Latissimus Dorsi Flap Procedures to Cover Myelomeningocele In Utero: A Feasibility Study in Human Fetuses

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• There is experimental and clinical evidence that in utero repair of myelomeningocele (MMC) may preserve neurological function. In five aborted human fetuses (gestational age, 18 to 29 weeks), the authors tested whether proximally and distally based latissimus dorsi flaps (LDF) can be used to cover MMC lesions. Fetal soft tissues were developed enough to allow surgical handling, preparation of both flap types was technically easy, and the vascular pedicles could be preserved. The proximally pedicled LDF was suitable to cover the upper spine from lower cervical to lower thoracic levels, whereas the distally pedicled LDF was suitable to cover the spine between lower thoracic and lower sacral levels. These results suggest that various LDF procedures are technically feasible in early gestational human fetuses and could be used for in utero repair of MMC.

INDEX WORDS: Myelomeningocele, spina bifida, fetal surgery, latissimus dorsi flap.

WE RECENTLY demonstrated in fetal sheep that in utero repair of experimental myelomeningocele (MMC) spares neurological function at birth.[1,2] Moreover, studies in human fetuses who have MMC supported our hypothesis that there is in utero acquired secondary damage to the openly exposed neural tissue that might be prevented by timely prenatal intervention.[3-6]

Ideally, fetal surgical repair of human MMC should be safe, quick, technically easy, and provide a robust and definitive coverage of the lesion. In previous animal experiments we successfully used the latissimus dorsi flaps (LDF) to repair experimentally created MMC in utero.[7] The aim of this study was to determine the feasibility of various LDF procedures in early gestational human fetuses.

MATERIALS AND METHODS

Five freshly aborted, externally intact, and unpreserved (except for refrigeration at 4°C) human fetuses were used for this study after informed consent was obtained from the parents. In each fetus, the right latissimus dorsi muscle was prepared as a proximally pedicled flap, and the left as a distally pedicled flap. Flap dissections were carried out according to standard techniques.[8,9] For both flap types, a longitudinal incision through the skin and subcutaneous fat was made along the anterior border of the latissimus dorsi muscle between scapula and iliac crest. The muscle was dissected and then lifted off the underlying serratus anterior muscle, which required transection of the vascular branches to the serratus. To create a proximally pedicled flap, the origin at the iliac crest, the paraspinal insertions, and the paraspinal and intercostal perforator vessels were transected, leaving the muscle attached to its humeral insertion and the dominant thoracodorsal pedicle. For preparation of the distally pedicled flap, the lower paraspinal perforators and the eleventh posterior intercostal vessels were preserved. The humeral insertion of the muscle, the thoracodorsal pedicle, and the paraspinal insertions were transected, leaving the muscle attached to the posterior iliac crest and the distal vascular pedicle. Subsequently, the skin between the two flank incisions, ie, the entire integument of the dorsal aspect of the trunk was mobilized and then longitudinally incised along the spine. This maneuver created two large subcutaneous tunnels between the sites of flap preparation and the spine through which the muscle flaps could be pulled to be placed over the spine. Although the proximally based LDF could simply be swung over the spine, the distally based LDF had to be flipped over ("reverse" LDF[9,10]) and then be pulled through the subcutaneous tunnel and over the spine (Fig 1). The flaps were sutured in place over different spinal levels using 5-0 Maxon (Davis and Geck, Manati, PR) interrupted sutures.

Additionally, in each fetus a circular skin sample (different locations from cervical to sacral) was excised to mimic the skin deficit of a large MMC. Based on the largest lesions found in our previous examinations of human fetuses who had MMC,[5,6] defect diameters were chosen from 3 cm for 18 weeks' gestational age to 5 cm for 29 weeks' gestational age. Skin incisions were closed using 5-0 Maxon interrupted sutures.

RESULTS

In all five fetuses (gestational ages of 18, 23, 24, 26, and 29 weeks, with crown-rump lengths of 15, 19.5, 20, 23.5, and 27 cm) the procedures could be successfully performed within 48 hours of abortion. Irrespective of fetal age, the surgical handling of skin and muscles did not result in tissue disruption despite the general fragility of fetal tissues and despite the fact that tissue autolysis was already minimally in progress. All relevant vascular structures were easily identifiable and could be transected or preserved respectively (Figs 2 and 3). The proximally pedicled LDF could be swung over the spine without tension and be placed in various areas ranging from low cervical to low thoracic levels. In all locations, the flap could be spread out to entirely cover 4 to 5 vertebrae (Fig 4). Kinking, torsion, or tension of the thoracodorsal pedicle was not observed. The findings regarding the distally pedicled LDF were identical except for two points. First, the flap had to be flipped over, ie, be used as

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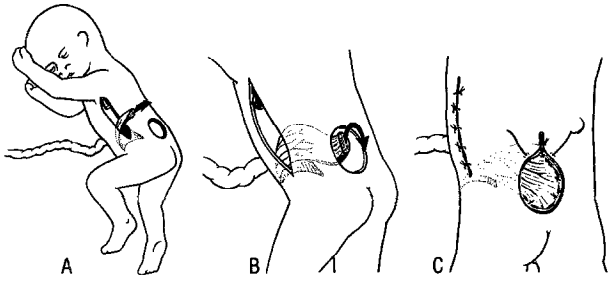

Fig 1. (A) Raising the distally based LDF. (B) The LDF is flipped over and pulled through subcutaneous tunnel. (C) Flap covers lesion and is sutured in place; skin closure.

a "reverse" (upside down) flap[9,10] because rotation of the flap in its original position would have visibly compromised the vascular supply. Second, the spinal areas that could be covered ranged from low thoracic to low sacral levels (Fig 4).

In all fetuses, the flank skin incisions used for flap preparation as well as the skin defects mimicking the MMC lesions could be closed. The generous mobilization and the elasticity of the fetal skin allowed for closure without excessive tension.

DISCUSSION

This postmortem study demonstrates that both proximally and distally based human fetal LDF can be easily prepared and then used for in utero coverage of presumed MMC lesions at all spinal levels where the natural malformation may be located.

We have carried out this feasibility study in fetuses with gestational ages of 18 to 29 weeks, during which fetal surgery can be safely performed.[11] Ideally, in utero repair should be performed around midgestation because there is experimental[12] and clinical[5,6] evidence that the exposed, and thus unprotected, neural elements in MMC

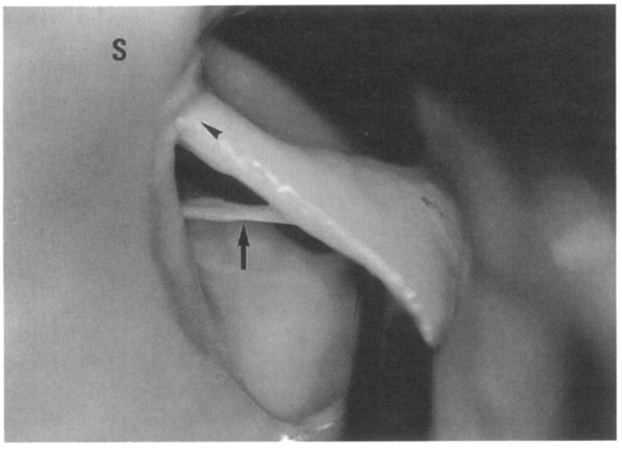

Fig 2. Proximally based LDF (fetus of 24 weeks' gestation). Lifting the flap off the underlying serratus muscle allows visualization of the humeral insertion (arrowhead) and of the thoracodorsal pedicle (arrow). S, right shoulder.

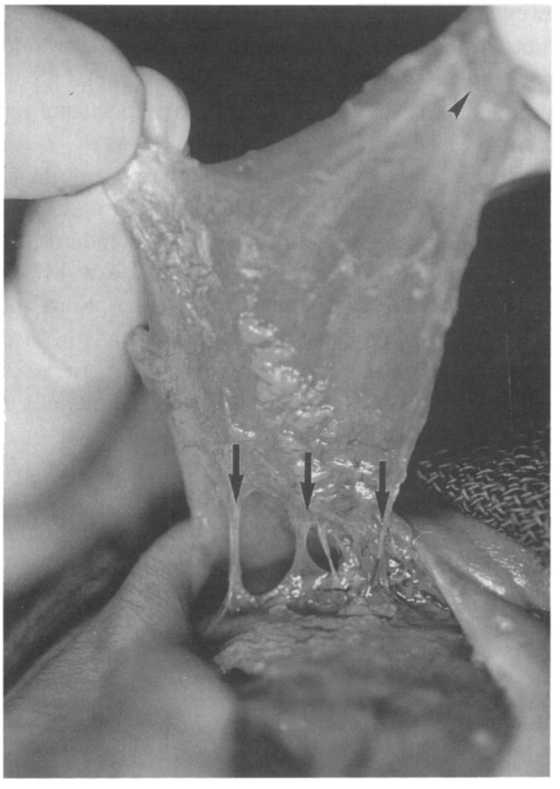

Fig 3. Distally based LDF (fetus of 29 weeks' gestation). The muscle, with its humeral insertion (arrowhead) already transected, is left attached to its iliac crest origin. The vascular supply consists of several perforator vessels (arrows).

are progressively damaged, particularly during the second half of gestation and delivery. Flap preparation was technically easy, it could be performed within 10 to 15 minutes, and it was not associated with any obvious problems. This study cannot answer the question of vascular pedicle patency and long-term flap survival.

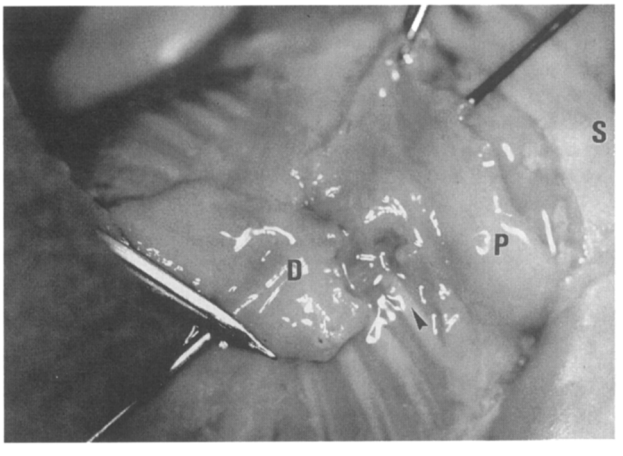

Fig 4. Both flap types in situ over the spine that is marked with metal rod (skin is removed for visualization purposes). The proximally based LDF (P) covers thoracic levels 4 through 8, the distally based "reverse" LDF (D) covers thoracic levels 9 through 12 and lumbar level 1. S, right shoulder; arrowhead, 8th rib.

However, although monitoring for flap viability in utero is not available today, there is no reason for concern because this flap was successfully used for fetal repair of experimental MMC[7] as well as for early postnatal repair of human MMC.[13,14]

It is important to point out that the purpose of the LDF is to attain optimal protective coverage of fragile, potentially functional fetal neural tissues in a standard MMC, not to repair the rare giant defects.[7] We reviewed alternatives to the LDF, but none of the options (other muscle flap,[15] skin flaps/grafts alone,[16] and the use of synthetic materials[17]) met the ideal repair criteria of a versatile, definitive, robust, multilayered autologous coverage that can be performed safely, quickly, and easily.[7] Furthermore, the donor site motor deficit resulting from LDF preparation is not significant, in particular, it should not hamper the patient's ability to walk with crutches or drive a wheel chair.[18,19]

Before the LDF is placed over the lesion, resection of the cystic sac, reconstruction of the neural plate into a tube, and closure of the dura mater should be performed for postnatal repair.[20] Based on our experience with human MMC fetuses,[6] we think this is feasible in midgestational and older fetuses. Also, we anticipate that the entire operation from opening to closing the uterus could be performed within 40 to 60 minutes, which complies with the current prerequisites for human fetal surgery.[11]

We demonstrated the feasibility of various fetal LDF procedures for MMC coverage in human fetuses. If studies of the natural history of human fetal MMC suggest that neurological function can be preserved by repair before birth, the techniques described here can be applied clinically.

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