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Reconstruction of Myelomeningocele by Lumbar Artery Perforator Plus Flap: Retrospective Analysis of Case Series

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ABSTRACT

Background: Over the last two decades, a paradigm shift has occurred in the reconstruction of myelomeningocele defects with the emerging concepts of perforator flaps. The use of lumbar perforator flaps for reconstruction of those defects has superseded any other modes of reconstruction. This is attributed to the confidence in flap versatility and low donor site morbidity. Although the flap has good vascular reliability, there's still some risk for venous congestion.

Objectives: This study aims to present our experience and the outcome in the reconstruction of myelomeningocele defects using freestyle lumbar perforator plus flap.

Methods: Retrospective analysis of 16 newly born infants presented to the plastic surgery department between February 2018 to June 2020 presented with thoracolumbar, lumbosacral, or purely lumbar myelomeningocele. All patients underwent joint neurosurgical and plastic reconstruction procedures. Layered reconstruction was performed and dorsal intercostal or lumbar arteries perforator plus flap were used in all patients.

Results: Out of the 16 babies in this study, 15 babies (93.75%) had neurological deficits. The flap dimension ranged from (3.4x5.8cm) to (6x11cm). The blood loss was minimal with a mean of 22±4.5ml. No flap loss had occurred except for one partial 1cm distal necrosis treated conservatively. Follow-up for six months showed good soft tissue coverage in all cases without any need for further reconstructive procedures.

Conclusion: The lumbar artery perforator plus flap provides a well vascularized durable coverage, lower rate of complications or morbidity and more aesthetic appearance.

Key Words: *Myelomeningocele – Perforator plus – Lumbar artery – Dorsal intercostal artery flap.*

Ethical Committee: This study has been approved by the Departmental Ethical Committee of the Faculty of Medicine, Zagazig University.

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INTRODUCTION

Myelomeningocele is a congenital defect of the neural tube associated with significant morbidity in which intrauterine failure of closure in the neural tube leads to herniation of the meninges with or without the spinal cord through a vertebral defect **[1]**.

The etiology of spinal canal defects is multifactorial. Genetic characteristics, geographical factors, low economic status, and folate deficiency are well-known causes **[2,3]**. In the United States of America, it is estimated that the incidence of neural tube defects is nearly 0.5-1 per 1000 births, and females have a 3-7 times higher risk in comparison to males **[4]**. It has a higher incidence in developing countries **[5]**.

Surgery is a necessity and is considered as the primary approach in the management of myelomeningocele. The main goal of defect closure is not only to protect the neural tissue but also to have a tension-free skin closure, subsequently preventing wound complications such as wound breakdown and secondary infection **[6]**. Many surgical procedures and approaches have been adopted for myelomeningocele repair **[7-13]**. These techniques comprise simply direct skin closure after the dural repair or other more complex soft tissue closure techniques. Layered soft tissue closure techniques usually protect the spinal canal against CSF leak or pseudo meningocele formation **[14]**.

With the emerging concepts of perforator flaps in the last three decades, the reconstruction of myelomeningocele defects has completely changed since the anatomy of the dorsal intercostal artery perforators (DIAP) and lumbar artery perforators (LAP) has been fully studied. It was found that

the perforators of the second and fourth lumbar arteries have consistent anatomy. Therefore, a reliable axial pattern perforator flap extending from the posterior midline to the lateral border of the rectus sheath can be safely designed **[15]**.

The use of lumbar or dorsal intercostal arteries perforator flaps in the reconstruction of large myelomeningocele defects has been previously described with high success rates **[8,9,16,17]**.

Despite utilizing perforator flaps having greatly improved the outcome of myelomeningocele reconstruction, venous compromise remained a major concern associated with increased morbidity and complications **[7,16]**.

Thus, this study aimed to evaluate the importance of using the perforator plus technique in the reconstruction of myelomeningocele defect by lumbar or dorsal intercostal artery perforator flaps.

PATIENTS AND METHODS

Patients:

This study was conducted at Zagazig University Hospital between February 2018 to June 2020. All patients' parents gave informed written consent for the surgical intervention. The Declaration of Helsinki principles were followed during the conduction of this study.

Retrospective analysis of 16 newly born infants who presented with thoracolumbar, lumbosacral, or purely lumbar myelomeningocele between February 2018 and June 2020. All patients underwent joint neurosurgical and plastic reconstruction procedures. Layered reconstruction was performed and dorsal intercostal or lumbar arteries perforator plus flap was used in all patients. Complex neural tube defects such as lipomeningocele and lipomyelomeningocele were not included in this study.

All patients provided a thorough history and preoperative data including age, sex, birth weight, and hemoglobin were recorded. A complete neurological assessment was performed by documenting associated anomalies, neurological deficits, sac rupture, and the presence of hydrocephalus. The characteristics of the patients are summarized in (Table 1).

Table (1): Summary of demographic data and patient criteria.

	Number of patients (%)	Mean ± SD	Range
Age at time of surgery (days)		22.9±13.3	3-45 (days)
Gestational Age (week)		35.9±3.6	28-40 (weeks)
Sex:			
Male	5 (31.25%)		
Female	11 (68.75%)		
Weight of the patient at the time of surgery (gm)		2931.3±642.6	1800-3900 (gm)
Preoperative Hg concentration		12.7±1.1	10.2-14.1 (gm/dl)
Neurological Deficit	15 (93.75%)		
Hydrocephalus:	7 (43.75%)		
Primarily diagnosed	2 (12.5%)		
Postoperative	5 (31.25%)		
Shunt surgery:	7 (43.75%)		
Two stages	6 (37.5%)		
In the same session	1 (6.25%)		
Site of the lesion:			
Thoraco-lumbar	3 (18.75%)		
Lumbar	8 (50%)		
Lumbo-Sacral	5 (31.25%)		

Investigations in the form of routine preoperative laboratory and plain X-rays of the dorsal and lumbar spine were done. Computed tomography of the brain and/or magnetic resonance imaging was performed only when hydrocephalus was suspected.

Surgical technique:

The patient was placed in the prone position, with rolls under the chest and hip to allow the abdomen to hang freely. A handheld Doppler was used to locate the lumbar or dorsal intercostal artery perforators in the medial one-third of the dorsal region.

Supplemental Video_1 (1).mp4

Video (1): Preoperative mapping of the perforators using hand doppler.

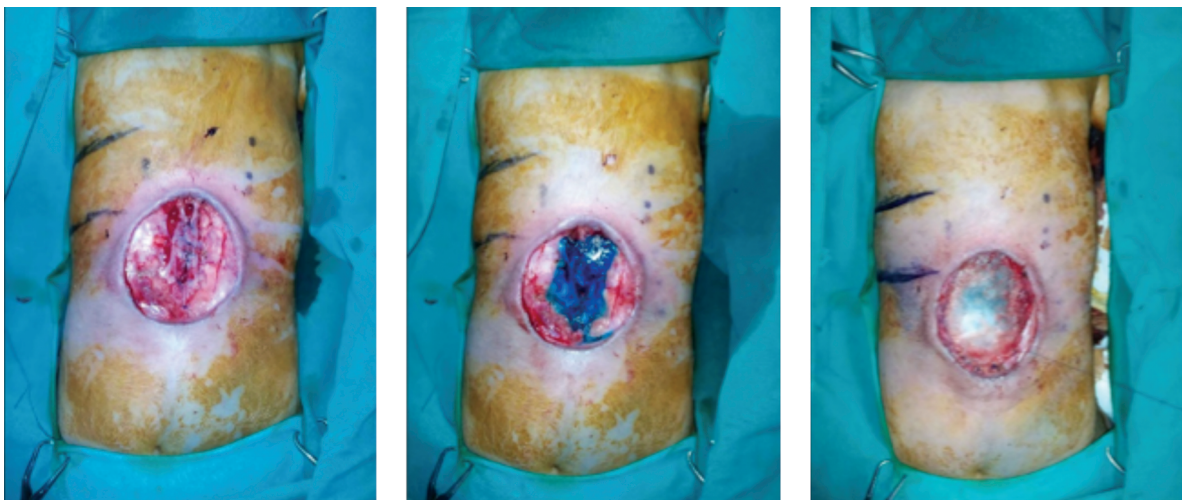
The flap was designed either transversely or obliquely over the defect, according to the size and location of the defect. The distal end of the flap could be extended anteriorly to the midaxillary line (Fig. 1).

After the repair of neural tissue and watertight closure of the dura by the neurosurgeon (Fig. 2), the flap was raised from lateral to medial in the subfascial plane. The flap was then transposed to the defect keeping a small skin island connected to the skin at its base. In most cases, the perforator could be identified (Fig. 3).

The wound was closed in a tension-free fashion with three layers of closure (fascia, subcutaneous layer, and skin) without drains. The donor site defect was closed primarily (Fig. 4).

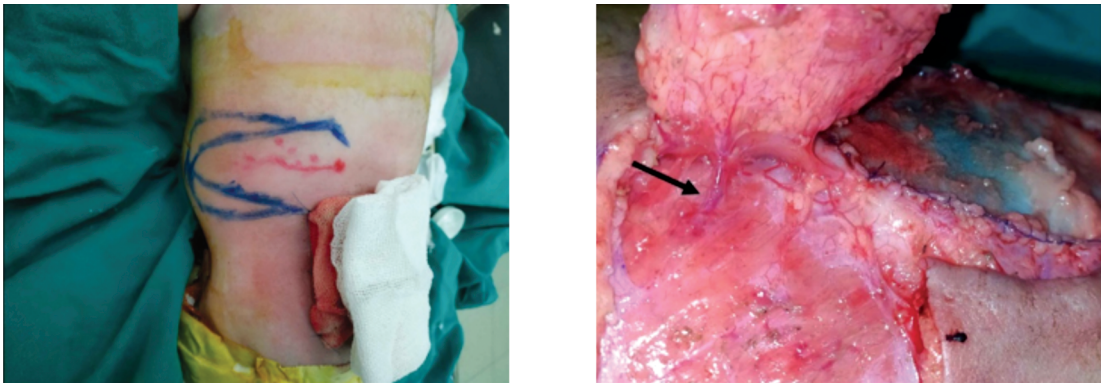
(A) (B)

Fig. (1): (A) Preoperative mapping of available perforators using handheld Doppler. (B) Different patient with preoperative marking of the flap after perforator localization.



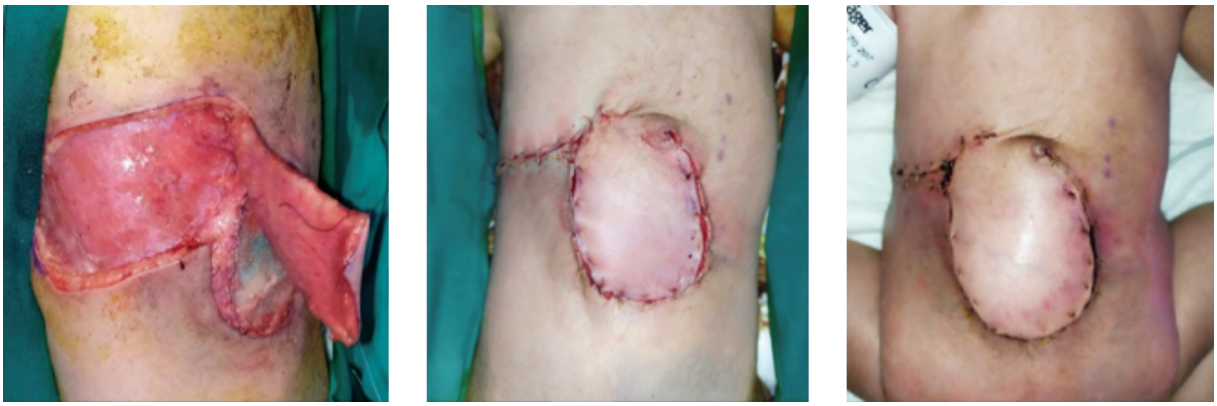
(A) (B) (C)

Fig. (2): (A) Watertight dural closure and facial layer repair. (B) Application of Dura Seal. (C) Fixation of dural patch.



(A) (B)

Fig. (3): (A) Flap marking showing different transposition angles. (B) Intra-operative Perforator identification (arrow).



(A) (B) (C)

Fig. (4): (A) The whole flap elevation showing sufficient length. (B) In-setting the flap position to cover the whole defect. (C) 10 days post-operative showing complete healing.

Intraoperative data including site and size of the defect, flap size and rotational angle, operative time, and estimated blood loss were collected and documented in (Table 2).

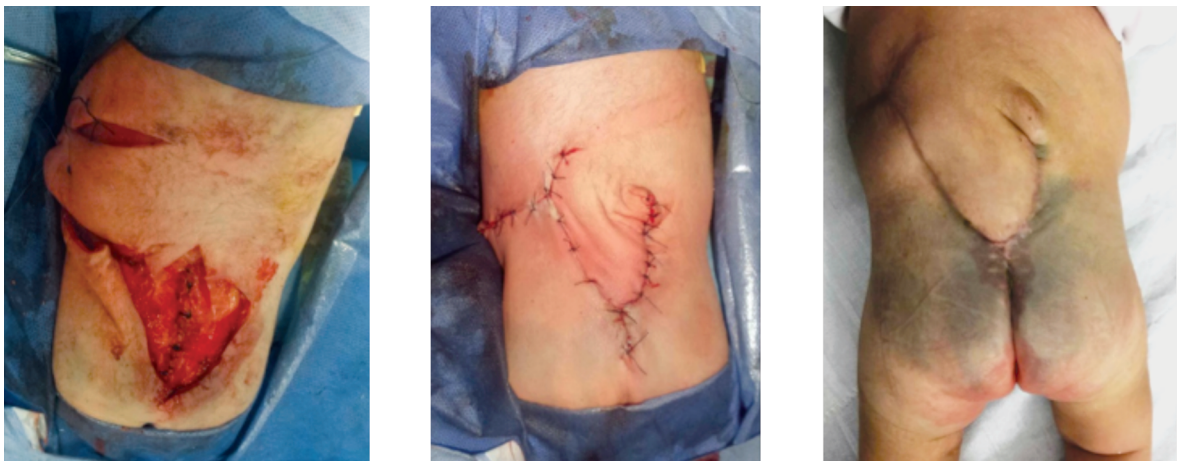
Table (2): Summary of the operative data and lesion criteria.

	Number of patients (%)	Mean ± SD	Range
Height of the defect	16	5.8±1.2	4-8.4cm
Width of the defect	16	4.4±0.8	3-5.8cm
Perforator signal	16 (100%)		
Perforator visualization	12 (75%)		
Flap length	16	8.4±1.7	5.8-11cm
Flap width	16	4.8±0.6	3.4-6cm
Rotational angle	16	106.9±7.5	95-120 degree
Blood loss	16	22±4.5	15-32ml
Operative time	16	46.6±6.8	35-60 minutes

Early follow-up and recording of any complication including flap loss, wound infection, wound breakdown, CSF leak, bleeding or hematoma, meningitis, and anesthesia complications. Regular follow-up was done for a minimum of 6 months (Fig. 5).

Statistical analysis:

Descriptive Statistical analysis was carried out utilizing STATA version 15. Data are summarized as mean ± standard deviation (SD) and/or median with interquartile range and proportions as appropriate.



(A) (B) (C)

Fig. (5): (A) Intraoperative flap elevation. (B) Flap in-setting and closure of the defect completely. (C) Late postoperative image showing stable scar and acceptable aesthetic results.

RESULTS

This study included 16 babies with myelomeningocele (5 males and 11 females), their mean age at the time of surgery was 23±13.3 days. The youngest was 3 days and the oldest was 45 days, while the mean weight of the babies at the time of surgery was 2.9±0.6kg and the youngest was 1.8kg. It is also worth mentioning that the mean gestational age at birth was 36±3.6 weeks with the youngest one being 28 weeks preterm. The mean preoperative hemoglobin concentration was 12.7±1.1gm/dl.

The myelomeningocele sac was located in the thoracolumbar area in 3 babies while 8 babies had lumbar myelomeningoceles and 5 babies had lumbosacral sacs. In this study, five babies (31.25%) had a preoperative rupture of the sac and early intervention for repair was completed.

Out of the 16 babies in this study, 15 babies (93.75%) had neurological deficits. Hydrocephalus has been diagnosed in 7 patients (43.75%), two of them (12.5%) have been diagnosed preoperative and 5 patients (31.25%) developed hydrocephalus after the repair of myelomeningocele. Out of the 5 patients who developed postoperative hydrocephalus, 4 patients had ruptured sacs before the reconstruction and had second-stage surgery for the insertion of a Ventriculoperitoneal shunt.

The defect size ranged from (3x4cm) to (5.8x 8.4cm) and the mean length was 5.8±1.2cm with 8.4cm maximum length while the mean width of the defect was 4.4±0.8cm with 5.8cm maximum width.

Pre-operative lumbar artery perforator signals have been identified and confirmed by handheld Doppler in all cases, but intraoperative visualization of the perforator could be achieved only in 12 cases (75%).

The smallest flap dimension was (3.4x5.8cm) and the largest (6x11cm) with a mean length of 8.4±1.7cm and a maximum length of 11cm while the mean width of the flap was 4.8±0.6cm with 6 cm maximum width. The mean rotation angle ranged from 95 to 120 degrees with a mean rotational angle was 106.9±7.5 degrees.

The mean time required by plastic surgeons for flap elevation and in-setting was 46±7 minutes, while the maximum time required was 60 minutes. Blood loss during surgery was minimal with a mean estimated blood loss of 22±4.5ml while the maximum blood loss was 32ml and no hypovolemic complications occurred.

The most commonly encountered post-operative complication was a minor CSF leak associated with wound dehiscence in 2 cases managed conservatively (Table 3).

Table (3): Showing percentage of encountered complications.

Complication	Number	%
Flap Loss	0	0
Distal end flap necrosis	1	6.25
Wound infection	0	0
CSF Leak	2	12.5
Meningitis	0	0
Wound dehiscence	2	12.5
Hematoma formation	1	6.25

No flap loss had occurred except for one patient in whom there was a 1cm partial loss of the distal flap end treated conservatively. In addition, one baby developed a small hematoma that was drained in the Neonatal Intensive Care Unit (NICU) without further complications.

Follow-up for a minimum of six months showed good soft tissue coverage in all cases without any need for other reconstructive procedures.

DISCUSSION

Reconstruction of myelomeningocele requires good surgical planning and a combined procedure by both neurosurgeon and plastic surgeon. This optimizes the outcome to achieve a durable, well-vascularized, layered coverage after restoration of the neural tube and a watertight dural closure. It also ensures a well-protected neural tube with an absolute minimal risk of infection or CSF leakage **[7,18]**.

Luce et al., **[19]** mentioned that the optimal reconstruction for these defects should be large enough to cover the entire defect, well vascularized to ensure survival of the flap, preserve the integrity of the structures enclosed in the flaps, ensure long-term durability of the closure, be esthetically acceptable, and present the least morbidity and mortality.

These goals were achieved in this series while avoiding the major complications of other reconstruction options, such as unstable scarring after skin grafting and the use of nonexpendable trunk muscles, which may preclude mobility and rehabilitation.

Various reconstructive options used to close similar large lumbar defects. Mustarde **[20]** was the first to propose split-thickness skin grafts for the closure of myelomeningocele. Other authors reported a successful method to close the defect area using muscle flaps, e.g., latissimus dorsi or gluteus maximus, but some disadvantages specific to this procedure were also reported, such as loss of function of the major muscles, increased blood loss, and prolonged surgical time **[12,21]**.

Several skin flap procedures have been described for the closure of myelomeningocele, including transposition, rotational flaps, V-Y flaps, and bilobed and Limberg flaps **[13,22,23]**.

Perforator flaps have made an important contribution to plastic surgery. Duffy et al., **[11]** repaired lumbosacral myelomeningocele defects with a superior gluteal artery perforator flap in 6 patients. In 2005, Muneuchi et al., **[24]** reported closure of a myelomeningocele defect with a rhomboid perforator flap. Interestingly, they presented a scheme showing that the blood supply to the flap was provided by the perforator vessels **[24]**.

Atik et al., **[25]** described the anatomical localization and diameter of DIAPs in 10 cadavers. They successfully used the DIAP flap in 8 patients with large myelomeningocele defects with a mean defect size of (7x5.5cm). Furthermore, Cologlu et al., **[7]** reported the use of bilateral propeller flaps in 7 cases with a mean defect size of (10.2x8.6cm). They reported 3 cases of postoperative venous congestion.

The LAP flap was previously used for coverage of myelomeningocele in only a few series. To our knowledge, the LAP flap has been used specifically for such cases in only two studies **[9,16]**.

Perforator Plus principle involves the transfer of a tissue flap that contains a perforator blood vessel, but without disrupting the underlying muscle or soft tissue. This technical advantage can lead to faster healing and fewer complications, specifically venous congestion. Additionally, this technique can provide a more natural-looking result, as the transferred tissue closely mimics the texture and appearance of the surrounding tissue and better functional outcomes. It was also found that patients who underwent the Perforator Plus technique had shorter hospital stays and fewer complications, such as flap loss or wound healing problems, compared to those who underwent the perforator flap technique **[26]**.

Elsabbagh et al., **[16]** reported the use of LAP flap in 15 cases. They used LAP flaps both unilaterally and bilaterally in defects ranging in size from 3.5x4 to 6x10cm (compared with 3x4cm to 5.8x8.4cm in our series). They also reported a mean operative time of 40 minutes (46 minutes in our series). He reported 2 cases of partial flap necrosis and 1 case of total flap loss. In contrast, only 1 case of small necrosis at the distal end (1cm) occurred in our series.

The other series was by Ucak **[9]**, who used only unilateral LAP flaps in 38 cases, with a mean defect size ranging from 6x5cm to 10x10cm. The mean angle of rotation was 126 degrees (compared with 107 in our series). He reported minimal blood loss with a mean of 16ml (compared with 22ml in our series). Surprisingly, he reported no postoperative necrosis, hematoma, infection, or CSF leak. In our series, there were 2 cases of minor CSF leak

associated with wound dehiscence, 1 case of hematoma, and 1 case of negligible necrosis at the distal margin. These cases were managed conservatively.

Although the use of the concept of a perforator flap has revolutionized the reconstruction of myelomeningocele, venous stasis remains a major problem, leading to increased morbidity and complications. Therefore, in this study, we adopted the concept of perforator-plus flap (leaving a bridge of skin paddle). In particular, this has led to improved overall outcomes in terms of flap safety and feasibility. Moreover, this type of reconstruction eliminates the need for midline scar placement, which theoretically adds more scar instability and the frequent risk of wound breakdown.

There are several reasons why Perforator Plus flaps may have a lower incidence of venous congestion compared to other types of flaps. First, the Perforator Plus technique harvests a tissue flap that contains only the skin and subcutaneous fat layers, without any underlying muscle tissue. This can reduce the overall bulk of the flap, which in turn can decrease the pressure on the venous system and improve blood flow. Second, the Perforator Plus technique preserves the integrity of the perforator vessels, which are the main source of blood supply to the tissue flap. By preserving, the perforator vessels and minimizing the amount of tissue that is removed, the Perforator Plus technique can improve blood flow and decrease the risk of venous congestion. Finally, the Perforator Plus technique may have a more reliable blood supply than other types of flaps. Because the tissue flap is based on a single perforator vessel, the blood supply to the flap can be more predictable and consistent than in other types of flaps that rely on multiple blood vessels for their blood supply **[27,28]**.

Conclusion:

The lumbar artery perforator plus flap has a consistent anatomy and can be used safely to cover myelomeningocele defects. It provides a well-vascularized durable coverage, a lower rate of complications or morbidity, and a more aesthetic appearance.

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