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A BURR-LIKE DEVICE TO FACILITATE TEMPORARY ABDOMINAL CLOSURE IN PLANNED MULTIPLE LAPAROTOMIES

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ABSTRACT

Objective: To describe and test a method foi temporary closure of the abdomen.
Design: Open laboratory and clinical studies.
Setting: Department of Surgery, Medical College of Wisnsin, USA.
Subjects: 11 patients who underwent planned relaparotomy.
Material. The burr consists of two adherent sheets of polyamide and polypropylene, which may be trimmed to accommodate any wound. One sheet consists of micromushrooms, the second of multiple slings. The two sheets stick to each other upon pressure and can easily be separated to open the wound.
Intervention: Planned relaparotomy or staged abdominal repair.
Outcome Measures: Measurements of tensile strength and microbiological cultures.
Results: The shearing force required to separate the burr is 150 ± 27 N/5 cm^2 when gas sterilized and 77 ± 11 N/5 cm^2 when used in five subsequent laparotomies. No adverse microbiological effects were seen.
Conclusion: The artificial burr can be used for temporary closure of the abdomen. It circumvents the problems that occur with zip fasteners, Marlex mesh, slide fasteners, and towel clips.

RÉSUMÉ

ut: Décrire et tester une méthode permettant d'assurer fermeture temporaire de l'abdomen.
Type d'étude: ouverte, expérimentale et clinique.
Provenance: Département de chirurgie, Ecole de médecine du Wisconsin, USA.
Malades: Patients ayant une laparotomie itérative programmée.
Materiel: Le système est formé de deux feuillets adhérents de polyamide et de polypropylène, qui peuvent être taillés pour s'adapter à tous les types d'incision. L'un des feuillets est recouvert de structures proéminantes en forme de champignon et le deuxième de multiples sillons adaptés à recevoir la tête des champignons. Les deux feuillets adhèrent l'un à l'autre par simple contact et peuvent être facilement séparés pour réouvrir l'incision
Intervention: Laparotomie itérative programmée ou réparation abdominale en plusieurs temps.
Principaux critères de jugement: La mesure de la résistance et les cultures bactériologiques.
Résultats: La force de cisaillement nécessaire pour séparer les deux feuillets est 150 ± 27 N/5 cm^2 si sterilisée avec éthylenoxyde et 77 ± 11 N/5 cm après 5 laparotomies itératives programmées. Elle est plus important que celle du fascia. Aucune complication infectieuse n'a été observée.
Conclusion: Le système décrit peut être utilisé pour assurer la fermeture temporaire de l'abdomen. Il évite les inconvénients que l'on peut recontrer avec la fermeture éclair, les plaque de Marlex, les fermeture à glissière et les sangles à clips.

INTRODUCTION

Since the suggestion by Pujol (26), many have advocated operative strategies other than the classic single operation for advanced intra-abdominal disease. Both leaving the abdomen open (5, 13, 30) and multiple planned relaparotomies (10, 23, 39) have been recommended. The latter approach requires temporary abdominal closure until the disease resolves and the abdomen can be closed. Planned relaparotomies have been recommended in the management of ischemia of the bowel, diffuse suppurative peritonitis (39), pancreatitis (32), major haemorrhage requiring packing (8, 17), massive oedema of the bowel preventing primary reapproximation of the fasciae (1, 6), and other conditions associated with progressive deterioration precluding definitive operation (1, 31, 34).

Devices described for temporary abdominal closure include: retention wires (39); a zip fastener (22); polyamide (10), polypropylene (41), or polyglycolic acid mesh (25); a combination of mesh with a zip fastener (16); a slide fastener with large slides (37, 39); and towel clips (8) as well as other heroic forms (9). None of the devices is completely satisfactory In this paper we describe a new device for temporarily closing the abdomen.

MATERIALS AND METHODS

The artificial burr consists of two sheets of knitted synthetic fibres, each with clinging elements on one surface, which adhere to each other. The main components of both parts are polypropylene and polyamide. The back of each sheet is reinforced for stability and handling with Pextol BV595(R), an aqueous dispersion of the ethyl-ester of acrylic acid. The material is available in various sizes (HIDIH Surgical, Schloßtraße 13, D-6531 Dörrebach, Germany) and may be trimmed as needed.

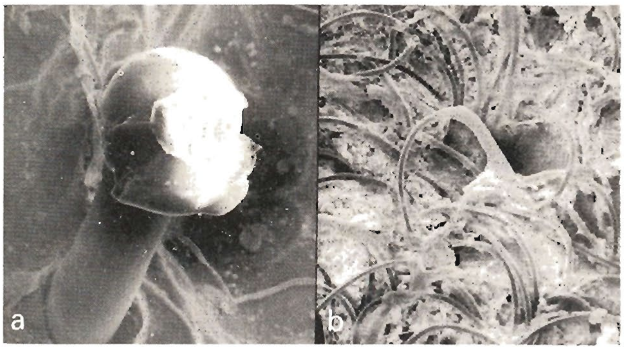

Fig. 1. Electron micrographs of the burr. (*a*) the closure side showing the mushroom-like structures (magnification ×300). The diameters of the heads of the mushrooms range between 0.3 and 0.6 mm. (*b*) the loop side showing multiple slings (magnification ×150).

The mechanism of adherence has been copied from nature and is similar to that of the fruit of certain plants of the genus *Arctium* (*Arctium lappa, Arctium tomentosum*). Common terms for these plants are burr, burdock breech, sticktight, and cockleburr. We have called the device an artificial burr.

The loop sheet of the burr (Fig. 1 *b*) has a velour-like soft surface and a flexible reinforced back. It consists of chain-woven 100% polyamide (nylon 66) velour with multiple small loops on one side. The closure sheet (Fig. 1 *a*) consists of 70 to 80 micro-mushrooms/cm^2 on a round knitted, reinforced surface. The diameter of each micro-mushroom is about 0.18 mm. Firm pressure of the closure sheet against the loop sheet allows penetration of the free ends of the mushrooms into the network of loops. The burr can be opened by peeling, shearing or lifting the two sheets apart. Peeling is the most common and gentlest method. The burr is chemically stable and also stable up to temperatures of 130°C. It can be sterilised by both gas and steam autoclaves.

Operative Technique. The operative technique is described in detail elsewhere (39). In that publication we utilized the term "Velcro analogue" to emphasize the similarities of the artificial burr to Velcro® Velcro® is the trade name of a product that is similar to the artificial burr but is comprised of one sheet with hooks, rather than mushrooms, and one sheet with loops. In using the artificial burr, the two sheets of the material are trimmed with scissors, the loop sheet is sutured with a running, doubled, monofilament suture to the fascia on one side of the incision with the loops facing outwards, the reinforced back of the loop sheet is gently slipped beneath the opposite fascia, and the closure side is then sutured to the fascia of the other side of the incision with another running suture. The fascial closure is completed by gently pressing the closure side on to the loop side, while exerting slight tension. The skin and subcutaneous tissue are left open.

Measurements of tensile strength. In addition to the technical data obtained from the manufacturer, we tested the tensile strength of eight samples of unsterilised burr as well as samples after gas sterilisation, steam sterilisation, and after recovery from a patient who had had five consecutive relaparotomies. For each fabric sample test, eight strips, 1–2 cm wide and 10 cm long, were cut from the sheets of loop and of mushroom material. The ends of a pair of loop and mushroom strips were clamped into the jaws of a tensiometer The strips were pressed together over a defined area ranging from 1–5 cm^2. The tensiometer jaws were driven apart at a rate of 1 mm/second until the burr strips opened or the material tore in the non-adherent portion. The results were compared using the two-tailed paired t-test.

Microbiological investigation. Specimens were taken from the abdominal fluid and from both parts of the burr at the first laparotomy and during subsequent relaparotomies in eleven patients. The specimens were transported immediately to the laboratory. Pieces of the burr about 1 cm^2 were oscillated ultrasonically (20 kHz for 10 min) to free any adherent bacteria into liquid nutrient broth (trypticase-soy, Baltimore Biological Laboratory, Baltimore, MD). The broth was then inoculated into the following media for aerobic and anaerobic isolation: trypticase-soy blood agar, colistin-nalidixic acid blood agar, MacConkey agar, Centers for Disease Control formulation of anaerobic blood agar, kanamycin-vancomycin anaerobic blood agar, and phenyl-ethyl alcohol anaerobic agar. Aerobic media were incubated at 35°C and examined at 24 and 48 hours. All aerobic bacterial isolates were identified by standard methods. Anaerobic plates were incubated at 35°C and examined at 48 and 96 hours. Anaerobic bacteria initially were identified by macroscopic and microscop criteria. The isolates were tested for tolerance to oxygen. Strict anaerobes were inoculated into pre-reduced, anaerobically sterilised, carbohydrate media. Volatile and non-volatile metabolic by-products were analysed by gas liquid chromatography. Biochemical evaluations were made using standard techniques.

RESULTS

Tensile strength measurements are recorded in Table I and displayed in Fig. 2. The shearing forces required to disrupt the unsterilized burr ranged between 23 ± 6 N/cm^2 and 164 ± 12 N/5 cm^2 and were related to the area of adherence. Sterilisation resulted in a decrement in strength of adherence with steam but not with gas sterilisation. After five relaparotomies, the tensile adhesive strength was significantly decreased ($p < 0.09$) although the residual strength was still of sufficient magnitude to be clinically effective.

Cultures of peritoneal fluid and of both the loop and hook sides of the burr taken from one patient with intra-abdominal trauma showed no bacterial growth. In six other patients with secondary bacterial peritonitis, bacteria recovered from the burr were identical to those recovered from the peritoneal fluid. In another patient with diffuse peritonitis following small bowel perforation, an additional coagulase positive staphylococcus was isolated from the burr during the third procedure but was not found subsequently. At the fifth relaparotomy in this patient, a coagulase negative staphylococcus and an *Enterococcus faecium* were isolated but were not recovered during subsequent reoperations. At the tenth and last procedure, a *Lactobacillus* was isolated from the burr but was not recovered from the wound. In another patient with peritonitis, an *Enterococcus avium* was isolated from peritoneal fluid but not from the burr.

Table I. *Force (N) required to disrupt the artificial burr related to the area of adhesion (cm^2)*

Fabric sample	Non-sterilised					Steam sterilised	Gas sterilised	Abdominal reclosure ‡
	1 cm²	2 cm²*	2 cm²†	4 cm²	5 cm²	5 cm²	5 cm²	5 cm²
1	26.7	53.5	71.3	106.1	178.2	138.2	156.2	80.1
2	19.6	57.9	66.9	111.4	182.8	133.7	164.7	55.6
3	31.2	66.9	57.9	88.1	156.2	102.6	156.2	71.1
4	26.7	55.7	71.3	122.6	169.2	120.2	178.2	80.1
5	24.5	49.1	55.7	120.2	156.2	115.7	169.2	93.6
6	26.7	53.5	75.7	133.8	147.2	93.6	120.2	78.1
7	15.6	49.1	57.9	133.8	153.7	89.1	98.1	78.1
8	15.6	53.5	89.1	133.8	169.2	142.7	160.2	80.1
Mean	23.4	54.9	68.2	118.7	164.1	117.0	150.4	77.1
SD	5.8	5.7	11.2	16.2	12.6	20.5	27.1	10.7

* Fabric oriented so that 1 cm side gripped by tensiometer jaws.
† Fabric oriented so that 2 cm side gripped by tensiometer jaws.
‡ Abdomen closed after exploration 5 times successfully in 7 days.
Comparing non-sterilised burr with steam sterilised burr, $p < 0.001$ (paired t-test).
Comparing non-sterilised burr with gas sterilised burr, $p = 0.125$ (paired t-test).
Comparing gas sterilised burr with steam sterilised burr, $p = 0.002$ (paired t-test).
Comparing gas sterilised burr with burr used five times, $p < 0.001$ (paired t-test).

Two other patients had *Bacteroides* and *Bacillus* spp. in their peritoneal fluid which were not isolated from the burr.

DISCUSSION

If advanced peritonitis (40) and severe intra-abdominal injuries (1) cannot be managed adequately by a single operation, second or multiple procedures have been advocated (1, 6, 8, 10, 16, 17, 25, 32, 34, 39–41). After a single relaparotomy ("second look" procedure) fascial reapproximation may not be a problem, but if multiple reoperations are required in the presence of oedematous tissues or increased abdominal pressure, closure under tension becomes difficult and may be dangerous. Increased intra-abdominal pressure causes cardiovascular (12, 15, 19), respiratory (3, 7, 28) and renal dysfunction (2, 4, 14, 27, 29) which, in a septic or injured patient, may increase risk of multisystem organ failure and death. Abdominal decompression reverses these effects (2, 4, 15, 20, 29).

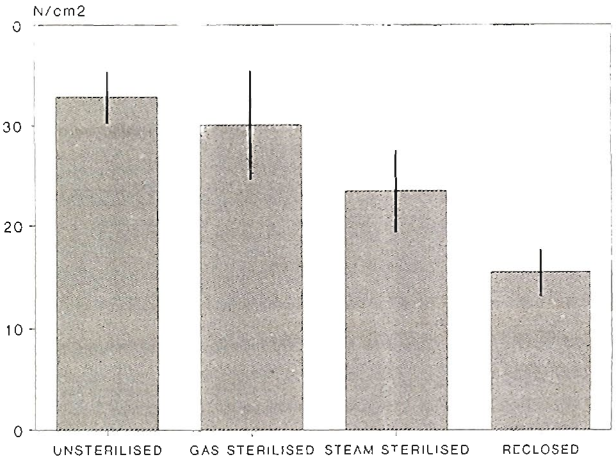

Fig. 2. Shearing force (Newtons) required to disrupt the burr. Data are derived from 8 measurements of non-sterilised, gas sterilised, steam sterilised, and reused burr and are expressed as the mean ± SD

When more than two abdominal explorations are needed, frequent re-suturing may result in tissue damage and abdominal wall necrosis. Retention sutures permit easy reopening of the abdominal cavity but do not permit the fascia to separate to decompress the abdomen. A device for temporary abdominal closure that is practical, safe and allows for a reduction in intra-abdominal pressure, while preventing retraction of the fascial edges, is needed. A number of devices have been suggested but do not fully meet the need.

A zip fastener (22, 32, 33) can easily be sutured to the fascia, does not carry an additional risk of bacterial infection, and does not preclude definitive closure of the abdominal cavity or primary closure of the skin after it has been removed (36). Because of its narrow margins, a zip fastener cannot reduce intra-abdominal pressure. To overcome this problem, some have sutured zip fasteners to sheets of polypropylene or polyglycolate which, in turn, were sutured to the fascia (9, 16).

Others have used a slide fastener with larger borders, which responds to the increase in abdominal girth that accompanies increased intra-abdominal pressure (37, 39). This device may, however, open spontaneously, resulting in evisceration. Further-more, like the zip fastener/mesh composites, it has to be replaced by a new fastener with progressively smaller borders as inflammatory oedema and bowel distension decreases. This causes injury to the wound margins, and re-approximation for definitive closure may be difficult.

Closure with towel clips (9) in an emergency situation can lead to protein losses similar to those that occur when the abdomen is left open (13, 24, 26, 40). Leaving the abdomen open is also complicated by a high incidence of bowel fistula and always results in a huge incisional hernia (24).

Problems of biocompatibility have not been described with any of the devices used for temporary abdominal closure. Polyamide is commonly used to make artificial joints and intravenous catheters. Polypropylene mesh has been studied most extensively (18, 21, 38). Biocompatibility of the burr should be comparable, as it is made of polypropylene and polyamide.

While colonisation of the burr with pathogenic bacteria is possible, no adverse microbiological effects were seen in those patients in whom detailed studies were made. In patients with peritonitis, the bacteria isolated from either sheet of the burr were identical with those isolated from the peritoneal fluid. On four occasions during 25 relaparotomies in seven patients, additional bacteria were isolated from the burr but were not seen during subsequent reoperations. Except for one instance of recovery of a coagulase positive staphylococcus, the bacteria found were of low pathogenicity and are not known to produce life-threatening toxins.

Greenstein et al. reported the bursting pressure of the abdominal wall as being 195 mmHg (= 2.6 N/cm^2) (11). Similar experimental data were published by Jenkins et al. (18), who showed that in the early postoperative period the mean (SD) pressure required to burst fascia was 146(31) mmHg (= 1.9 N/cm^2), and 424(40) mmHg (= 5.6 N/cm^2) in the eighth postoperative week. The bursting pressures required to disrupt a fascial defect that had been sutured or repaired with polypropylene and other mesh were between 76(3) mmHg (= 0.9 N/cm^2) and 221(74) mmHg (= 2.9 N/cm^2). The tensile strength of the normal fascia was 0.96(0.25) Kg (~ 9.4 Newton) and 2.50(0.67) Kg (= 24.5 Newton) (18).

The shearing force required to disrupt the burr is of the order of 75–150 N/5 cm^2, which is in excess of the force that experimentally will disrupt the fascia of the abdominal wall. Since the adhering surfaces usually include an area of 100 cm^2 or more when the device is used clinically, the burr can resist a force, well above that required to disrupt intact or sutured abdominal fascia.

REFERENCES

1. Aprahamian C, Wittmann DH, Bergstein JM, Quebbeman EJ. Temporary abdominal closure (TAC) for planned relaparotomy (Etappenlavage) in trauma. J Trauma 1990; 60: 719–723.
2. Bradley SE, Bradley GP. The effect of increased intra-abdominal pressure on renal function in man. J Clin Invest 1947; 26: 1010.
3. Burchard KW, Ciombor D MacK, McLeod MK, Slothman GJ, Gann DS. Positive end expiratory pressure with increased intra-abdominal pressure. Surg Gynecol Obstet 1985; 161: 313–318.
4. Celoria G, Steingrub J, Dawson JA, et al. Oliguria from high intra-abdominal pressure secondary to ovarian mass. Crit Care Med 1987; 15: 78–79.
5. Champault G, Magnier M, Psalmon F, Patel JC. L'évisceration controllé dans le traitement des peritonites grâves. Chirurgie 1979; 105: 866–869.
6. Cue JI, Cryer HG, Miller FB, Richardson JD, Polk HC Jr. Packing and planned reexploration for hepatic and retroperitoneal hemorrhage: critical refinements of a useful technique. J Trauma 1990; 30: 1007–1111.
7. Cullen DJ, Coyle JP, Teplick R. Long MC. Cardiovascular, pulmonary, and renal effects of massively increased intra-abdominal pressure in critically ill patients. Crit Care Med 1989; 17: 118–121.
8. Feliciano DV, Mattox KL, Burch JM, Bitondo CG, Jordan GL. Packing for control of hepatic hemorrhage. J Trauma 1986; 26: 738–743.
9. Feliciano DV, Burch, JM. Towel clips, silos, and heroic forms of wound closure. Adv Trauma Crit Care 1991; 6: 231–250.
10. Goris RJA. Ogilvie's method applied to infected wound disruption. Arch Surg 1980; 115: 1103–1107.
11. Greenstein SM, Murphy TF, Rush BF, Alexander H. The experimental evaluation of a carbon-polylactic acid mesh for a ventral herniorrhaphy. Curr Surg 1984; 41: 358–62.
12. Guazzi M. Polese A, Magrini F, Fiorentini C, Olivari MT. Negative influences of ascites on the cardiac function of cirrhotic patients. Am J Med 1975; 59: 165–170.
13. Guivarch M, Roullet-Audy JC, Chapman A. La non fermeture parietale dans la chirurgie iterative des peritonites. Chirurgie 1979; 105: 287–290.
14. Harman PK, Kron IL, McLachlan HD. Elevated intra-abdominal pressure and renal function. Ann Surg 1982 196: 594–597.
15. Hirsch S, Kelly KM, Benjamin E, Gentili DR, Premus G, Iberti TJ. The hemodynamic effects of increased intra-abdominal pressure in the canine model. Crit Care Med 1987; 15: 423.
16. Heddrich GS, Wexler MJ, McLean APH, Meakins JL. The septic abdomen: open management with Marlex mesh with a zipper. Surgery 1986; 99: 399–408.
17. Ivatury RR, Nallathambi M, Gunduz Y, Constable R, Rohman M, Stahl WM. Liver packing for uncontrolled hemorrhage: a reappraisal. J Trauma 1986; 26: 744–753.
18. Jenkins SD, Klamer TW, Parteka JJ, Condon RE. A comparison of prosthetic materials used to repair abdominal wall defects. Surgery 1983; 94: 392–398.
19. Knauer CM, Lowe HM. Hemodynamics in the cirrhotic patient during paracentesis. N Engl J Med 1967; 276: 491–501.
20. Kron IL, Harman PK, Nolan SP. The measurement of intra-abdominal pressure as a criterion for reexploration. Ann Surg 1984; 199: 28–30.
21. Lamb JP, Vitale T, Kaminski DL. Comparative eval-

uation of synthetic meshes used for abdominal wall replacement. Surgery 1983; 93: 643–648.
22. Leguit P. Zip-closure of the abdomen. Neth J Surg 1982; 34: 40–41.
23. Maetani S, Tobe T. Open peritoneal drainage as effective treatment of advanced peritonitis. Surgery 1981; 90: 804–809.
24. Mastboom WJB, Kuypers HHC, Schoots FJ, Wobbes T. Small-bowel perforation complicating the open treatment of generalized peritonitis. Arch Surg 1989; 124: 689–692.
25. Muhrer KH, Grimm B, Wagner KH, Börner U. Serum-Endotoxin-Spiegel während des Verlaufs der offenen Peritonitisbehandlung. Chirurg 1985; 56: 789–797.
26. Pujol JP. La non fermeture des incisions abdominales d'urgence. Techniques et résultats. Thèse de Médicine, Université de Paris VII, U.E.R. Faculté de Medicine, Xavier-Bichat 1975.
27. Richards WO, Scovill W, Shin B, Reed W. Acute renal failure associated with increased intra-abdominal pressure. Ann Surg 1983; 197: 183–187.
28. Richardson JD, Trinkle JK. Hemodynamic and respiratory alterations with increased intra-abdominal pressure. J Surg Res 1976; 20: 401–404.
29. Smith JH, Merrell RC, Raffin TA. Reversal of post-operative anuria by decompressive celiotomy. Arch Intern Med 1985; 145: 553–554.
30. Steinberg D. On leaving the peritoneal cavity open in acute generalized suppurative peritonitis. Am J Surg 1979; 137: 216–220.
31. Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. Ann Surg 1983; 197: 532–535.
32. Stone HH, Strom, PR, Mullins, RJ. Pancreatic abscess management by subtotal resection and packing. World J Surg 1984; 8: 340–345.
33. Strauss AA. A new method and end results in the treatment of carcinoma of the stomach and rectum by surgical diathermy. JAMA 1936; 106: 285–286.
34. Svoboda JA, Peter ET, Dang CV, Parks SN, Ellyson JH. Severe liver trauma in the face of coagulopathy: a case for temporary packing and early reexploration. Am J Surg 1982; 144: 717–721.
35. Tauber R, Seidel W, Mees P. Die Brauchbarkeit von Catgut, PGS und Polyester zum Verschluß der Abdominalfaszie. Res Exp Med 1975; 165: 153–161.
36. Teichmann W, Eggert A, Wittmann DH, Böcker W. Der Reissverschluss als neue Methode des temporären Bauchdeckenverschlusses in der Abdominalchirurgie. Chirurg 1985; 56: 173–178.
37. Teichmann W, Wittmann DH, Andreone PA. Scheduled reoperations (Etappenlavage) for diffuse peritonitis. Arch Surg 1986; 121: 147–151.
38. Usher FC. Further observations on the use of marlex mesh: a new technique for the repair of inguinal hernias. Am Surg 1959; 25: 792–804.
39. Wittmann DH, Aprahamian C, Bergstein JM. Etappenlavage, advanced diffuse peritonitis managed by planned multiple laparotomies utilizing zippers, slide fastener, and velcro for temporary abdominal closure. World J Surg 1990; 14: 218–226.
40. Wittmann DH, Schein M, Nystroem P.-O. Open packing (Laparotomy) in the septic abdomen (SIS). In Th. Ruedi (Ed.) State of the Art of Surgery, International Society of Surgery, Ch-4153 Reinach BP 1, Switzerland 1992: 30–34.
41. Wouters DB, Krom RAF, Slooff MJH, Kootstra G, Kuijjer PJ. The use of marlex mesh in patients with generalized peritonitis and multiple organ system failure. Surg Gyn Obstet 1983; 156: 609–614.