Application of an Acellular Dermal Matrix Patch in Infant and Neonatal Abdominal Wall Reconstruction

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ABSTRACT

Objective: *This study aimed to investigate the feasibility of using an acellular dermal matrix (ADM) biological patch for abdominal wall reconstruction and in the treatment of infant and neonatal giant omphalocoele as well as other large abdominal wall defects.*
Methods: *A retrospective analysis of the surgical use of an ADM biological patch for reconstructing the abdominal wall was performed. Eleven infants with giant omphalocoele, one with an iatrogenic large abdominal wall defect, and one with a large abdominal wall hernia were treated by filling the abdominal wall defect with the biological patch and expanding the abdominal cavity volume to avoid sharply increased pressure after the direct suture closure of the abdominal incision. This procedure obtained good results.*
Results: *Infants with giant omphalocoele had good results in 10 of 11 cases (the parents of one patient ended treatment). One infant with an iatrogenic abdominal wall defect and one with a large abdominal wall hernia had good results; at follow-up, neither infant has had complications.*
Conclusion: *Large abdominal wall defects in neonates and infants can be reconstructed by ADM patches with good results.*

Keywords: Acellular dermal matrix, large abdominal wall defect, reconstruction of the abdominal wall

Aplicación de un Parche de Matriz Dérmica Acelular en la Reconstrucción de la pared Abdominal de Infantes y Neonatos

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RESUMEN

Objetivo: *Este estudio tiene como objetivo investigar la viabilidad del uso del parche de matriz dérmica acelular (MDA) biológico para la reconstrucción de la pared abdominal y el tratamiento de onfaloceles gigantes, así como otros defectos de la pared abdominal en infantes y neonatos.*
Métodos: *Se realizó un análisis retrospectivo del uso quirúrgico del parche biológico de MDA para reconstruir la pared abdominal. Once infantes con onfalocele, uno con un defecto iatrogénico grande de la pared abdominal, y otro con una hernia grande de la pared abdominal, fueron tratados rellenando el defecto de la pared abdominal con el parche biológico y ampliando el volumen de la cavidad abdominal, para evitar un aumento agudamente considerable de la presión tras el cierre de la sutura directa de la incisión abdominal. Este procedimiento dio buenos resultados.*
Resultados: *Los infantes con onfalocele gigante tuvieron buenos resultados en 10 de los 11 casos (los padres de un paciente dieron por terminado el tratamiento). Un niño con defecto iatrogénico de la pared abdominal y uno con una hernia grande de la pared abdominal tuvieron buenos resultados. En el seguimiento, ninguno de los niños tuvo complicaciones.*
Conclusión: *Los defectos grandes de la pared abdominal en recién nacidos y niños pequeños pueden ser reconstruidos con parches de MDA con buenos resultados.*

Palabras claves: matriz dérmica acelular, defecto grande de la pared abdominal, reconstrucción de la pared abdominal

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INTRODUCTION

Omphalocoele is an anterior abdominal wall defect covered by an outside cyst membrane through which the abdominal content is pushed out and the umbilical cord enters the cyst membrane. This disease has an incidence of about 1/3000–1/10 000 in surviving newborns (1) and occurs more in males than females (3:2). The specific aetiology of omphalocoele is unknown, but it is generally believed that the defect occurs in the third-week of pregnancy and is caused by embryonic coelom closure occurring prematurely. More than 50% of omphalocoele cases are complicated by other serious defects in the digestive tract, cardiovascular system, genitourinary tract, skeletal muscle, central nervous system and sometimes even by chromosomal syndromes. Omphalocoele can be diagnosed by prenatal ultrasound, and its early detection can offer opportunities for formulating the best maternal delivery plan and providing professional treatment for newborns.

The defect diameter of an omphalocoele is generally 2–10 cm and emergency treatment is required in the neonatal period. The fatality rate was once as high as 80% (2); at present, with improvement in prenatal diagnosis, treatment methods, intravenous nutrition, and respiratory and circulatory management, the omphalocoele mortality rate has been reduced but is still 25.8–43% (3). Because of wide abdominal wall defects, a giant omphalocoele treatment is still extremely difficult. In a giant omphalocoele, the periumbilical abdominal wall defect diameter is larger than 5 cm. Besides an intestinal tract bulging, there is often substantial organ or bladder prolapse. Because of the large abdominal wall defect, severe illness and concurrent malformation, early and sound treatment is critical. For one-stage giant omphalocoele procedures, the repositioning rate is low and the operation difficulty is great. Mortality is closely related to the time of treatment after birth, the infant's critical state (*ie,* respiratory distress, capsular rupture, and fatal malformation) and other factors. Respiratory and circulatory failure and infection are the main causes of postoperative death in these infants (4, 5).

Besides giant omphalocoele, treating a residual abdominal wall defect after abdominal wall tumour resection is also a problem in paediatric surgery. Abdominal wall defects of various causes are common in clinical practice, which may include a large area of the abdominal wall being lost because of trauma, abdominal wall tumour, congenital defects, or tissue necrosis from a serious infection. Abdominal wall reconstruction is a complex and challenging operation.

In adult abdominal wall defect treatment, a synthetic patch has been regarded as a good alternative repair material, but it has greater risk of contamination or infection because it is a foreign body. There is no experience with synthetic patches in neonatal and paediatric surgery; this may influence the infants' safety and future growth and development.

With the ongoing development of tissue engineering technology, new biological materials are constantly emerging. Acellular dermal matrix (ADM) is a new type of tissue-defect repairing material that has been used in clinics and has achieved good treatment effects (6, 7). Inspired by this, our hospital recently successfully used the allogeneic ADM RENOV biological patch (Beijing Qingyuan Albert Biotechnology Co, Ltd, Beijing, China) in 13 cases of neonatal and infant abdominal wall reconstruction and achieved satisfactory results. In combination with the related literature, we discuss our therapeutic experience as follows.

SUBJECTS AND METHODS

General data

Eleven infants with congenital giant omphalocoele at the Children's Hospital of Hebei Province between 2010 and 2013 were enrolled in this study, including one case of an abdominal wall defect induced by an abdominal resection of neurofibroma and one case of huge abdominal wall hernia formed by a congenital omphalocoele without repair. Admission times of these cases were 3–25 hours after birth (mean 11.2 hours). Intestine and colon exposure was observed through use of capsule endoscopy: seven patients had spherical liver bulges into the abdominal cavity, with a size range of 8–10 cm × 6–10 cm × 6–10 cm. The smallest diameter abdominal wall defect was more than 6 cm, which was consistent with the diagnostic criteria for a giant omphalocoele. All of these patients were diagnosed as having giant omphalocoele. One infant (age one year, four months) with abdominal wall neurofibroma had an abdominal wall muscular layer defect (7 × 6 cm) as a result of abdominal wall tumour resection. The infant with the large abdominal wall hernia (formed by a congenital omphalocoele without repair) was age two years and six months. That child underwent giant omphalocoele gross repair in the neonatal period in another hospital; this resulted in an abdominal wall hernia (abdominal wall defect 11 × 10 cm), with the hernial content being intestine and liver. This study was conducted in accordance with the Declaration of Helsinki, with approval from the Ethics Committee of Children's Hospital of Hebei Province. Written informed consent was obtained from all the guardians of participants.

Repair of the defect

All patients were intubated and administered intravenous general anaesthesia. An annular incision was made at the junction of the cyst membrane and skin, and the cyst membrane and umbilical cord were resected. After examining the abdominal cavity to exclude any abnormality, the intestinal contents were pressed out through the anus. After rinsing the abdominal cavity, the intestinal canal was restored to the abdominal cavity. The peritoneum and residual aponeurosis and muscle layer were dissociated. The ADM patch was used to repair the defect. The patch was trimmed into an oval shape and flattened to eliminate tension; the size was slightly larger than the umbilical ring. The patch was placed between the peritoneum and residual aponeurosis and muscle layer. Interrupted mattress sutures using 5−0 absorbable stitch was followed by the interrupted suture of the subcutaneous tissue and skin. For the infant with abdominal resection of a neurofibroma, after

complete resection of tumour, the size of the abdominal wall defect was 7 × 6 cm. The size of the patch was adapted to the abdominal wall defect. For the infant with the abdominal wall hernia, the size of abdominal wall defect was 10 × 8 cm. The size of the patch was adapted to the hip tissue defect and the patch was placed outside the muscle layer. After the operation, the patient, who underwent tracheal intubation, was taken to the intensive care unit with ventilator-assisted breathing.

Postoperative treatment

All infants received postoperative ventilator support and intravenous nutrition therapy. One to two days after the operations, when the infants recovered respiratory function, ventilators were withdrawn. Four to six days after the operations, the infants were fed formula, after recovery of normal gastrointestinal function.

RESULTS

Operative results

Eleven infants with giant omphalocoele were treated with one-stage repair surgery. Because of congenital heart disease (multiple atrial septal defect, ventricular septal defects, patent ductus arteriosus, severe pulmonary hypertension) one infant failed to achieve ventilator, 48-hour withdrawal after the operation. The family asked to end treatment and initiate discharge. The other 10 infants were able to stop ventilator support 1.3–3 days after the operation and were discharged 12–21 days after surgery. At discharge, there was no wound swelling or cataclysm and the incision edge was neat. There was no sense of emptiness or abdominal bulge during crying.

The infant with the abdominal wall defect after resection of a neurofibroma recovered gradually and was discharged 14 days after surgery. At discharge, there was no wound swelling or cataclysm and the skin cutting edge was neat. There was no sense of emptiness or abdominal bulge during crying. The infant with the abdominal wall hernia recovered well and was discharged on the 20th day after surgery. At discharge, the wound was not swollen and was without fluctuation or emptiness. The stitches were removed, and the wound healed well.

Follow-up results

Of the 13 cases, 12 were followed until recently, with the shortest follow-up time being longer than six months. All patients had an abdominal computed tomography scan six months after surgery. These scans showed the patch tissue and peripheral tissue basically fused, with no clear boundary, foreign body, abdominal wall scleroma, enclosed mass, or limited abdominal distention during crying and standing. The abdominal walls of these patients had good flexibility, resistance to tension, and no foreign body reaction, which was consistent with the ideal reconstruction of an abdominal wall graft.

DISCUSSION

Research status of tissue defect repair

It has been reported that staging the repair of a huge abdominal wall defect has a poor therapeutic effect (6–8). One-stage repair of an abdominal wall is often a challenge because of insufficient tissue that will lead to increased abdominal pressure because of forcing the tissue to draw around the wound and suturing. Adult large abdominal wall defect repair often uses synthetic patches to make-up for the lack of tissue; experience using a synthetic material to repair an infant's large abdominal wall defect is limited. Therefore, one-stage repair and restoration of an infant's large abdominal wall defect is an important challenge for paediatric surgeons.

Several synthetic materials have been widely used in adult abdominal wall hernia and defect repair, with the tension-free hernia repair technique becoming the standard for abdominal wall hernia or defect repair. When surgeons encounter an adult's abdominal wall defect caused by a large hernia incision, they often use artificial patch repair and expand the abdominal cavity to reconstruct the abdominal wall. But this procedure also has some problems, such as patch infection, abdominal adhesions, intestinal cutaneous fistula, mesh displacement, the discomfort at the repair area, and other adverse reactions (9). These complications have precluded this procedure from the repair of infant and neonatal full-thickness abdominal wall defects.

Hormonnai *et al* (10) reported male patients with infertility and testis size changes after tension-free hernioplasty in 1980. Through animal experiments, researchers have found that a polypropylene hernia patch can cause testicular vein congestion (11). As a result, for juveniles, especially neonates and infants, unabsorbable synthetic materials should not be used.

The group in our study included 13 neonatal and infant patients who underwent treatment of whole-layer large abdominal wall defects. These procedures are always difficult. Allograft ADM can play a support role in the short-term after a repair operation, but will eventually be replaced by the self-tissue intrusion, and the patch will be absorbed *in vivo* with no residue and will not impact tissue structure and function. This new material provides new options for the reconstruction of neonatal and infant abdominal walls.

Advantages of the biological patch

Good biological compatibility is a necessary characteristic of an allograft, and tissue compatibility and angiogenesis speed are two important aspects of acellular dermal matrix ADM biocompatibility. Takami *et al* (12) and Sun *et al* (13) implanted ADM into rats subcutaneously and observed that ADM could be quickly vascularized, that neovascularization occurred in ADM material within one-week and that neovascularization covered all of the ADM material layers within two weeks. There was a mild inflammatory reaction, the collagen structure did not change until the 20th week, and no immune rejec-

tion was observed. After the ADM is implanted into the body, it can quickly vascularize and support the growth of autograft or autologous cells, which may make it superior to other dermal substitutes. This good histocompatibility overcomes the synthetic material's long-term foreign body stimulation, but its flaw is that it is not suitable for neonates and infants.

In this study, 13 patients were followed until recently, with the shortest follow-up exceeding six months. The *in vivo* time of ADM material absorption and alteration in hosts has been exceeded, reaching stability with no postoperative complications. This confirms that the ADM patch is better than a synthetic mesh, has no residual foreign body reaction and that the repair is permanent.

Acellular dermal matrix has good biocompatibility, but also can effectively integrate with the host tissue, ensuring good tissue strength after the repair. A rabbit model demonstrated that ADM is superior as a fascia substitute in reconstructing the abdominal wall and that, after ADM implantation, there are revascularizations, fibroblasts and inflammatory cells in the repair area. Its effectiveness is consistent with that of expanded polytetrafluoroethylene (14), this point has been confirmed by clinical application (15).

An acellular dermal matrix can function as an anti-infective and anti-adhesive material (16, 17) and can survive in contaminated and infected wounds. It will not lose strength and can be used for one-stage reconstruction of complex and contaminated wounds. Patton *et al* (18) used ADM in 67 reconstructive abdominal wall defects with accompanying contamination; wound infection occurred in 16 cases, most of which were superficial infections that could be cured through nonsurgical treatment. Five patients needed further surgery, only two required removal of the ADM and 12 patients had a recurrence. The results were better than with a synthetic patch. In our group of 13 patients, three had wound infections that healed well only through wound therapy and local treatment, but with no complications such as abdominal wall hernia.

Application feasibility of ADM in infants and newborns

An ideal material for repairing abdominal wall defects should have the following characteristics: good biocompatibility and flexibility, resistance to tension because it is close to abdominal wall muscles and tendon tissues, little to no rejection, available easily and in large quantity and convenient to use (19–21), and the ability to be absorbed without residue. Allogenic ADM has these characteristics; in addition, the material is a three-dimensional networked structure composed of collagen fibres, is porous, and has a large internal surface area, which is not only beneficial to the cells' vascular growth, but also to the infiltration of nutrients and discharge of metabolism. After implantation, endogenous tissue regeneration can begin, gradually completing tissue reconstruction and vascular regeneration by using the host's own cells; these characteristics make ADM ideal for grafts. In addition, allogenic ADM has a better performance-to-price ratio than acellular porcine small intestinal submucosa materials (22–24). In recent years, worldwide use of the ADM patch has been used in reconstruction of the adult abdominal wall, but not in infants and neonates. The patients in the present study were followed for obvious adverse reactions and complications, suggesting that this material is expected to be an ideal material for neonatal and infant abdominal wall reconstruction, but the long-term effects still need long-term follow-up and large studies for confirmation.

CONCLUSION

This retrospective study shows that ADM patches were successful in reconstructing neonatal and infant abdominal walls and provides an alternative surgical treatment for neonatal and infant large abdominal wall defects. Acellular dermal matrix patches should be expected to be used in further research in neonatal gastroschisis and other abdominal wall defect diseases.

AUTHORS' NOTE

All authors have no conflict of interest regarding this paper.

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