

# Repair of Cloacal Exstrophy, Omphalocele, and Gastroschisis Using Porcine Small-Intestinal Submucosa or Cadaveric Skin Homograft

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The traditional surgical methods typically used to repair the abdominal wall defect present in cloacal exstrophy, omphalocele, and gastroschisis during the neonatal period include definitive primary muscle, fascia, and skin closure, primary skin closure only with late ventral hernia repair, and a staged closure using a silo. The method chosen usually depends on the extent of visceral edema, the size of the defect, and physiologic derangements related to an increase in intraabdominal pressure during placement of abdominal contents into the coelom.<sup>1</sup> Although definitive muscle, fascia, and skin closure is preferred, increased intraabdominal pressures during attempts to reduce the herniated contents may prevent the use of this option.

The technique of widely mobilizing skin flaps with late fascial repair is associated with low rates of morbidity and mortality. However, there are some important disadvantages to this technique. Large dead spaces within the wound are common, thereby increasing the risk of infection. Additionally, loss of abdominal domain may produce a giant ventral hernia, which may be difficult to repair.<sup>2</sup> Abdominal silos prevent loss of body fluid and heat and allow progressive reduction of abdominal contents.<sup>3</sup> However, silo removal is usually required 5 to 7 days after placement. If primary fascia closure still cannot be achieved upon silo removal, a variety of alternative treatments including biologic dressings can

be used to cover the abdominal wall defect to achieve a definitive or temporary closure.

The use of porcine skin and amniotic membranes for the treatment of complicated gastroschisis and omphalocele was first described in 1975 by Seashore et al.<sup>4</sup> Although these biologic dressings are useful adjuncts that promote wound healing and are often used for burn victims, they have a number of disadvantages, including a daily replacement requirement, increased risk for wound infections including sepsis, enteric fistula formation, abdominal wall cellulitis, and loss of abdominal domain and creation of giant ventral hernias.<sup>4</sup> Various topical drugs and chemicals, such as mercurochrome and benzalkonium chloride, stimulate the formation of a thick eschar and have been used for large omphaloceles. Morbidity and mortality rates of these topical drugs are comparable to those associated with conventional primary or staged closure techniques. However, these drugs can be absorbed systemically and may result in intoxication, metabolic acidosis, or electrolyte abnormalities.<sup>5-8</sup>

We present two alternative methods in the repair of complicated abdominal wall defects using porcine small-intestinal submucosa or a cadaveric skin homograft. We describe the preparation and application of these grafts for a giant omphalocele associated with cloacal exstrophy and for complicated omphalocele and gastroschisis.

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## PATIENTS AND METHODS

In the majority of our patients, abdominal wall defects are closed primarily using standard techniques described elsewhere, including the technique of posterior relaxing incisions to allow mesial movement of myocutaneous rectus abdominis/internal-external oblique flaps.<sup>9,10</sup> Staged reduction with a silo and ensuing fascial closure is used in patients in whom we cannot achieve primary closure secondary to increased intraabdominal pressure with subsequent physiologic derangements.

*Graft Preparation and Application*

Porcine small-intestinal submucosa (Surgisis ES; Cook Tissue Engineering Products, Bloomington, Ind.) is a relatively new biomaterial consisting of an acellular matrix of collagen, growth factors, glycosaminoglycans, proteoglycans, and glycoproteins derived from the small-intestinal submucosa of pigs. Histological studies have shown that small-intestinal submucosa attracts host cells and acts as a scaffold for host cell incorporation and tissue remodeling.<sup>11-13</sup> A section of readily usable porcine small-intestinal submucosa is trimmed to the appropriate size. This section is then sewn to the fascia without tension using interrupted 3-0 long-lasting absorbable sutures. Skin, when available, is then closed over the porcine small-intestinal submucosa.

The homograft is a cryopreserved preparation of human skin procured aseptically from a cadaver donor (American Red Cross Tissue Services, Costa Mesa, Calif.). Cadaveric skin prevents desiccation, promotes bacterial sterilization of infected wounds,<sup>14,15</sup> and promotes re-epithelialization and neovascularization of the wound bed.<sup>16</sup> At bedside, a sheet of cadaveric skin is cut to the appropriate size to fully cover the wound. Small holes are then incised in the homograft to allow drainage, and the graft is secured to the wound edges with nonabsorbable sutures. Xeroform (Sherwood Medical, St. Louis, Mo.) is then placed over the graft and covered with 4 × 4 gauze and a circumferential abdominal pad. Nonadherent portions of the homograft usually separate within 2 weeks and are then excised or can be débrided with a moist 4 × 4 gauze pad. The cadaveric skin homograft is replaced every 2 to 4 weeks at bedside until the wound is epithelialized. In some cases, only one homograft may be needed. The skin is then closed over the graft, accepting a manageable ventral hernia. How-

ever, if the wound is well epithelialized, skin closure may be unnecessary. The ventral hernia is repaired when the patient is 1 to 2 years old.

The following case reports describe those patients who required alternative methods of abdominal wall closure.

## CASE REPORTS

*Case 1*

A 32-week, 1.6-kg girl was born with cloacal exstrophy and a 10-cm omphalocele. On her second day of life, the non-adherent portions of the omphalocele membrane were excised, the colon plate was tubularized, and an end colostomy was constructed. The bladder halves were partially reapproximated. Primary closure and reapproximation of the pubic symphysis and bladder plates were not possible because of limited intraabdominal domain in this premature neonate with an atypically large omphalocele for cloacal exstrophy. Attempts to bring together the bladder halves and pubic bones resulted in physiologic instability secondary to high intraabdominal pressures. The viscera were reduced and porcine small-intestinal submucosa was sutured to the abdominal wall fascia and the bladder edges. Adequate skin was not available in this patient to close primarily over the small-intestinal submucosa. Ten months after the application of the small-intestinal submucosa, the wound was well epithelialized. However, a ventral hernia was discovered. This patient will most likely undergo abdominal wall tissue expansion to repair the defect.

*Case 2*

A 36-week, 2.7-kg girl was born with gastroschisis. Several hours after delivery, the small bowel was decompressed, the viscera were partially reduced, and a silo was placed over the defect. On postoperative day 5, the silo was removed and replaced with a Gore-Tex patch (W. L. Gore and Associates, Flagstaff, Ariz.). The patch was removed 10 days later, and abdominal wall tension prevented primary closure. Porcine small-intestinal submucosa was sutured to the fascia and the skin was closed primarily over the small-intestinal submucosa. At age 10 months, the abdominal wall muscle and fascia are intact and the dermis has completely covered the porcine small-intestinal submucosa.

*Case 3*

A 40-week, 3.4-kg boy was born with a 6-cm omphalocele. Two days after cesarean delivery, the amniotic sac was excised and a silo was placed. During silo removal on day 17 of life, respiratory insufficiency developed during attempted closure of the abdominal wall defect. The wound was then irrigated and débrided, and cadaveric skin was placed over the defect. Two weeks later, the old homograft was replaced with a new homograft. The defect was well covered by the homografts, without infection and with good epithelialization of the wound. At age 5 months, the patient died of respiratory and septic complications related to underlying lung hypoplasia and complications of long-standing high-pressure ventilatory requirements.

*Case 4*

A 38-week, 3.4-kg girl was born with a 4-cm omphalocele. Several hours after delivery, the viscera were easily reduced and the abdominal wall fascia and skin were closed primarily

without tension. The amniotic sac was not excised. An abdominal wound infection developed 3 weeks later. The wound was opened, irrigated, and débrided, and the amniotic sac was then removed. One week later, cadaveric skin was sutured over the defect. Two weeks after homograft application, nonadherent portions were excised and the skin was closed primarily. The patient underwent uneventful ventral hernia repair at age 18 months.

#### Case 5

A 36-week, 2.4-kg boy was born with gastroschisis. A few hours after delivery, a silo was used secondary to high intra-abdominal pressures on attempted primary closure. Staged reduction was attempted for 8 days, and the silo was then removed. The fascia could not be reapproximated secondary to high intraabdominal pressures. A Silastic patch was placed over the defect and sutured to the skin. One week later, the patch was replaced with cadaveric skin homograft. The homograft had mostly incorporated into the wound and the defect was well epithelialized 2 weeks after placement. The ventral hernia was repaired when the patient was 2 years old.

#### DISCUSSION

Elliott and Hoehn<sup>17</sup> were the first to report the clinical use of porcine skin as a wound dressing in 1973. Since this time, reported uses of porcine small-intestinal submucosa have been mostly limited to animal models. Porcine small-intestinal submucosa has been used with relative success as an arterial and venous graft material in canines,<sup>18-20</sup> as a dural substitute in canines,<sup>21</sup> in diaphragmatic reconstruction<sup>22</sup> and bone repair in rats,<sup>23</sup> and in urethral regeneration in rabbits<sup>24</sup> and pigs.<sup>25</sup> It was used in the repair of full-thickness abdominal wall defects by Prevel et al.<sup>26</sup> in 11 rodents and by Clarke et al.<sup>27</sup> in six canines, without graft rejection, fistula formation, erosion into abdominal viscera, infection, or hernia recurrence. There was rapid host-tissue ingrowth and absence of an acute or delayed hypersensitivity response on histopathological examination. Because of tissue ingrowth, porcine small-intestinal submucosa is theoretically resistant to infections seen with other prostheses. We were able to construct an abdominal wall colostomy adjacent to the uncovered small-intestinal submucosa in a patient with cloacal exstrophy without resultant infection of the submucosa. However, 10 months after porcine submucosa placement, a large ventral hernia was discovered, indicating graft failure. Adequate skin was not available in this patient to close primarily over the small-intestinal submucosa. In contrast, we were able to close the skin primarily over the submucosa in the patient with gastroschisis. The 10-month follow-up visit for the latter patient did not reveal a ventral

hernia. These results may indicate primary skin closure over the porcine small-intestinal submucosa might be required for successful fascial tissue in-growth and subsequent restoration of abdominal wall domain.

The cadaveric skin homograft has been routinely used as a temporary skin substitute in the treatment of burn victims since 1953,<sup>28</sup> as adjunct therapy for nonhealing ulcers,<sup>29</sup> and in the treatment of nonburn traumatic wounds.<sup>30</sup> Cadaveric skin allows for early wound coverage, even in the setting of an infected wound. However, it does not allow for definitive abdominal wall closure, and a manageable ventral hernia will most likely need to be repaired at a later point.

To our knowledge, no previous studies have reported the use of porcine small-intestinal submucosa and cadaveric skin homograft in the repair of a giant omphalocele associated with cloacal exstrophy, or for complicated omphalocele or gastroschisis. The porcine small-intestinal submucosa and the cadaveric skin homograft are simple to manipulate, elicit a favorable biological response, and provide good mechanical strength. No histological studies on tissue excised during ventral hernia repair were performed. We conclude that these grafts provide stable coverage in neonates with large abdominal wall defects associated with cloacal exstrophy, omphalocele, and gastroschisis that cannot be closed by traditional methods. Porcine small-intestinal submucosa does not seem to provide a stable fascial closure. However, more cases with and without skin coverage of the porcine small-intestinal submucosa are necessary to support this conclusion. The resulting ventral hernias are acceptable in size and can be safely and easily closed when the patient is approximately 2 years old, following the use of porcine small-intestinal submucosa and cadaveric skin homograft.

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