Comparative Medicine
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Vol 68, No 2
April 2018
Pages 177–181

Case Report

Repair of a Large Ventral Hernia in a Rhesus Macaque (*Macaca mulatta*) by Using an Abdominal Component Separation Technique

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Here we present a 32-y-old rhesus macaque (*Macaca mulatta*) with a large recurrent ventral incisional hernia. The initial surgery included midline celiotomy for treatment of endometriosis, in which the animal developed a hernia that was repaired with interposition of mesh. Hernia recurrence at 1 y resulted in a defect measuring 7 × 13 cm, with loss of abdominal domain. Skin breakdown was noted with areas of exposed mesh through the skin with associated acute on chronic infection. Clinically, the animal was lethargic, not eating, and failing to thrive. The present surgical treatment included midline celiotomy, removal of mesh, and attempted primary fascial closure. Due to the large defect and high tension, the fascia could not be closed. To facilitate closure, abdominal component separation technique was used and consisted of skin and subcutaneous dissection, external oblique muscle release, and dissection between the external and internal oblique musculature. This technique allowed for primary fascial closure and resection of excess diseased skin. A piece of polypropylene mesh was placed in a sublay fashion to reinforce the primary fascial closure. The animal tolerated the procedure well and has demonstrated steady weight gain, with no recurrence at 12 mo. Large ventral abdominal hernia defects in after surgery or trauma in NHP can present reconstructive challenges to veterinary surgeons. Failure to achieve a dynamic, low-tension closure can result in hernia recurrence, necessitating additional operations. Abdominal component separation is not commonly used in veterinary surgery and may be a helpful tool in cases of difficult abdominal reconstructions.

The incidence of large abdominal hernia defects after surgery or trauma in the NHP population is unknown. Such defects can result in substantial morbidity in affected animals and present a reconstructive challenge for veterinary surgeons. Principles of abdominal wall reconstruction include prevention of evisceration with restoration of the abdominal domain and provision of a dynamic, low-tension repair.[4,5] In humans, abdominal component separation procedures have become a standard method to repair large ventral abdominal wall defects. After midline celiotomy and lysis of adhesions, component separation consists of a lateral subcutaneous dissection, release of external oblique muscles, and dissection between the external and internal oblique muscles, resulting in significant hemiabdominal wall advancement and reduction in tension (Figure 1).[12,15]

Here we describe a case of a large ventral abdominal hernia in a rhesus macaque (*Macaca mulatta*), in which reconstruction involved an abdominal component separation technique. To our knowledge, this method has not been described previously in the veterinary literature. Low-tension closure of the fascia with resection of nonviable skin was achieved successfully in this macaque.

Case Report

A 32-y-old 8.2 kg female rhesus macaque (*M. mulatta*) presented with a large ventral abdominal hernia (Figure 2). This animal was part of an IACUC-approved caloric restriction study at the University of Wisconsin. Surgical history included midline celiotomy for the treatment of endometriosis and a repeat midline celiotomy for repair of a subsequent ventral hernia. Primary fascial closure was not achieved at the initial hernia repair because the defect was too large, and a piece of interposition polypropylene mesh was placed (Ethicon US, Somerville, NJ). At 12 mo after this procedure, the hernia recurred, with lateral retraction of the fascial edges and greater than 50% evisceration of the intraabdominal contents. The animal subsequently developed multiple areas of skin breakdown and ulceration, with exposure of the mesh. Clinically, the animal was failing to thrive, as evidenced by anorexia and weight loss. To prevent necropsy, an attempt at hernia repair was necessary.

After induction of general anesthesia by using intramuscular ketamine, the macaque was placed supine on the operating room table, and anesthesia was maintained by using fentanyl and isoflurane. Examination under anesthesia confirmed the size of the hernia defect and areas of skin breakdown (Figure 2). The previous midline celiotomy scar was used for the incision, and the skin and subcutaneous tissue were dissected sharply off of the mesh cranially, caudally, and laterally to expose the fascial edges. The mesh was removed, with lysis of adhesions to the underlying omentum and abdominal viscera. Reduction of the abdominal hernia contents revealed a 7×13-cm fascial defect (Figure 3). Primary fascial closure with a supporting mesh underlay was attempted to decrease the risk of recurrence and allow for resection of nonviable skin. Two Alice clamps were placed at opposing fascial edges at the level of the umbilicus and were pulled toward the midline. Substantial tension was

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Received: 09 Oct 2017. Revision requested: 16 Oct 2017. Accepted: 21 Nov 2017.
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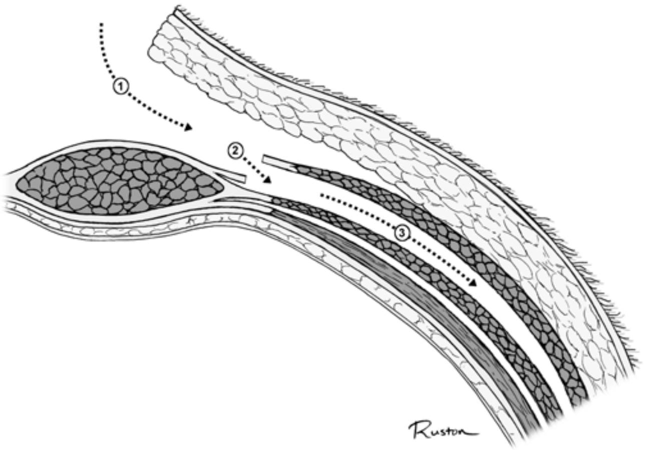

Figure 1. Diagram of a hemiabdominal wall defect in the axial plane, outlining the operative steps of component separation of parts. Step 1; release of subcutaneous tissues to anterior axillary line. Step 2: release of the external oblique muscle. Step 3: dissection between the internal oblique and external oblique muscles to the anterior axillary line. Reproduced with permission from reference 1.

Figure 2. Prerepair photo of large incisional hernia defect in the abdominal wall; the macaque is supine on the operating table. Note the skin breakdown and extrusion of previous placed mesh.

Figure 3. Intraoperative photo of hernia fascial defect after removal of old mesh and lysis of adhesions. Hernia measures 7 cm wide by 13 cm craniocaudally.

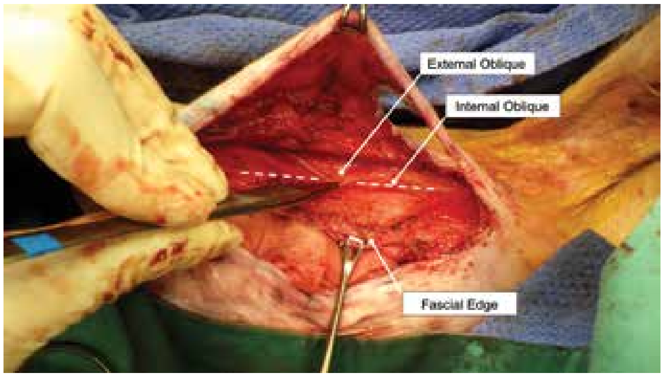

Figure 4. Intraoperative photo of component separation. This photo demonstrates the elevation of the skin and subcutaneous tissue off the left hemiabdominal wall and incision of the external oblique aponeurosis at 1 cm lateral to the linea semilunaris from the costal margin to the inguinal ligament (dotted line). The internal oblique muscle and aponeurosis can be visualized under external oblique aponeurosis. The same procedure was performed on the right hemiabdominal wall.

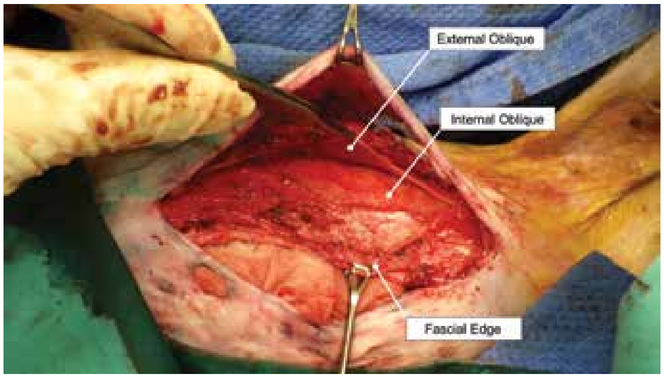

Figure 5. Intraoperative photo of component separation. This photo demonstrates the left hemiabdominal dissection between the external oblique aponeurosis and muscle and in the internal oblique aponeurosis and muscle to the anterior axillary line. The same procedure was performed on the right hemiabdominal wall.

required to bring the fascial edges within 1 cm of each another, thus making primary closure impossible.

We then decided to perform abdominal component separation. On each side, skin and subcutaneous tissue were elevated off the anterior rectus sheath and external oblique aponeurosis, extending 2 cm lateral to the linea semilunaris. At the level of the umbilicus, an incision was made in the cranial–caudal direction through the external oblique aponeurosis, 1 cm lateral to the linea semilunaris. This incision ran from the costal margin to just cranial to the inguinal ligament (Figure 4). Dissection was continued laterally until the anterior axillary line, in a plane between the external oblique and internal oblique aponeuroses and muscles (Figure 5). This dissection resulted in a sliding myofascial abdominal flap, with its innervation and blood supply maintained in the plane between the internal oblique and transversus abdominus muscles. Additional advancement of 1.5 cm per hemiabdomen (3 cm total) was achieved, allowing easy fascia-to-fascia approximation with minimal tension.

Polypropylene mesh was then sutured to the undersurface of the abdominal fascia in a sublay technique, over which the fascia was closed primarily by using a running 2-0 polydioxanone suture (PDS, Ethicon US, Somerville, NJ; Figures 6 and 7). Primary fascial closure led to considerable skin redundancy, due to tissue expansion from the hernia. All nonviable skin was resected, and the skin was closed primarily on the midline by using interrupted deep dermal sutures and a running subcuticular 3-0 polyglycolic acid suture (Ethicon US; Figure 8).

The macaque tolerated the procedure well and was extubated without complication. Buprenorphine (0.01 mg/kg IM)

Figure 6. Intraoperative photo of mesh sublay prior to primary fascial closure. The mesh was placed beneath the rectus muscle and sutured to the undersurface of the abdominal fascia.

Figure 7. Intraoperative photo of primary fascial closure over a polypropylene mesh underlay by using 2-0 polydiaxanone suture. Note the fascial advancement due to left hemiabdominal wall component separation (dotted line).

was administered twice daily as needed for pain during the postoperative period. The macaque was kept in isolation, with close monitoring, for 3 d until strength and regular dietary habits were regained. At 3 d postoperatively, the animal returned to the research protocol and pair housing. Routine husbandry practices followed the Wisconsin National Primate Research Center protocol. As of the 12-mo follow-up examination, the animal is gaining weight appropriately, and there is no evidence of wound complication or hernia recurrence.

Discussion

Here we describe an abdominal component separation technique, commonly used in humans, that we applied successfully to repair of a large ventral abdominal hernia defect with loss of abdominal domain in a rhesus macaque. Primary fascial closure with minimal tension was achieved, allowing for a low risk of hernia recurrence and, in this animal's case, removal of nonviable skin. Ultimately, this procedure prevented euthanasia of the animal, allowing it to continue on an important research protocol studying the effects of long-term calorie restriction.

Figure 8. Intraoperative photo of tension-free closure after resection of nonviable skin.

Hernias of the abdominal wall are common in all domestic species and include umbilical, incisional, and inguinal hernias. Ventral incisional hernias commonly arise from obstetrical operations but may also result from trauma or surgery for other indications including planned research procedures. Surgical closure of incisional hernias is often indicated to reduce the risk of intestinal incarceration and to restore dynamic core strength to the abdominal wall.[11]

In humans, incisional hernias remain a challenging surgical problem, with recurrence rates as high as 50%. To reduce the incidence of recurrence, reinforcement with permanent prosthetic mesh and component separation are commonly used, with reported recurrence rates as low as 20% and 15%, respectively.[7,9] A combination of abdominal component separation with mesh reinforcement has the lowest reported rate of recurrence, 11%, and has become the standard-of-care treatment for large defects.[9]

As typically performed, abdominal component separation consists of a lateral subcutaneous dissection, release of external oblique muscles, and dissection between the external and internal oblique muscles. This procedure produces a myofascial advancement flap with preserved innervation, providing both a structural and dynamic closure. Advancement of the hemiabdomen in the adult human population of as much as 6 cm in the upper abdomen, 10 cm in the middle abdomen, and 5 cm in the lower abdomen has been described.[12,15] In addition, marked reduction in tension on the abdominal closure after each step of component separation is reported.[1] Modifications to allow additional advancement of the muscle flap are few and include release of the internal oblique muscle, release of the transverse abdominis muscle from its deep surface, and variable releases of the anterior and posterior rectus sheaths.[1,6,8,12,15]

The use of mesh is associated with decreased hernia recurrence rates. Options for mesh selection include nonabsorbable, absorbable, and biologic materials.[3,10,13] We selected nonabsorbable mesh (that is, polypropylene) for use in the current case because of its light weight, large pore size, relative low cost, and availability at our institution.[3] Despite its widespread use, nonabsorbable mesh may be complicated by extrusion, infection, fibrosis, chronic inflammation, and abdominal wall inflexibility.[3,13] The use of absorbable mesh (for example, polyglycolic acid or glactin) is limited by its relative lack of strength, especially during the first 30 d,[13] but it may minimize adhesions when the mesh must be placed over bowel and is beneficial in

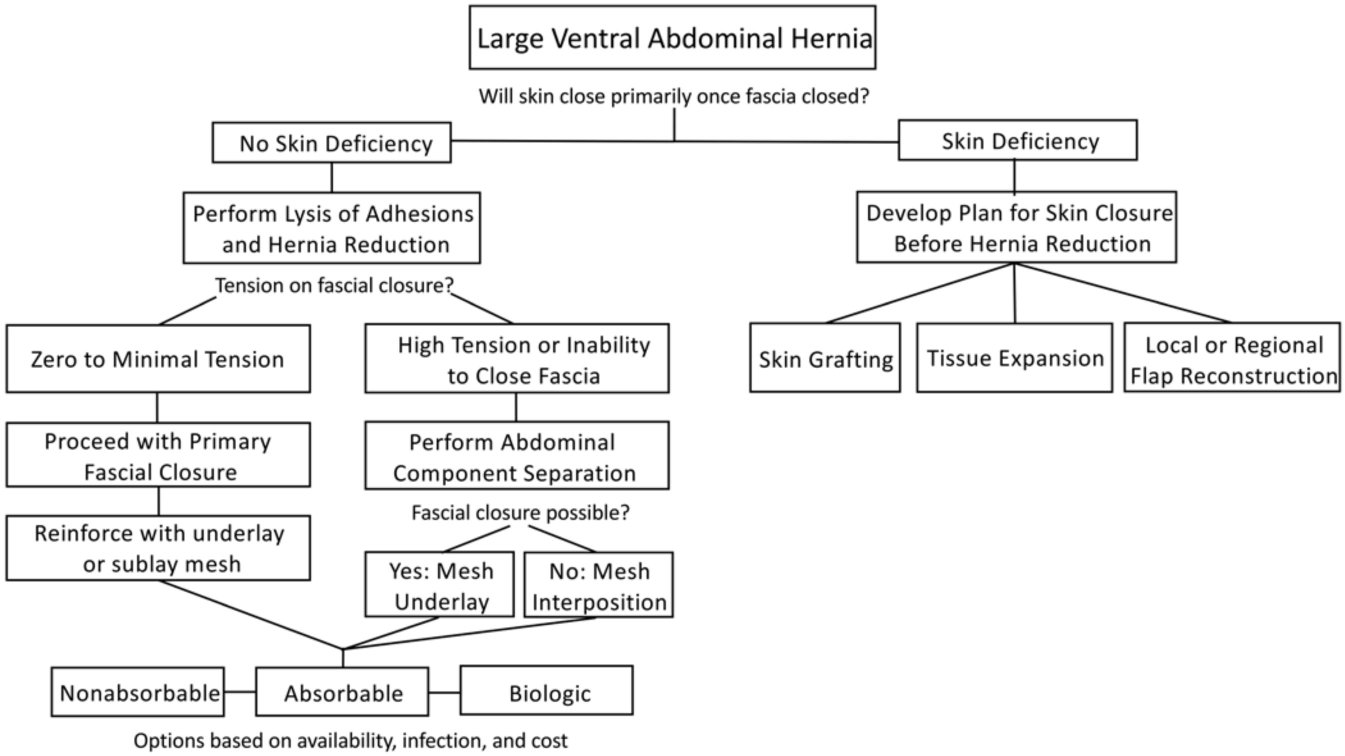

Figure 9. Algorithm for reconstruction of large hernias in NHP.

the setting of active infection.[3] Biologic mesh (for example, acellular dermal matrix, commonly manufactured by using cadaveric human or porcine skin) is associated with a decreased risk of infection in the setting of a chronic or contaminated wound, as well as increased neovascularization and decreased risk of enterocutaneous fistula.[13] However, the use of acellular dermal matrix carries an increased risk of seroma and postoperative abdominal bulge, as well as increased cost.[3,10] Other mesh materials and brands have variations in intrinsic properties, such as strength, weight, pore size, and elasticity, that may affect outcomes.[3]

Once a mesh type has been selected, the location of mesh placement must be considered, although the ideal plane remains under debate among hernia surgeons. One systematic review revealed that underlay and sublay (rectorectus) placement is associated with the lowest rates of hernia recurrence and complications (that is, seroma and infection).[2] When primary fascial approximation is not possible, bridging interposition mesh placement is necessary, although rates of seroma formation, infection, and recurrence are high.[2] Using an onlay mesh after primary fascial closure is associated with frequent recurrence and complications but may be the best option for an abdomen where the risk associated with the lysis of adhesions necessary to place an underlay mesh is unacceptably high.[2,14] Consequently, the location of mesh placement should be considered on a case-by-case basis.

When approaching a ventral incisional hernia, we suggest applying the following algorithm (Figure 9). First, make sure that, after fascial repair, enough skin is available for primary closure. In the majority of cases, excess skin will be present, due to tissue expansion from the hernia bulge. In the setting of anticipated skin deficiency, preemptive tissue expansion is common in humans but will likely not be tolerated by NHP and may limit the ability to perform the repair. After lysis of adhesions and hernia reduction, primary approximation of the fascial edges should be attempted. When tension is minimal, primary repair can be done and should be reinforced with an underlay or sublay mesh. When fascial edges cannot be brought together or when tension is high, a component separation of parts should be performed. Primary fascial closure should be reattempted, with mesh underlay. When approximation is still not possible, mesh interposition between fascial edges should be performed. Mesh selection should be made on an individualized basis, though availability, and resources may limit the surgeon. A lightweight, monofilament polypropylene mesh is appropriate for most situations.[3] We applied this algorithm was applied to the macaque in the current study, ultimately achieving primary facial closure under minimal tension.

References

1. **Afifi AM, Hartmann E, Talaat A, Alfotooh AA, Omar OS, Mareei S, Sanchez R, Kempton SJ.** 2017. Quantitative assessment of tension reduction at the midline closure during abdominal component separation. J Am Coll Surg **224:**954–961.
2. **Albino FP, Patel KM, Nahabedian MY, Sosin M, Attinger CE, Bhanot P.** 2013. Does mesh location matter in abdominal wall reconstruction? A systematic review of the literature and a summary of recommendations. Plast Reconstr Surg **132:**1295–1304.
3. **Brown CN, Finch JG.** 2010. Which mesh for hernia repair? Ann R Coll Surg Engl **92:**272–278.
4. **DiBello JN Jr, Moore JH, Jr.** 1996. Sliding myofascial flap of the rectus abdominus muscles for the closure of recurrent ventral hernias. Plast Reconstr Surg **98:**464–469.
5. **Fry DE, Osler T.** 1991. Abdominal wall considerations and complications in reoperative surgery. Surg Clin North Am **71:**1–11.
6. **Jernigan TW, Fabian TC, Croce MA, Moore N, Pritchard FE, Minard G, Bee TK.** 2003. Staged management of giant abdominal wall defects: acute and long-term results. Ann Surg **238:** 349–355.
7. **Langer C, Neufang T, Kley C, Liersch T, Becker H.** 2001. Central mesh recurrence after incisional hernia repair with Marlex—are the meshes strong enough? Hernia **5:**164–167.

8. **Novitsky YW, Elliott HL, Orenstein SB, Rosen MJ.** 2012. Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. Am J Surg **204:**709–716.
9. **O'Halloran EB, Barwegen CJ, Dombrowski JM, Vandevender DK, Luchette FA.** 2014. Can't have one without the other: component separation plus mesh for repairing difficult incisional hernias. Surgery **156:**894–899.
10. **Patel KM, Bhanot P.** 2012. Complications of acellular dermal matrices in abdominal wall reconstruction. Plast Reconstr Surg **130 Suppl 2:**216S–224S.
11. **Pearson LK.** 2016. Hernias. Merck and the Merck Veterinary Manual, 11 ed. [Cited 8 April 2017]. Available at: http://www.merckvetmanual.com/digestive-system/congenital-and-inherited-anomalies-of-the-digestive-system/hernias.
12. **Ramirez OM, Ruas E, Dellon AL.** 1990. "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg **86:**519–526.
13. **Rice RD, Ayubi FS, Shaub ZJ, Parker DM, Armstrong PJ, Tsai JW**. 2010. Comparisons of surgisis, alloderm, and vicryl woven mesh grafts for abdominal wall defect repair in an animal model. Aesthetic Plast Surg **34:**290–296.
14. **Rodriguez ED, Bluebond-Langner R, Silverman RP, Bochicchio G, Yao A, Manson PN, Scalea T.** 2007. Abdominal wall reconstruction following severe loss of domain: the R Adams Cowley Shock Trauma Center algorithm. Plast Reconstr Surg **120:**669–680.
15. **Shestak KC, Edington HJ, Johnson RR.** 2000. The separation of anatomic components technique for the reconstruction of massive midline abdominal wall defects: anatomy, surgical technique, applications, and limitations revisited. Plast Reconstr Surg **105:**731–738.