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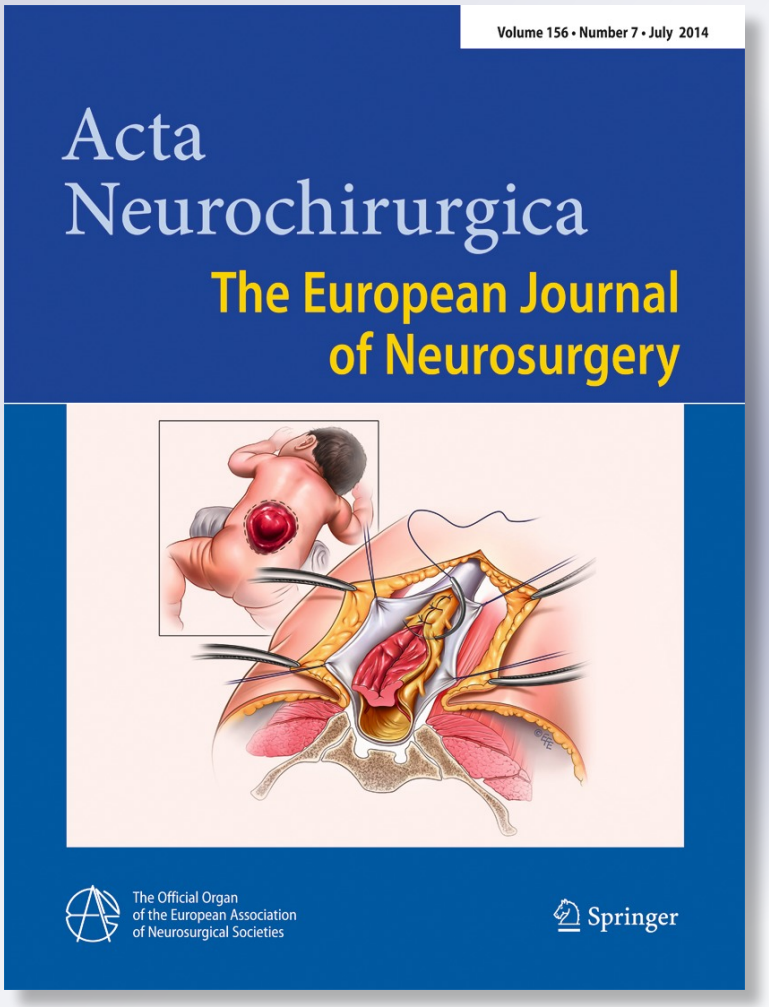

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CLINICAL ARTICLE - PEDIATRICS

Use of the bovine pericardial patch and fibrin sealant in meningomyelocele closure

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Abstract
Background Meningomyelocele is the most common and complex birth defect of the central nervous system. The operative principle of meningomyelocele repair consists of consecutive separate closures of the neural placode, dura mater, lumbar fascia, subcutaneous layer, and skin. While the neurosurgical techniques for the closure of the neural placode and dura mater have been well accepted, the most appropriate soft tissue closure technique has not yet been applied.
Methods This study reviews a case series of eight meningomyelocele patients treated with the bovine pericardial patch and fibrin sealant. Following the reconstruction of the neural placode and the closure of the dura mater, soft tissue coverage was achieved using the bovine pericardial patch and fibrin sealant.
Results In this series of eight patients, stable coverage was achieved with the application of a bovine pericardial patch and fibrin sealant technique. After the operations, none of the possible complications such as cerebrospinal fluid leak, seroma, hematoma, skin necrosis, deep or superficial infection, and wound breakdown was observed.
Conclusions The usage of the bovine pericardial patch and fibrin sealant technique at the fascial level–between the dural sac and the skin–provides adequate soft tissue coverage in meningomyelocele repair surgery.

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Introduction

Meningomyelocele (MMC) is the most common and complex birth defect of the central nervous system that results from a defect of closure of the neural tube elements [15, 11]. Precautions against folic acid deficiency and prenatal screening with intrauterine diagnosis caused a decrease in the incidence of MMC, but it still has a prevalence of 0.3-4 per 1000 infants [9].

The basic principles of MMC repair have been clearly described in the literature and widely accepted by pediatric neurosurgeons [30]. The operative principle of MMC repair consists of consecutive separate closure of the neural placode, dura mater, lumbar fascia, subcutaneous layer, and skin. The neurosurgical technique for the closure of the neural placode and dura mater have remained unchanged over decades, but different soft tissue closure techniques have still been argued in the literature [1, 5, 9, 11, 13–16, 18–20, 22, 28–32, 38, 40]; although the most appropriate technique is still being debated.

The bovine pericardial patch and fibrin sealant use for the soft tissue closure of MMC has never been reported. Here we describe a new technique for MMC closure and present our experience with eight infants.

Materials and methods

From January 2012 to February 2013, eight infants were diagnosed with MMC, and the defects were closed with the bovine pericardial patch and fibrin sealant. Informed patient consent was taken from the parents of the infants. All the

patients underwent the same surgical procedure described below within the first 24 h after birth.

Surgical technique

After the induction of anesthesia and endotracheal intubation, a latex-free Foley's catheter is inserted in place. Then the patient is placed in a prone position. A proper dose of ceftriaxone is administered with the induction of anesthesia, and continued for three days postoperatively. Meningomyelocele is observed (Fig. 1a); dysplastic tissue and normal epidermis are identified. For the assistance of hemostasis, lidocaine with 0.25 % adrenaline is injected subcutaneously along the line of incision. The neural placode is sharply dissected from the dysplastic meningeal tissues and from abnormal skin. Meticulous care is taken to preserve as much of the vital tissues as possible. Also to minimize potential injury to the neural tissue, electrocautery is not used. After the successful circumferential mobilization of the neural placode, dysplastic meningeal tissues and inadequately vascularized cutaneous layers are removed; then, the dysplastic tissue is excised and the underlying layers identified before the reconstruction of the neural tube is performed. The tube is reformed by imbricating the lateral borders with 5-0 absorbable sutures (Fig. 2a). After the neural tube is closed, the dural plane is identified. To form a spacious techal sac for the spinal cord and nerve roots, sufficient tissues are released. Then the dura is closed in a watertight fashion with primary 4-0 non-absorbable sutures (Fig. 2b). At this point, without fascia and muscle dissection, a proper sized bovine pericardial patch (Tutopatch®, Tutogen Medical GmbH, Germany) is placed over the dura and sutured circumferentially into the peripheral lumbar muscle-fascia layer to cover all the neural elements with 3-0 non-absorbable sutures (Figs. 1b and 2c). Then, a fibrin sealant (Tisseel®, Baxter Healthcare Ltd., United Kingdom) is applied circumferentially onto the sutures (Figs. 1c and 2d). This provides an additional barrier between the skin and the neural elements. The skin is closed either with simple linear sutures or with advanced skin flaps (S-, Z-, or V-Y plasty) where necessary. No additional muscle flap transfer and/or transposition of the paraspinal fascia is performed. If a ventriculo-peritoneal (V-P) shunt is required, it is placed after the MMC repair in the same surgical session.

Results

Eight infants (5 female, 3 male) with the diagnosis of MMC were treated using the bovine pericardial patch and fibrin sealant technique. All the patients were operated on within 24 h after birth. The size of the defects ranged from 40 X 50 mm to 60 X 80 mm. Five of these MMCs were located in the lumbosacral region, and others were in the thorocolumbar region. All patients except one were paraplegic preoperatively. Hydrocephalus was diagnosed in five patients with preoperative magnetic resonance imaging and all required V-P shunt placement in the same surgical session with MMC repair. There were no major periperative complications. Postoperative follow-up was at least 8 mos (8 to 18, mean 12 months). All infants had stable and reliable wound coverage. No postoperative complications such as cerebrospinal fluid (CSF) leak, seroma, hematoma, skin necrosis, deep or superficial infection and wound breakdown was observed. Of the five infants in whom a V-P shunt was placed, three required additional shunt revision due to shunt malfunction.

The demographic and clinical data of the patients were summarized in Table 1.

Discussion

Meningomyelocele is a congenital malformation resulting in a defect involving multiple tissue levels. Traditionally, as was widely accepted, MMC closure consists of the repair of the neural placode and closure of the dura, paravertebral muscle, fascia, and lastly, the skin. The main goal is to provide adequate, stable, and tension-free soft tissue closure and skin to cover over the repaired neural placode and the dura; thus, the risk of CSF leak and infection were minimized [22]. But traditional methods were unsatisfactory and may result in

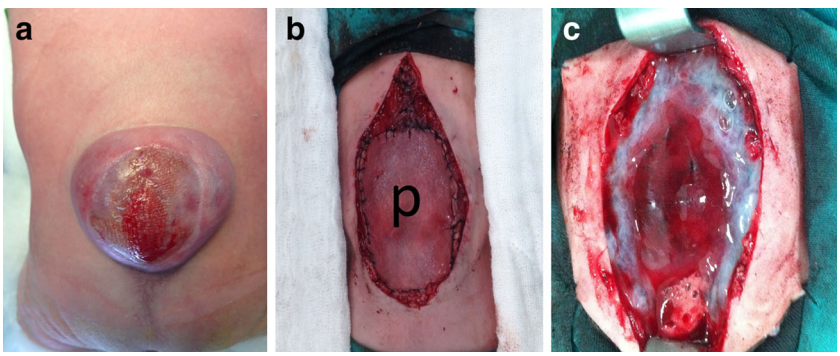

Fig. 1 **a.** Preoperative photomicrograph of an infant with lumbosacral meningomyelocele. **b.** Intraoperative photomicrograph showing the bovine pericardial patch (p) sutured over the reconstructed neural placode and the dura mater. **c.** Intraoperative photomicrograph showing the circumferential application of the fibrin sealant onto the sutures

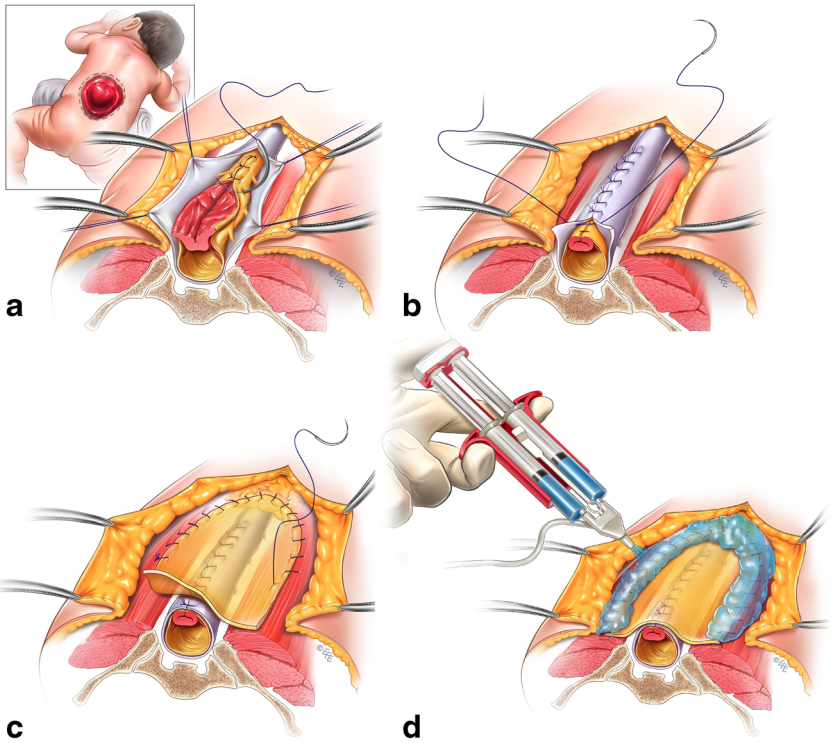

Fig. 2 Illustrations summarizing the surgical technique. After the mobilization, the neural placode is closed in a tubular manner (**a**). Then, the dura mater is closed in a watertight manner (**b**). After the reconstruction of the neural placode and the dura mater, the bovine pericardial patch is sutured circumferentially into the lumbosacral fascia covering all the neural elements (**c**). A fibrin sealant is then applied over the sutures (**d**)

complications such as CSF leak, superficial or deep infections, scarring, necrosis, and contraction of the soft tissues [3, 10, 18, 22].

So far, neurosurgical techniques for the reconstruction of the neural placode and the closure of the adjacent dura mater have remained unchanged for decades and widely accepted by pediatric neurosurgeons. But increasing attention has been directed at soft tissue closure with multiple anatomical layers and different surgical techniques [1, 5, 9, 11, 13–16, 18–20, 22, 28–32, 38, 40]. The best technique for soft tissue closure in MMC repair has been a topic of discussion in the literature, and no consensus has been reached yet.

In 1978, Welsh et al. [39], described a simple method for the repair of skin defects, where repaired dura is covered with bilateral lumbar transposition flaps and with split-thickness skin graft. Also, Bajaj et al. [4] described another simple repair method where the dura is covered only with split-thickness skin graft without any fascia repair. Furthermore, applications of complex fasciocutaneous flaps, such as double Z-rhomboid technique [8], V-Y advancement flaps [2], and bilobed flaps [20] were all described, and somehow satisfactory results were obtained. On the other hand, these basic methods, which do not cover the repaired placode and dura mater adequately, may result in wound problems and CSF leaks leading to sepsis.

To provide more successful repair of the MMC defects, muscle and musculocutaneous flaps were described and widely used [30]. Clark et al. [7] described the bilateral reverse latissimus dorsi muscle flaps for the closure of myeloschisis defects. They performed good muscle coverage over the dural closure and provided a long-standing, durable coverage in two patients. In later years, bilateral reversed latissimus dorsi flaps have been frequently applied to cover large MMC defects [16, 40].

Moreover, advanced techniques using musculocutaneous flaps such as Limberg-latissimus dorsi myocutaneous flap [27], distally-based latissimus dorsi flap [33], bilateral pedicled latissimus dorsi flap [26], latissimus dorsi and gluteus maximus flap [21], latissimus dorsi and trapezius flaps [24], and dorsal intercostal artery perforator flap [18] have been used to cover repaired neural placodes and the dura mater.

All these techniques are complex and require longer operation times, causing extensive surgical exposure, sacrifice of the muscles, and increases in intraoperative blood loss. In neonates, who are prone to perioperative complications, operation time is extremely important, as longer operation times may result in undesirable consequences [15]. The sacrifice of the functional back muscles will be a challenge for the growing paraplegic infant, where the use of a wheelchair is mandatory for ambulation. Furthermore, these patients are prone to decubitus ulcers, and the treatment of these ulcers would be difficult because the local intact muscles had been used before [18]. Also, in an infant with a limited blood reservoir, muscle and fascia dissections may cause more blood loss than can be tolerated. On the other hand, unwanted complications such as wound dehiscence, superficial or deep infections leading to meningitis or ventriculitis, skin necrosis, CSF fistula, and sepsis have all been previously reported in infants treated with those techniques [18, 22, 30, 34, 36].

Table 1 Demographic and clinical data relevant to the study cohort

Patient	Sex	Age (h)	Size of skin defect (mm)	Region	Associated Anomaly	Neurological Status	Skin flap reconstruction	Complication
1	F	6	50 X 70	Lumbosacral	Chiari Type II, HCP	paraplegic	S-plasty	None
2	F	5	40 X 50	Thorocolumbar	Prematurity, pes equinovarus	paraplegic	Simple linear	None
3	M	7.5	60 X 80	Lumbosacral	Chiari Type II, HCP	paraplegic	Z-plasty	None
4	F	9	40 X 50	Lumbosacral	none	intact	Simple linear	None
5	M	12	40 X 70	Thorocolumbar	HCP	paraplegic	Simple linear	None
6	M	18	50 X 50	Lumbosacral	Chiari Type II, HCP	paraplegic	Simple linear	None
7	F	20	60 X 80	Thorocolumbar	HCP	paraplegic	V-Y plasty	None
8	F	5.5	50 X 50	Lumbosacral	none	paraplegic	Simple linear	None

HCP: hydrocephalus

Therefore, surgeons attempted to find more sophisticated methods that do not require muscle or fascia dissection. Hasegawa et al. [14], reported that after the reconstruction of the neural placode and dura mater, they placed an autologous amniotic membrane over the sutured dura as an onlay graft in a newborn with MMC. Nice wound healing without complications was achieved in this patient.

Agag et al. [1] reported the neurosurgical reconstruction technique with acellular dermal matrix in six cases. Two of those six cases were neonates with MMC defects, and both were treated with an acellular dermal matrix placed over the dural closure. Recently, Hill et al. [15] presented three patients with MMCs who were treated with acellular dermal matrix to provide stable soft tissue coverage to preserve local muscle and fascia. The acellular dermal matrix technique provided uncomplicated results in both series.

The bovine pericardial patch is a collagenous membrane that provides reliable closure on tissue defects and serves as a scaffold for the patient's own tissue [35]. The bovine pericardium is used to replace or strengthen connective tissues as a barrier membrane, especially in neurosurgical operations [12]. Furthermore, plastic surgeons use the bovine pericardial patches to fill subcutaneous defects, or as a subdermal implant for facial wrinkle corrections and breast reconstructions [35].

Fibrin sealants, or fibrin glues, are topical hemostatic agents, which are the source of fibrinogen and thrombin [23]. Fibrin sealants provide adequate tissue adhesion in many clinical situations [25]. Also, it is widely used to treat CSF leaks in neurosurgical operations [6, 17].

As previously mentioned, the use of muscle flaps to repair MMC defects may result in complications. To avoid the use of such muscle flaps, we described a new technique of using the bovine pericardial patch and fibrin sealant in eight MMC patients. After the reconstruction of the neural placode and closure of the dura mater, the bovine pericardial patch is sutured into the adjacent thorocolumbar fascia to cover all the neural elements and the defect. Then the circumferential application of the fibrin sealant onto the suture lines of the bovine pericardial patch provided excellent surgical results without any wound-related complications. By adding an additional layer of soft tissue closure with the described technique, the spinal canal and neural elements were protected without causing any tethering, and CSF leak or pseudomeningocele formation was prevented. With this novel, easy-to-apply technique, no functional muscles were sacrificed, and no postoperative complications occurred. This technique provides protection of the neural placode and dura mater with stable soft tissue coverage. Furthermore, application is easy, fast, and not extensive compared to other muscle flap techniques.

In this study, the incidence of symptomatic hydrocephalus was 63 %, and all children with hydrocephalus were treated with a V-P shunt during the same operative session. Because of the high incidence of shunt-related complications such as infection, shunt failure, and death, some neurosurgeons are more prone to wait for the treatment of HCP. On the other hand, simultaneous placement of the V-P shunt is also favored, because diverting the CSF aids the wound-healing process and prevents the adverse effects on cognitive function resulting from elevated intracranial pressure in the case of delayed shunt placement. Furthermore, early shunting avoids the need for a second operation and reduces the duration of hospitalization [37]. There is still ongoing debate on simultaneous versus conventional sequential treatment of the HCP; we preferred simultaneous shunt placement in the presented case series.

The most important limitation of this study is the small number of patients included. More research with prospective controlled studies is necessary to provide sufficient data on the efficiency of the bovine pericardial patch and fibrin sealant technique in MMC repair. Also, longer follow-up of the patients is needed. The present technique is not always necessary, especially when it is possible to achieve closure with the native tissues.

Conclusion

In this patient group, it was demonstrated that usage of the bovine pericardial patch and fibrin sealant at the fascial level (between the dural sac and the skin) provides adequate soft tissue coverage in MMC repair surgery. We advise that this technique is indicated as a viable option in cases where native tissue is not available to achieve closure and shall not be used as a routine component of MMC repair.

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Conflict of interest None

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