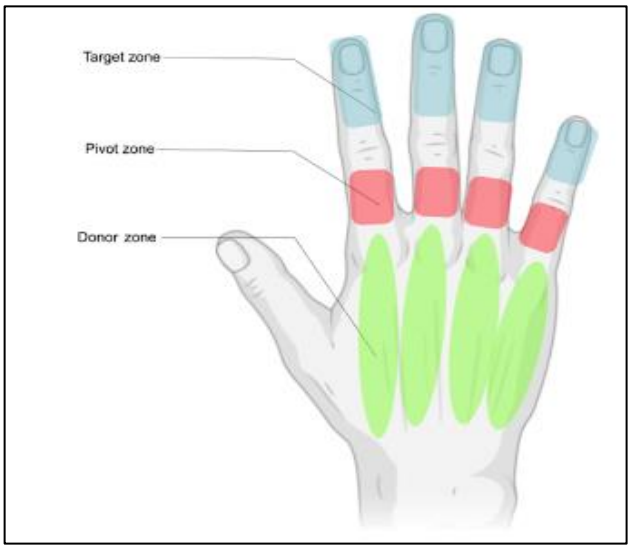

Figure 4: Extended RDMA planning.
*The four and five metacarpal arteries cannot always be used to RDMA.[22] Created with BioRender.com.

CLINICAL OUTCOMES

The reverse metacarpal artery flap is a well-established technique used for the reconstruction of soft tissue defects in the hand. Clinical results have generally shown favorable outcomes in terms of both functionality and aesthetics. Most patients achieve significant functional recovery postoperatively, experiencing a good to

excellent range of motion in the affected digits. Over time, grip strength and dexterity typically improve, often approaching pre-injury levels. Additionally, the reverse metacarpal artery flap provides a good color and texture match with the surrounding tissue, resulting in aesthetically pleasing outcomes. Minimal donor site morbidity is observed, with scars usually well-concealed and acceptable to patients. Sensory restoration in the flap, however, can be variable; while some patients report satisfactory sensory return, others may experience diminished sensation. Techniques such as nerve coaptation can improve sensory outcomes. Overall patient satisfaction is high, with many patients reporting an improved quality of life and satisfaction with the surgical results.

PROBABLE COMPLICATIONS

While the reverse metacarpal artery flap is associated with high success rates, several potential complications can arise, including compromised flap perfusion or venous congestion, the latter being the most frequent, can lead to partial or total flap necrosis, making it crucial to ensure proper surgical technique and postoperative care to mitigate this risk. As with any surgical procedure, there is a risk of infection at both the donor and recipient sites, necessitating prompt identification and treatment with antibiotics. Factors such as poor vascularity, diabetes, or smoking can contribute to delayed wound healing, highlighting the importance of careful patient selection and management of comorbidities. Although minimal, complications at the donor site can include hematoma, seroma, and decreased hand function, which are typically managed conservatively and tend to resolve over time. Some patients may experience persistent numbness or altered sensation in the flap or donor area, often due to nerve damage during flap harvesting or inset. Additionally, in rare cases, patients may experience decreased hand function due to stiffness, tendon adhesions, or joint contractures, and physical therapy is often recommended to improve functional outcomes.

DISCUSSION

Finger injury with exposed bones, tendon or neuromuscular bundles is frequently encountered in the emergency department. RDMA-based flaps are an important tool that have had a very significant evolution in recent years.[1] The second metacarpal artery was initially described in 1928 by Adachi in Japan.[2] Lister described a flap likely based on the RDMA in the 1950s, which he called an axial flag flap from the dorsum of the hand.[3] Earley and Milner helped to popularize the second DMCA. The use of RDMA to make flaps of the back of the hand to cover digital injuries was planned by Maruyama and Quaba, it took many years to fully exploit the RDMA-based flaps.[4,6] Beldame et al showed communication between dorsal metacarpal arteries and palmar digital arteries in their anatomical studies.[7]

In 1997, Santa-Comba and colleagues described the use of the RDMA as an osteocutaneous flap. A variety of RDMA has also been described for distal defect coverage, the extended RDMA, changing the pivot point of the flap to the proximal phalanx using the connections between the dorsal metacarpal and the palmar digital arterial systems.[8,9]

The ideal cover is one which gives best aesthetic as well as the functional outcome.[17] The skin over the dorsum of the finger is thin and pliable; because of this, its reconstruction is also challenging. The options of reconstruction of finger defects vary from local flaps to free tissue transfer.[18] For small defects various reconstructive procedures have been described for digital defects reparation, including V-Y advancement flap, a rotation flap, or a reverse digital island flap. For moderate defects cross finger flap, especially the adipofascial variant is commonly used. For dorsum of the fingers, the use of free tissue transfer is reserved for bigger defects, unlike for volar and fingertip defects.[14,19]Arterialised venous flaps are also used for large dorsal finger defect associated with dorsal hand defects especially when the local options are not available. The digital artery flaps sacrifice the main artery of the finger and can only cover a small area of wound defect. Moreover, the donor sites must be repaired by skin grafting. The cross-finger flap needs 2-stage procedures and immobilization for 3 weeks. Size-independent free tissue transfer is used in volar finger defects, but free flap option is considered especially in large defects in dorsal defects. The RDMA flap is a well described entity for the finger defect reconstruction.[20] The use of proximally based DMCA flap for the finger reconstruction is also described in the literature. The dorsal finger and hand arterial anatomy is well studied.

These results indicate that the first to third reverse dorsal metacarpal arterial flaps can be consistently harvested and rotated to the distal part of the finger, but that fourth and fifth flaps cannot always be created. However, a Quaba pattern fourth dorsal metacarpal flap is always possible, although 35% of the flaps are actually based on perforators arising from the palmar metacarpal artery.[22]

In a cadaveric study carried out by Yoon et al. It was shown that despite the fact that there was a fourth metacarpal artery, the piercing arteries of the skin were inconsistent.[23] The study of Omokawa et al he showed the parallel orientation of the metarcpian arteries from the first to the fifth dorsal. The origin of the first and second DMA comes from the radial artery and the dorsal metacarpal arch and the rest of the communicating branch of the palmar arteries in the metacarpal base. The basis of the RDMA flap is the communication between the palmar arteries and the dorsal arteries. These communications are more in the radial flaps than in the lateral flaps. From the first to the third DMCA, it constantly communicates with the palmar arteries compared to the fourth and fifth DMCA.[22,23]

This flap has been used by Sebastian et al. in their study to cover finger defects proximal to the tip of the finger. Sixty RDMA flaps were used in fifty-six patients, of which one flaps were used to cover distal defects to the proximal interphalangeal joints. They concluded that the most frequent complications are venous congestion and arterial failure. In very large effects, they had the need to use skin grafts in the donor area. The aesthetic results on the scar delivered a well-healed linear wound without complications.[24] Koch et al I used the RDMA extended flap technique in twelve patients and they obtained good results. He reported venous congestion in two of his patients, one of whom lost the flap. They also found venous congestion in three of their patients and one of them had partial loss of the flap. In their series, they used the subcutaneous pedicle and the pedicle tunnel. None of the patients presented a passive or active restriction of movement when compared to the normal hand.[9,24]

Wang et al in their study showed that the RDMA flap of the second and third intermetacarpal space is a very viable option for the reconstruction of finger defects in the distal and middle segment.[25] Gregory et al described the infection of the site as one of the reasons for the failure of the procedure. They used both the classic RDMA flap and the extended flap in their population of sixty-nine patients. In ten patients had complications (14.50%), seven had partial loss (10.14%) and three patients had complete loss of the flap (4.34%).[26] Balan et al he reported a series of cases of fourteen patients with the use of RDMA and extended RDMA, in which three patients with venous congestion (21.42%) with partial loss of the flap were reported in one of the patients (7.14%).[27]

Reverse dorsal digital and metacarpal flaps are based on arterial branches which anastomose the volar and dorsal digital arteries. They are homo- digital flaps and consequently the nintegrity of adjacent fingers is preserved. The flaps combine a reliable skin paddle with a wide rotation arc (180 or more). These features allow coverage of wide and distal finger defects. However, sensitivity cannot be totally restored, thus these flaps do not offer an adequate option for fingertip defects coverage. They are mainly indicated for coverage of distal dorsal and dorsolateral defects of the fingers. Dissection of the flap is a straight forward, one stage procedure, which can be performed under local anaesthesia in an outpatient setting. Immobilization of the finger is minimal and the volar digital artery is not sacrificed.[24-27]

The major disadvantages of the extended RDMA flap are the relatively bulky pedicle and the potential of venous congestion during the first 3 to 7 days after surgery. Either the skin paddle or skin graft for the pedicle was bulkier than the digital island flap. The contraindication is when the proximal phalanx is injured, as the perforator is may possibly be damaged.

CONCLUSION

The RDMCA Flap continues to be an essential technique in hand reconstructive surgery. To achieve the best functional and aesthetic results, surgeons need to perfect the details of designing, elevating, and placing the flap. This flap is dependable for covering relatively large soft tissue defects from the PIP joint to the fingertip without compromising the digital artery and nerve. If the flap's width is under 3 cm, the donor site can be closed primarily. The process of dissecting and elevating the flap is straightforward and quick, and it can also function as a composite flap. Venous congestion, while not rare, can be managed effectively with heparin injections over 3 to 7 days. The teardrop-shaped skin pedicle helps to reduce tension but may lead to a slightly bulky appearance.

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