History of Abdominal Wall Repair: In Search of New Techniques and Materials

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Introduction

The abdominal wall was not meant to be violated. An early description of defect closure came from Plutarch in his description of the suicide of Cato the Younger in 46 BCE. Cato, the stoic, had thrown in his lot with Pompeius Magnus against the imperial Caesar, and all had turned out badly for him. After the death of Pompey and the defeat of forces in Utica, Cato decided to end his life by sword to the abdomen. He was successful in opening the abdominal wall and apparently fainted. A brave physician was called, who recognized that the situation might be remedied by surgical skill and daring. "The physician put in his bowels, which were not pierced, and sewed up the wound." This was successful, but when Cato regained consciousness and realized his global failure had even extended to his own suicide, he ripped open the wound and tore out the intestine, dying promptly as he always intended but now as a surgical complication [1].

Surgeons have struggled with the daunting task of restoring the abdominal wall despite its nature, their patients' intent, and personal inadequacy. There were many attempts at laparotomy that, despite best intentions, ended in peritonitis and death. The first success was that of Ephraim McDowell in 1809. In Danville, Kentucky, he removed an ovarian tumor without benefit of anesthesia or antisepsis. He was clean in his habits, which may explain why this procedure was followed by a 33-year survival for his patient [2]. Throughout the nineteenth century, there were many bold efforts at operating in the abdomen, and the successful reports did not seem to include any problem with healing of the abdominal wound.

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Early Reports in the Annals of Surgery

The great prospect of laparotomy, with some caveats, was declared in the *Annals of Surgery* in 1886 [3]. Reports were duly made to the American Surgical Association for pistol shot [4], gunshot [5], and splenectomy [6], and all successes were reported without failure of the abdominal wall. Dixon reported concerning an appendectomy for purulent perforation and in the same issue reported a laparotomy for strangulating hernia [7, 8]. Not only could the pristine abdomen be treated but also potentially septic pathology could be managed. Reports of ventral hernia after laparotomy were slow to come. The first report in the *Annals of Surgery* was in 1901 from Eads [9]. The early problem was considered that of great difficulty, and the reports of hernia were notably lacking in the bravura of earlier reports of successful laparotomy. When the surgeon was confronted with massive protrusion of abdominal contents, which could be seen writhing in peristalsis just beneath the thin skin, there was a strong urge to repair the problem. Many of these efforts followed in the twentieth century and today.

The persistence in innovation for repair of the anterior abdominal wall strongly suggests that there is no good way to repair the problem even now. The current incidence of incisional hernia may be as high as 11% across the board. One might implicate a poor effort at the closure of the original laparotomy. However, the surgeon who undertakes to remedy the earlier mess is rewarded with a 33% likelihood of hernia recurrence. The second or third effort at repair of abdominal wall defects is associated with an even higher likelihood of recurrence [10].

The options to repair include movement of local tissue into a configuration that will restore wall integrity. This approach was the mainstay for most of the history of laparotomy. However, the inadequacy of this approach in general led to a relentless search for autologous, allogeneic biological material or prosthetic materials for over a century.

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Prosthetic Materials

In 1947, Koontz (Baltimore, MD) reported at the Southern Surgical Association on his work with tantalum gauze. Tantalum was an interesting choice based on the tragic story of the element's namesake, the mythological Tantalus, who was condemned to stand in a pool of water he could never reach to drink. Certainly, the identification of a prosthetic material to slake the knowledge thirst of frustrated surgeons did not end with this material; it continues to the present. Koontz had previously reported the use of preserved ox fascia but now moved on to a relatively inert metal that could span the defect of an abdominal hernia. Experimental repair preceded his clinical application, and he was insightful in recognizing that the strength of his experimental repair was because of the infiltration explained by the structural strength of the repair and not the mesh itself. Furthermore, he described the use of the material as a full replacement of the defect as well as an overlay for tenuous fascia approximation. He described the need to overlap the fascia and the material with generous sutures [11]. Koontz also described the desirability to divide the rectus fascia vertically to provide the abdominal fascia mobility in seeking midline union. His work followed a half century of difficult work with silver mesh. That material was not only antiseptic but also irritating, eventually dissolving.

The local tissue approach to reapproximate the anterior abdominal wall continued as an evolving challenge with a seminal development by Albanese in the 1950s and popularized by Ramirez in 1990. He described the elevation of subcutaneous flaps far lateral of the midline and the division of the external oblique fascia. This plane also became undermined, and the rectus fascia was divided just posterior to the midline to allow advancement of the rectus. This dissection and fascial division allowed advancement perhaps 10 cm to the side to provide a generous coverage of even huge hernias while relying on the redundancy of the abdominal wall layers to ensure structural integrity [12]. Regional flaps—such as tensor fascia lata, latissimus dorsi, and free flaps—have been applied for specific needs, but these are generally proposed for initial repair of large defects created in the resection of abdominal wall tumors.

Finding the Perfect Mesh

There has been great interest in finding a polymer that would approximate collagen in strength, durability, and flexibility. Such a polymer has not been found. In this search, a reasonable set of criteria was proposed by Cumberland [13] and Scales [14] in 1952 and 1953, respectively. They proposed eight characteristics for an ideal mesh; the ideal mesh should be noncarcinogenic, chemically inert, resistant to mechanical strain, suitable for sterilization, biologically inert, nonallergenic, limited foreign body tissue reaction, and amenable to production in useful form for surgery. Polypropylene was first synthesized in its crystalline isotactic form in 1954. Commercial production began in 1957, and Usher described the first use of polypropylene mesh for hernia in 1959 [15, 16]. The mesh was marvelously flexible, durable, and strong. It also harbored bacteria in its many interstices; an infection could flare many years after implantation. Undesirably, the material not only incorporated the invading fibrous tissue but also engendered adhesions to the intestine and created a prospective intestinal obstruction. Polyester has similar qualities.

Because of adhesions and infections, new expectations were placed on the ideal mesh. It would be desirable if the mesh resisted infection, presented a nonadherent face to the abdominal cavity, and could respond biologically in a manner similar to autologous tissue [17]. A review of prosthetics by Shankaran et al. was superb, timely, and scholarly.

Nonabsorbable Mesh

The polymer meshes include polypropylene (Prolene®, Ethicon, Somerville, NJ; Marlex®, C.R. Bard, Murray Hill, NJ); lightweight polypropylene (Vypro®, Ethicon; ProLite™, Atrium, Hudson, NH); polyester (Dacron, Mersilene™, Ethicon); and expanded polytetrafluoroethylene (ePTFE, GoreTex®, W.L. Gore & Associates, Newark, Delaware). They differ by pore size; ePTFE has smallest and therefore has the least likelihood to harbor bacteria. They differ in tensile strength, but all exceed the necessary strength. They are of similar thickness. They differ in varying degrees in postoperative pain syndromes, and there are varying reports of recurrence. Generally, after a mesh repair of an incisional hernia, there is a recurrence rate of 2–30% compared to open/primary repair failures of 18–62% [18–22]. None of the polymer meshes achieve the ideals listed previously. A large number of coated or composite meshes have been introduced to address needs. Mesh has been coated with bioabsorbable but initially active agents such as poliglecaprone (Ultrapro®, Ethicon); carboxymethylcellulose–Seprafilm on polypropylene (called Sepramesh™, C.R. Bard); omega-3 fatty acids (C-Qur™, Atrium); cellulose (Proceed®, Ethicon); and collagen-polyethylene-glycerol on polyester (Parietex™, Covidien, Dublin, Ireland). Each has great proponents and detractors, but a definitive advantage is not obvious. The mesh has been made double sided to address the special issue of reactivity next to the bowel on the peritoneal side. Lightweight or heavyweight polypropylene on ePTFE (Composix™, C.R. Bard) is dual sided, and there is dual-sided ePTFE with a different surface, resulting in a nonporous material (DualMesh®, W.L. Gore) as need proposed. The chemistry of the mesh occupied most of the discussion and progress in understanding and treating massive abdominal trauma in the latter part of the twentieth century. The technique regarding placement of the mesh relative to the abdominal viscera has continued to add fuel to the debate, and the truth is still out there somewhere [23–27].

Absorbable Mesh

Absorbable mesh has also been considered in order to provide a temporary matrix and strength, with subsequent replacement with natural tissue. Polyglycolic acid (Dexon™, Covidien) and polygalactin (Vicryl®, Ethicon) had been used, but problems with failure to control infection and high recurrence rates have dimmed enthusiasm except in severe circumstances of sepsis for which a temporary barrier is all that is required [28].

Laparoscopic Repair

In 1982, laparoscopy was applied to ventral hernia for the first time with internal closure of a hernia sac [29]; a full description and result were published in 1993 by Le Blanc and Booth [30]. Full anatomic reconstruction of the abdominal wall by laparoscopy has been a growing trend because of its decreased injury and quicker return to function [31]. The data have been subject to the improved database registry of the American College of Surgeons National Surgical Quality Improvement Program [32]. Despite lower overall morbidity with laparoscopic technique, this 2011 report only accounted for 17% of the procedures in a registry of over 71,000 ventral herniorrhaphies for the years 2005–2009. Laparoscopy for massive abdominal wall defects is considered difficult because of alternate entry ports, adhesions, and the disorientation of the surgeon confronted with terribly distorted anatomy. Comparison of open versus laparoscopic procedures examined ten randomized controlled trials in the Cochrane Database [33]. A general review of the dramatic progress in herniorrhaphy was published by Gray et al. in 2008 [34].

Conclusion

The next level of endeavor for the thousands of disabled patients threatened by abdominal hernia probably lies with improved skills in laparoscopy. Most likely, materials science is not going to offer the next frontier in hernia repair. The possibility of tissue engineering manufacturing a truly comparable dynamic tissue to substitute for the abdominal wall should be anticipated, however. Further improvement in results will certainly come from agreement on proper surgical indications, eliminating high-risk patients from the tally. Finally, better understanding of the biology of the marvelous structure, function, and plasticity of the abdomen may offer sound and new principles in the initial repair of this essential barrier to prevent such a prevalent and almost always iatrogenic scourge.

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