Small Bowel Transplantation and Staged Abdominal Wall Reconstruction after Shotgun Injury

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Penetrating injuries to the abdomen from shotguns carry significant mortality and morbidity.[1] Such injuries can result in loss of the abdominal wall and various injuries to the viscera.

Complex injuries require early extensive evaluation, resuscitation, and management. Cooperation with other specialists, prioritization, and staging of procedures is extremely important and highly recommended to reduce the number of complications and achieve the best possible results and rehabilitation.

We present the case of a victim of a shotgun wound to the abdomen who was transferred to our institution with multiple organ failure; partial loss of the abdominal wall; dehiscence of a previous laparotomy incision; and loss of the entire small bowel, the left kidney, and spleen (Fig. 1). He was managed jointly by the transplant and the plastic surgery services and underwent several procedures before total rehabilitation.

CASE REPORT

A 28-year-old man sustained an extensive abdominal injury from a close-range shotgun blast. He was admitted to a local hospital with an entrance wound on the right upper quadrant of the abdomen and significant soft tissue damage. The patient was unstable and underwent urgent exploration through a midline incision. Because of significant damage to the superior mesenteric pedicle and the lack of perfusion to the small bowel, a near-total resection of the small bowel was performed. In addition, a left nephrectomy, distal pancreatectomy, and splenectomy were performed at the same setting. The duodenum was stapled 3 cm distally to the ampulla. A gastrostomy was also placed and the abdominal wall was closed in layers after debridement of all grossly devitalized tissues. A few days later, the abdominal wound developed an infection and total dehiscence. The duodenal stump dehisced as well, and high-output content was spilling into the abdominal cavity.

The patient was transferred to our institution approximately 5 weeks after the injury and the initial exploration for further care. On transfer, the patient was cachectic and suffered from multiple organ failure. His weight was 45 kg. The abdominal wound was open, the abdominal cavity, including the left lobe of the liver, was entirely exposed, and the duodenal stump was wide open.

After resuscitation and stabilization, the abdominal wound was debrided to healthy tissue, a draining catheter was placed in the duodenal stump, and total parenteral nutrition

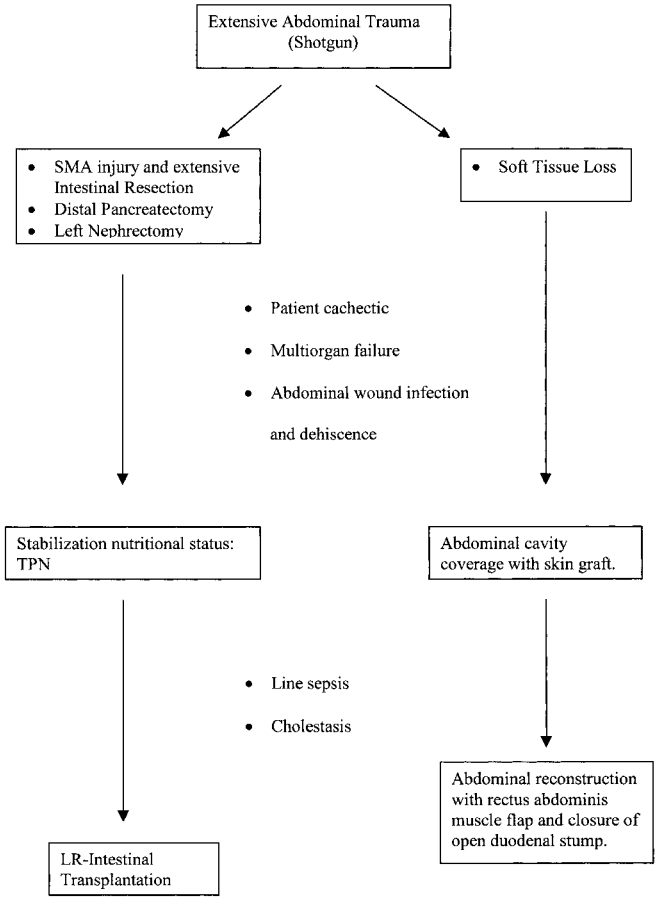

Fig. 1. *Surgical events following the trauma.*

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Fig. 2. *Open abdominal wound with draining catheter in the duodenal stump and exposed left lobe of the liver.*

Fig. 3. *Meshed split-thickness skin graft directly applied to the exposed liver.*

(TPN) was initiated. Two weeks after admission to our institution, the patient was stabilized. At this point, we were faced with the following problems: an open abdominal wound 24 cm in length with partial loss of tissue in the right upper quadrant and exposed liver (Fig. 2), high-output drainage from the duodenal stump, and the complete absence of the small bowel.

A staged approach was designed in collaboration between the transplant and the plastic surgery services. Because of the patient's general condition and poor nutritional status, we first elected to perform a simple coverage of the liver with a split-thickness skin graft (Fig. 3). This procedure was successful, with complete acceptance of the graft and coverage of the exposed liver. Three weeks later, we proceeded to repair the duodenal stump and close the abdominal cavity. After limited debridement of the stump, because of the proximity to the ampulla, the stump was oversewn. Because tissues were extremely friable and to prevent further complications with dehiscence of the stump, the suture line was reinforced with a rectus abdominis muscle flap. The left rectus abdominis muscle was mobilized, based on the superior epigastric pedicle and sutured around the anastomosis, providing an additional layer of coverage with well-vascularized tissue (Figs. 4–6). The abdominal wound was then

Fig. 4. *Duodenal stump (*arrow*) after debridement and repair.*

Fig. 5. *Superiorly based left rectus abdominis muscle mobilized to completely cover the repair of the duodenum.*

closed in layers using a modification of the components separation technique[2] (Fig. 7).

This procedure was successful, the duodenal stump healed uneventfully, and the abdominal wound healed as well. The patient's general condition continued to improve. However, the patient experienced multiple episodes of line sepsis. Furthermore, he presented incipient cholestasis related to TPN, with a total bilirubin up to 3.2 mg/dL but with no evidence of cirrhosis by liver biopsy. The patient was evaluated as a candidate for intestinal transplantation. Six months after the initial injury, he underwent a living-related transplantation of 185 cm of ileus harvested from his father. The father was 1 haplotype-matched and ABO compatible with him. Both donor and recipient were found to have a negative

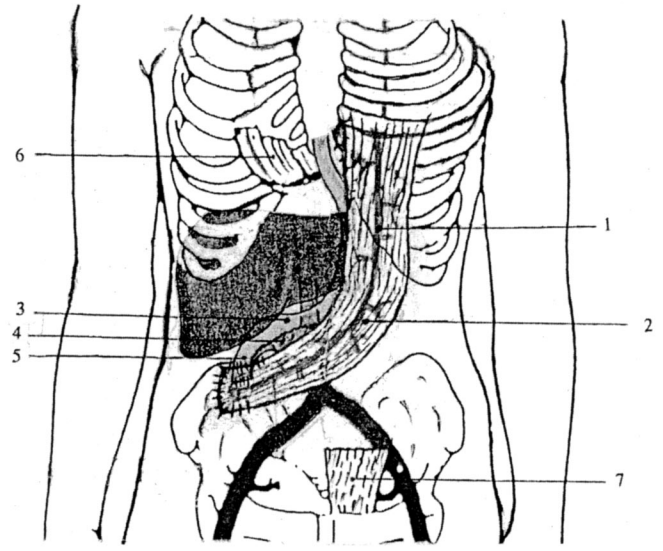

Fig. 6. *Coverage of duodenal stump.* 1, *Rectus abdominis;* 2, *superior epigastric pedicle;* 3, *stomach;* 4, *duodenum;* 5, *area of duodenal repair;* 6, *stump of right rectus abdominis;* 7, *stump of left rectus abdominis.*

Fig. 7. *Closure of abdominal wound after repair of the duodenal stump fistula.*

cytomegalovirus serology. The details of the surgical technique have already been described[3] (Fig. 8). Briefly, the segment of ileum was resected 15 cm from the ileocecal valve after measurement of the total length of the donor ileum. The donor ileum was primarily reanastomosed in end-to-end fashion using 4-0 polyglyconate for the mucosal layer and 4-0 polypropylene for the seromuscular layer. The graft was transplanted suturing the ileocolic vessels in an end-to-side fashion to the aorta and inferior vena cava using 6-0 polypropylene with a cold ischemia time of less than 10 minutes and a warm ischemia time of 30 to 40 minutes. The intestinal continuity was immediately reestablished proximally anastomosing the graft to the recipient's intestinal stump and distally to sigmoid colon, using similar suture materials as in the donor. A temporary distal loop ileostomy was performed to monitor graft output and to perform endoscopic surveillance and biopsies.

To prevent closure of the abdominal wall with undue tension, a 5 × 6-cm area of the abdomen was left open, covered only with an absorbable mesh. One week later, a

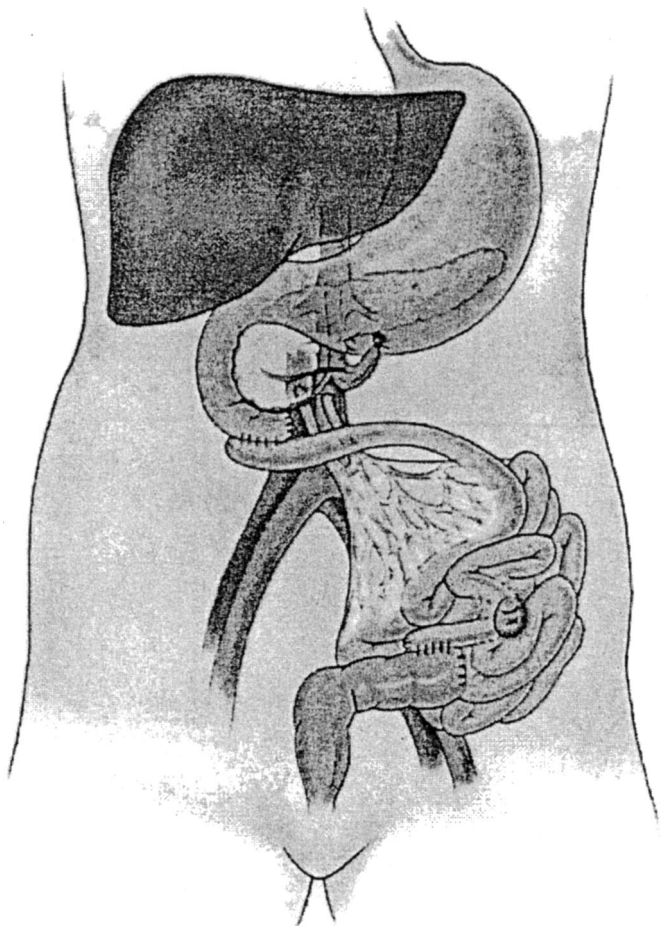

Fig. 8. *Small bowel transplant. Side-to-side anastomosis of the proximal end of the small bowel to the duodenum and the distal end to the sigmoid colon. The graft's ileocolic vessels were anastomosed end-to-side to the infrarenal aorta and vena cava. A temporary loop ileosigmoidostomy was performed to monitor the output and to perform biopsy of the bowel.*

split-thickness skin graft was applied over the granulation tissue on the mesh. The recipient had a smooth and uncomplicated recovery. He was able to tolerate a general diet by the seventh postoperative day, allowing early discontinuation of TPN. The patient did not experience any rejection episode and he has had no infectious complications to date. Short-course perioperative antibiotic prophylaxis with vancomycin (1 g intravenously before surgery) and piperacillin (3 g intravenously six or eight times a day, depending on renal function, for 3 days) was used, and antiviral prophylaxis was achieved using perioperative ganciclovir (5 mg/kg intravenously every 12 hours for 14 days) followed by high-dose acyclovir (800 mg per os four times a day for 3 months).

Immunosuppression consisted of oral tacrolimus (Fujisawa Healthcare, Inc., Deerfield, IL), prednisone, and intravenous induction with Atgam (antithymocyte globulin, Kalamazoo, MI) until therapeutic blood levels of tacrolimus were reached. Blood, stool, urine, sputum, and peritoneal fluids were collected as part of routine surveillance or when infections were clinically suspected and cultures were performed using standard microbiologic techniques. Serial biopsies (weekly for the first postoperative month and then on the basis of clinical indication) of the intestinal grafts were performed to evaluate rejection or viral infections.

Tacrolimus target blood levels were 20 to 25 ng/mL the first month, 15 to 20 ng/mL the second month, and 10 to 15 ng/mL thereafter.

His liver function tests normalized within 2 weeks; at that time, bilirubin was down to 1 mg/dL and remained normal thereafter. He experienced high stomal output in the first month posttransplant that progressively decreased to the point that the patient did not require any further assistance at 6 weeks posttransplant. The ileostomy was successfully taken down 4 months after the transplant. From a nutritional standpoint, a fat-soluble vitamin level and Schilling test were already normal 1 month posttransplant. Fat absorption documented by fecal fat studies was normalized by 6 months.

The D-xylose absorption test was back to normal at 6 months. The serum albumin level increased steadily after the transplant and has remained normal to date. Importantly, the patient has been able to gain weight and maintain it at 61 kg compared with 45 kg before the transplant. Thirty months after the procedure, he has doing well and has a stable abdomen (Fig. 9).

DISCUSSION

This case clearly demonstrates the need for close cooperation between specialists for the successful management of the various problems associated with complex penetrating injuries to the abdomen. Penetrating trauma is the leading cause of duodenal injury in countries such as the United States and South Africa, where 75% to 80% of the trauma is caused by gunshot wounds. According to the 1997 report of the International Registry for Intestinal Transplantation, 21% of the adult transplants are caused by ischemia and 15% are caused by trauma.[4] Our patient presented with superior mesenteric vessel ischemia, and with soft tissue trauma.

Injuries to the superior mesenteric artery are primarily because of penetrating trauma. Entrance wounds can be to the anterior abdomen, the flank, or the back. The majority of portal-superior mesenteric vein injuries are penetrating, and many are associated with an adjacent arterial injury.[5] Combination of superior mesenteric artery and vein injury has a significant mortality, reported to be 43%.[6] In a recent report of a multi-institutional experience with the management of superior mesenteric artery injuries, injury to the Fullen's anatomic zone I (trunk proximal to first major branch, inferior pancreaticoduodenal) corresponding to the maximal ischemic category affecting jejunum, ileum, and right colon presents the highest mortality (76.5%).[7] The American Association for the Surgery of Trauma Organ Injury Scale for abdominal vascular injury grades the superior mesenteric trunk injury as grade IV injury,[8] with overall mortality of

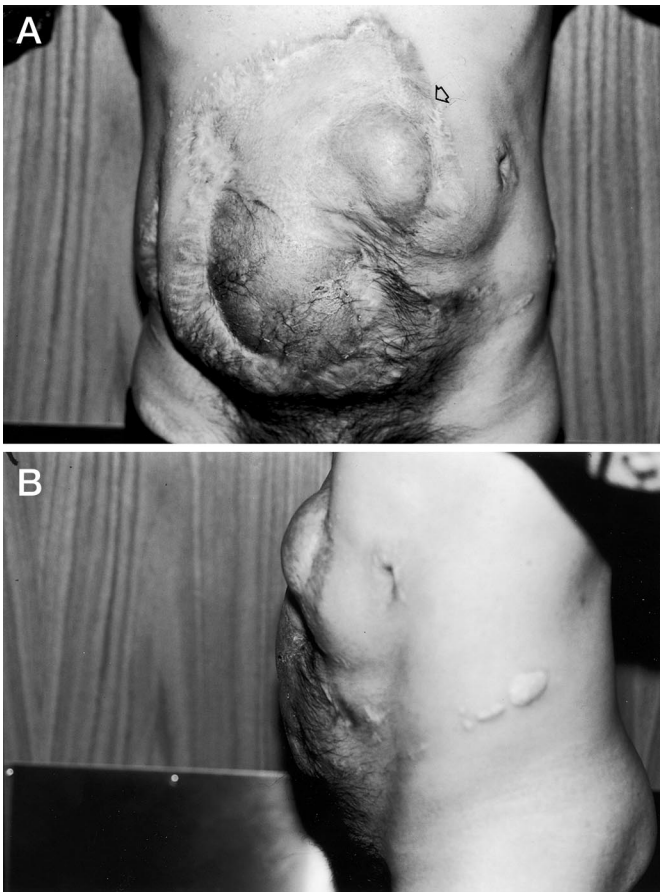

Fig. 9. *Result 18 months after small bowel transplant with completely healed and stable abdominal wall. The bulge in the abdomen (*arrow*) is not a hernia, but caused by the rectus abdominis flap.*

53.6%.[7] The retroperitoneal location of the duodenum and its close proximity to a number of other viscera and major vascular structures means that isolated penetrating injury of the duodenum itself is rare.[9]

In our case, there was a left kidney injury along with the injury to the superior mesenteric artery and vein. This injury resulted in left nephrectomy and near total enterectomy. A duodenal fistula and an extensive abdominal wall defect were present. A staged approach was elected in an effort to stabilize the patient and manage each injury in a logical approach, after prioritization of the patient's needs and establishment of a short- and long-term plan of action. Our initial attention was directed toward stabilization of the patient, management of the multiple organ failure, control of sepsis, improvement of nutritional status with TPN, and wound care.

The application of split-thickness skin grafts for temporary or permanent coverage of abdominal viscera has been well described and accepted.[10] The success rate of these grafts is extremely high, provided that there is no active infection and a granulative tissue bed has formed over the viscera. Even the presence of fistulas is not a contraindication for grafting. The skin grafts take well in all areas around the fistula. Advantages of skin graft application include wound stabilization, reduction of risk for secondary infection, rupture of anastomosis when present, and fistula formation. The loss of fluid and electrolytes from the open wound is reduced as well.

Furthermore, the procedure is quick and safe and is strongly indicated for debilitated patients, as in our case. There was significant tissue loss over the right upper quadrant, and coverage with complex reconstructive procedures and flaps was contraindicated at the time. It was our rationale that after stabilization of the wound over the liver we could close the abdominal defect without tension.

The use of muscle flaps to support friable anastomosis is also a well-accepted principle. Most reported cases include reinforcement of anastomotic areas of the bronchus, thoracic esophagus, heart, great vessels, and the bladder. A few scattered reports limited to a small number of patients have appeared in the literature for management of difficult and recalcitrant fistulas with muscle flaps.[11–13] Muscle flaps provide coverage of the suture line with well-vascularized tissue. Healthy tissue brought from areas outside the site of injury, fibrosis, and scarring are extremely helpful in promoting healing and reducing fistula recurrence.

The open duodenal stump in our patient was extremely difficult to manage because of its proximity to the ampulla; an ischemic and fibrotic stump would have resulted in an injury or ligation around the area of the ampulla. A major reconstructive procedure for biliary and pancreatic ducts was certainly not an option at the time.

In addition to the closure and coverage of the duodenal stump, the abdominal wall was closed at the same setting. There was very little tissue loss after the debridement of the dehisced midline incision. However, because of the unopposed pull of the lateral abdominal muscles and the subsequent tissue fibrosis, direct layered closure was not possible. We elected to use a modification of the components separation technique described by Ramirez et al.[2] The plane between the rectus muscle and the posterior rectus sheath on the right side was developed. A relaxing incision was then carried on the fascia of the external oblique and a plane was developed between this muscle and the internal oblique muscle. With this maneuver, the right rectus, the internal oblique, and the transversalis myofascial complex were mobilized medially by approximately 3 cm.

The final reconstructive problem we were faced with was the open abdominal wound after the small bowel transplant. Because of the contracted size of the abdominal cavity, primary closure of the entire cavity after small bowel transplantation was not feasible. Attempts for further closure would have resulted in dehiscence and further loss of tissue and could have placed the transplanted small bowel at risk from undue tension. An absorbable mesh was used to temporarily cover the remaining 5 × 6-cm defect. One week after the procedure, a split-thickness skin graft was applied over the granulating bed. The graft healed uneventfully.

The patient's general condition dramatically improved after the transplant. He was managed according to existing standard protocols, and at 18-month follow-up he presented with significant weight gain, excellent bowel function, and a stable abdomen. The progress in immunosuppressive therapy and the continuous technical refinements in the past decade have allowed a spectacular increase in the volume of clinical bowel transplantation. The most recent report of the International Intestinal Transplant Registry documented a total of over 270 cases of intestinal transplantation performed worldwide until February 1997, with a linear rate of growth from 1994.[4] The great majority of these cases are from cadaveric donors, and patient and graft survival rates (69% and 55% at 1 year, respectively) are still poor even only considering cases performed after 1995, according to the registry data. Furthermore, only 77% of the patients with functioning graft achieved the ultimate target of freedom from TPN. Technical complications, infectious complications, and rejection account for most of the patient and graft losses.[14] Segmental bowel transplantation from living-related (LR) donors could potentially improve the outcomes of the procedure in many ways. To date, 21 cases of intestinal transplantation using LR donors have been reported worldwide.[15] Similar to the transplant of other organs, intestinal living donation offers several advantages, such as reduced preservation injury, better HLA matching, and optimal donor and graft conditions. However, this procedure cannot be performed from living donors using the standardized techniques used with cadaver grafts, and a series of transplants using LR donors has not been available to unequivocally demonstrate such advantages. Moreover, LR small bowel transplantation has not encountered initial preference among the intestinal transplant surgeons because bowel grafts are widely available from cadavers. A standardized technique has been recently proposed for small bowel transplantation by Gruessner et al.,[3] who clearly demonstrated that the use of a segmental ileal graft vascularized by the ileocolic artery and vein, anastomosed to the infrarenal aorta and vena cava, is a reliable technique.

Most likely, better HLA matching could help to decrease the unacceptably high rate of rejection currently experienced in cadaveric small bowel transplants.[14,16,17] The donor can be easily matched on the basis of cytomegalovirus status. Once a suitable donor is identified, the transplant can be carried out expeditiously in an elective fashion, when both donor and recipient are in optimal conditions. Appropriate bowel preparation can be given. Cold ischemia time can be virtually eliminated and the warm ischemia time minimized, potentially improving mucosal preservation and decreasing bacterial translocation. A segmental graft may be quite helpful for potential recipients with a small abdominal cavity as a consequence of abdominal trauma and/or massive bowel resection. Finally, immunologic manipulations can be easily carried out in the elective setting of a living-related transplant.[16] The disadvantages of living-related small bowel transplantation include the risks for the donor, technical problems in transplanting a segmental graft in the recipient, and the concern regarding the functional ability of a relatively short graft to provide adequate absorption. The surgical risk of an elective small bowel resection with primary anastomoses is relatively low in experienced hands. The rationale to use 200 cm of bowel is dictated by the need for the longest possible segment with minimum risk for the donor and no long-term functional adaptation problems. The donor does not suffer any long-term absorption problem with an ileal resection limited to 200 cm, and the initial diarrhea can be easily controlled with medical therapy without any significant malabsorption (in particular, vitamin B_{12}).[3,16] Conversely, there are data suggesting that, through a progressive and relatively rapid functional adaptation, a 200-cm ileal graft can fully support the nutritional requirements of an active adult.[16]

In conclusion, several transplantation and reconstructive principles were used to manage this patient. With close cooperation between the transplant and the plastic surgeons, prioritization of the patient's needs, and short- and long-term planning, we were able to achieve total functional rehabilitation.

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