When is primary anastomosis safe in the colon?

B. Ostrow, MD, FRCS(C), Adjunct Lecturer, Office of International Surgery, University of Toronto, Canada

Reviewed July 2005 and updated August 2007

Introduction

The repair by suture or resection of diseased or injured colon is one of the most important skills in general surgery. Untreated or treated improperly these conditions cause significant morbidity in terms of intra-abdominal infection, fistulae, or death from generalized peritonitis. Today in Western medicine the two most common conditions requiring emergency colonic resection are obstructing colon cancers and complicated diverticulitis. In Africa, the equivalent conditions are gangrenous sigmoid volvulus and penetrating injuries resulting in colonic perforation. The deleterious consequences of primary anastomosis of the obstructed left colon with a tenuous blood supply, filled with pathogenic organisms and/or of the perforated colon with various degrees of peritoneal contamination fostered a surgical paradigm which precluded primary anastomosis of the left colon unless preoperative mechanical bowel preparation and antibiotic prophylaxis had been undertaken.

This was certainly the paradigm I was taught and which I practised throughout 1980-2000 in Canada. As Primary Surgery, Non-Trauma, an exemplary text for International surgeons from which I plan to quote extensively in these Reviews, states: *"You cannot safely anastomose large gut to large gut when it is obstructed and instead you have to let its contents escape through an ostomy. When large gut is to be anastomosed, it has to be carefully prepared first with enemas and antibiotics..."* (1). A similar attitude held for colonic injuries. The definitive International Committee of the Red Cross 1990 edition of Surgery for Victims of War states: *"The general rule is that a damaged colon should be exteriorized or defunctioned by proximal colostomy"* (1). Over the last decade the tenets underlying this paradigm have been seriously questioned and the whole approach to emergency colonic surgery has been revised. This Review will briefly consider the historical development of the paradigm and then detail its decline through experience with colon injuries, the morbidity of colostomies themselves, alternatives in acute colonic disease such as obstruction, diverticulitis and sigmoid volvulus and finally the fundamental questioning of the value of mechanical bowel preparation.

History - Development of the Paradigm

The history of the development of treatments for perforated, gangrenous or obstructed colons reflects the fear surgeons had for the dangers of anastomotic dehiscence. The late 19th century saw the development of standardized techniques for "two-layer" bowel anastomosis (3) and at the same time non-anastomotic techniques for the acutely diseased colon - the colostomy. The Paul-Mikulicz operation exteriorized the diseased colon as a double-barreled colostomy. Mayo in 1907 recommended temporary transverse colostomy for obstructing diverticulitis. In the 20th century treatment for perforated diverticulitis evolved towards the Hartmann procedure, proposed for colon cancer by Henri Hartmann in 1921, with resection of the perforated segment and proximal colostomy. This procedure showed an improvement in mortality over proximal colostomy, suture and drainage (4).

For obstructing left-sided carcinomas a traditional three-staged process was initially

proposed which included initial transverse colostomy, followed by resection-anastomosis and finally closure of the colostomy. Because of the recognized delay and difficulties of three operations, alternatives such as sub-total colectomy as well as techniques for on-table bowel cleansing and intra-colonic stents were developed. Lesions of the right and transverse colon could be managed by forms of right hemicolectomy and ileo-colic anastomosis. But the taboo of anastomosing unprepared left colon without proximal diverting colostomy persisted.

Ogilvie's WWII experience established exteriorization of the damaged bowel and fecal diversion as the primary modalities of therapy for wartime colon injuries. Mortality dropped from *50%* to 10% and this approach was initially applied to civilian penetrating colonic injury. The treatment for extra-peritoneal rectal injuries included colostomy, irrigation of the rectal stump and wide perineal drainage.

While some form of fecal diversion was considered mandatory for emergency left-sided colon lesions, an elaborate preparation was undertaken for elective colon surgery. Mechanical bowel preparations (MBP) to remove the fecal contents were developed. These progressed from prolonged fasting, fluids only and cathartics to rapid polyethylene glycol solution and sodium phosphate administration. At the same time multiple different regimes of peri-operative antibiotics have been found to be useful in reducing postoperative septic complications and mortality (5). The antibiotics need to be active against enteric aerobic and anaerobic organisms and should be limited to the operative period. A single dose is adequate for operations less than 2 hours in duration. Gentamycin and metronidazole are a good combination. Parenteral and oral antibiotics may have a cumulative effect (6). Of all the traditional recommendations concerning colon surgery, only those relating to peri-operative antibiotics have withstood scientific scrutiny and are uniformly practiced.

While much of surgical practice is a learnt behaviour arising from the apprenticeship system of surgical education, the second half of the 20th century has seen the rise of evidence-based medicine and the prospective, randomized clinical trial (RCT). These types of studies have begun to alter surgical practice.

Revision of the paradigm — colonic injuries

It was in the field of colon trauma that exceptions to the rule prohibiting primary colon repair initially began to be advocated. Beginning first with right-sided injuries; subsequently extending to left sided lesions; those that could be repaired without resection; then to resection with proximal colostomy and finally the most recent recommendations accepting resection and primary anastomosis without fecal diversion as appropriate surgery — a new paradigm has emerged for the treatment of colon injuries. The initial caveats to this most radical treatment included limited time from injury to repair, minimal contamination and few associated injuries. Whereas Cornwell (2) questioned the use of primary repair for high risk penetrating trauma patients, by 2001, the same group (8) having undertaken a multi-center prospective study, concluded that all colon injuries could be managed without fecal diversion without influencing morbidity or mortality. Gonzalez (2) drew similar conclusions. However, Miller (10) still raised a cautionary note for high risk patients, those with high trauma scores, destructive colon injuries, need for multiple blood transfusions, etc. In a meta-analysis, (which pools results from multiple RCTs), Singer (11), clearly favoured primary repair without diversion for all risk categories. Kamwendo (12) from South Africa showed that increasing time after injury did not preclude primary repair. Esraghi (13) reflected the changing opinions of American surgeons on this question. Demetriades (14) sums up current thinking. Note should be made that the need remains for colostomy in rectal injuries, because of the particular anatomy of this problem. These changes are reflected in the 1998 edition of Surgery for Victims of War which tentatively states that fecal diversion for colonic injuries *"has been the rule in war surgery, but the ICRCS working experience has shown that it is seldom necessary"(15)*.

Revision of the paradigm — the morbidity of colostomy

While colostomy itself in the proper setting may be a valuable procedure, the need for and risks of additional surgical procedures increase the morbidity to the patient. Khoury (16) reviewed the results of colostomy closure in 46 patients with a complication rate of 24%. Riesener (17) reviewed 548 closures since 1972. He advocated MBP and peri-operative antibiotics. However their best complication rate was still 27%. In Mealy (18) only 50% of patients had their stomas closed. Berne (19) reviewed colostomy closures after trauma and also found high morbidities, although this was not the case after rectal injury. Chandramouli (20) reviewed the experience of colostomies and their closure in children.

Revision of the paradigm –diverticulitis, obstruction and sigmoid volvulus

With the recognition of the increased morbidity of subsequent surgical procedures have come alternatives such as on-table lavage (21) and intra-colonic stenting.

However, in the 1990s more surgeons began to perform resection and primary anastomosis in acute non-traumatic colon conditions. Trillo (22) reported 43 cases without mortality. Goozen (23) reported 45 patients with acute obstructive or perforated diverticulitis treated with resection and primary anastomosis. There were three deaths from anastomotic leaks-all in obstructed patients. They cautioned its use in these cases. Salem (24) reviewed 98 published studies since 1957 and called for a RCT comparing resection and colostomy with primary anastomosis in acute surgical diverticulitis. Whetstone (25) giving guidelines for management of diverticulitis insisted that the Hartmann procedure is the appropriate operation when emergency surgery is indicated.

Various forms of right-hemicolectomy and ileo-colic anastomosis have been accepted for some time as the surgical procedure of choice in acute right-sided obstructions. For left-sided obstructions some authors advocate subtotal colectomy and ileo-colic anastomosis. Remst (26) is an example. Edino (27) carried out on table lavage in 32 consecutive patients without mortality. Harris (28) reviewed the use of endoluminal stents obviating the need for emergency surgery. DeSalvo (29) carried out a literature review and concluded that there existed inadequate studies comparing primary anastomosis and colostomy in left-sided obstructions and recommended further RCTs. Clearly no definitive conclusion can be drawn concerning the safety of primary anastomosis without colostomy for acute left-sided obstructions.

The non-Western experience with sigmoid volvulus also favours divergence from the paradigm. Kuzu (30) reported 102 patients with sigmoid volvulus requiring emergency surgery. Although the operative procedure was chosen by the surgeon about half the patients had resection and primary anastomosis and their infectious complications and death rates were similar to those with the Hartmann procedure. De (31) reported 197 patients who all had resection and primary anastomosis without preoperative or intra-operative bowel preparation. There were only 2 leaks and 2 deaths, a remarkable result. Raveenthiran (32) reported 57 patients half of whom had gangrenous colons with similar results. Despite the lack of clinical trials, surgeons in developing countries are using resection and primary anastomosis in sigmoid volvulus requiring acute surgical intervention.

Do stapled or hand-sewn techniques influence results?

Demetriades (33) published a prospective, but uncontrolled, study in colonic injuries comparing stapled and sutured repairs and found no difference in terms of anastomotic leak or morbidity. Lustosa (34) performed a meta-analysis of 9 RCTs and concluded that the two surgical techniques were indistinguishable in terms of results. These results are very significant for the African experience where hand-sewn techniques predominate.

Revision of the paradigm – the need for mechanical bowel preparation (MBP)

While the value of peri-operative antibiotics has stood the test of scientific scrutiny, the other "sacred cow" of elective colon surgery, the mechanical bowel prep, has not. Hughes in 1972 was the first to conduct a RCT of patients undergoing primary anastomosis after elective left-sided colon resection with and without MBP. No differences in terms of anastomotic leaks and morbidity were found. Geldere (35) reported 250 patients undergoing elective and emergency right and left colon resections, and anastomoses without MBP. This series had an anastomotic failure rate of only 1.25%. Zmora (36) and Ram (37) each published RCTs comparing elective resection and anastomosis with and without MBP and could find no difference in leakage rates or morbidity. Finally, Bucher (38) did a meta-analysis of 7 RCTs and found that MBP might actually be harmful. Patients undergoing MBP had a higher rate of septic complications than those with unprepared bowels. These reports show the capability of scientific studies to throw doubt on traditional surgical practice.

Conclusions

What kinds of recommendations can be made for Mrican surgeons undertaking colon surgery in 2005?

1. Any recommendation must be dependent on the surgeon's experience, the local conditions, anaesthetic facilities, etc.
2. Almost all colonic injuries can be repaired without fecal diversion. The sole exception would be for
   - severe injuries requiring major resection, where the patient requires multiple blood transfusions,
   - is in shock or has massive contamination.

3. Sigmoid resection and primary anastomosis without bowel preparation may be advised as the emergency operation for gangrenous or irreducible sigmoid volvulus.
4. The results of surgical repair are the same for stapled or sutured techniques.
5. In acute surgical left-colon diverticulitis and obstruction, the evidence is not yet conclusive as to the role of anastomosis without fecal diversion. Hartmann procedure may be the safer route, but this is not proven. On-table colonic lavage is an option instead of colostomy.
6. Colostomy closure is not a benign procedure.
7. Antibiotics with activity against aerobic and anaerobic bacteria need to be given parenterally in the peri-operative period alone. Their post-operative use should be restricted to cases with established infection. Pre-operative oral antibiotics may have an added value.
8. In elective colon operations there appears to be no value to mechanical bowel preparation. Even as I write this, my surgical prejudices rebel against such a notion.

Update — August 2007

The Review: When is Primary Anastomosis Safe in the Colon? discusses the major revisions to the classical surgical paradigm prohibiting primary anastomosis for acute colon, especially left colon, conditions. The new paradigm expands considerably the indications for which resection and anastomosis of the unprepared colon are allowed: especially colon injuries, diverticulitis, sigmoid volvulus, obstructing colon malignancies. A number of these conditions have great significance for African surgeons. The new paradigm extends to questioning the value of mechanical bowel preparation for elective colon resection. This update reviews the published literature from 2005-2007 on these questions. (The references can be found in the Update Reference List).

Colon injuries: The classical paradigm was first questioned in the case of colon injuries and data showing the efficacy of primary repair is most developed here. In 2006, Cleary et al. published a comprehensive review of the subject with management algorithms (1). In

brief primary repair of penetrating colon injury is advised for all grades of colon injury, unless there is sustained hypotension (BP<90mmHg), significant co-morbidities and significant associated injuries (using scoring indices such as the Penetrating Abdominal Trauma Index). Under these last conditions, colon injuries resulting in devascularization of the colon or damaging> 50% of the wall should be treated with diverting stoma. Blunt colon injuries are less common and a high index of suspicion is required to diagnose these. They are also more likely to have concurrent injuries and a higher mortality. Because of these facts colostomy may more often be required. For penetrating rectal injuries my Review advocated: fecal diversion, rectal washout and presacral drainage for extraperitoneal injuries. Cleary's Review suggests that primary repair may be advisable, especially in low velocity injuries without extensive destruction. Rectal washouts may be reserved for those injuries with extensive destruction and presacral drainage if the injury communicates with the presacral space. Evidence has not established the best treatment for severe rectal injuries.

Diverticulitis: Sigmoid diverticulitis is a common condition in the West and often presents with acute perforation and peritonitis. In 2005 the safety of primary resection and anastomosis (PRA) for these lesions was debated but not resolved. The standard treatment is Hartmann's procedure (HP). Richter published a non-randomized retrospective study of 41 patients with perforated diverticulitis (Hinchey grade 3&4) where PRA had lower mortality than HP (2). In 2006 Constaniides et al published a systematic review of the topic.(3) In the important cases with fecal peritonitis (Hinchey grade> 2) PRA had similar mortality rates as Hartmann's procedure. However the retrospective nature of the studies did not allow for a robust conclusion and further RCTs were recommended. No firm conclusion can yet be made as to which option is better.

Sigmoid Volvulus: Sigmoid volvulus is extremely common in the developing world. Oren et al. from Turkey has recently published a very large case series (4). Non-operative reduction using sigmoidoscopy ±1 tube

placement was possible in 70% of patients. Failure of this mandates emergency surgery for symptomatic volvulus. PRA appears safe even with gangrenous segments, if shock is not present. This is consistent with previous reports.

Obstructing left colon cancers: My 2005 review cautioned the application of the new paradigm to obstructing left colon cancers. Hsu from Taipei published a case series of PRA for colonic obstructions performed by a single surgeon where the mortality and anastomotic leak were basically equivalent comparing right and left-sided lesions (5). Patriti from Italy and Villar et al. from Spain published similar papers advocating PRA in emergency surgery of the left colon (6,7). Clearly surgeons are using these techniques with reasonable rates of anastomotic leak and death. However in the absence of clear scientific evidence based on prospective randomized trials, I cannot advocate this practice at present.

Mechanical bowel Drenaration (MBP) for elective colon resection: The evidence showing that mechanical bowel preparation for elective surgery of the left colon is unnecessary and even possibly harmful continues to accumulate. Zmora et al. from Israel published a small RCT showing equivalence between prep and no-prep (8). This is confirmed by much larger RCTs from Sweden and from the Netherlands showing no deleterious effects when MBP is omitted (9,10). It appears MBP is destined to disappear.

References

1. King M., editor. Primary Surgery Volume 1: Non-Trauma. Kuala Lumpur. Oxford University Press; 1990; 120.
2. Dufour D., Kromann Jensen S., Owen-Smith M., *et al.* editors. Surgery for Victims of War. 2nd ed. Geneva. *Int. Committee of the Red Cross.* 1990; 125.
3. Ellis H. Resection of the colon. In: Seymour I., Ellis H., editors. Maingot's Abdominal Operations. 9th ed. Volume II. Conneticut. *Appleton & Lange.* 1989; 1049-1075.
4. Parks T.G. Diverticular Disease of the colon. In: Seymour I., Ellis H., editors. Maingot's Abdominal Operations. 9th ed. Volume II. Conneticut. *Appleton & Lange;* 1989; 1014-1017.

5. Song F. and Glenny A.M. Antimicrobial prophylaxis in colorectal surgery: A systematic review of randomized controlled trials. *Brit. J. Surg.* 1998; **85:** 1232-1241.

6. Lewis R.T. Oral versus systemic antibiotic prophylaxis in elective colon surgery: a randomized study and meta-analysis send a message from the 1990s. *Can. J. Surg.* 2002; **24:** 173-180.

7. Coruwell E.E., Velmahos G.C., Berne T.V., *et al.* The fate of colonic suture in high-risk trauma patients: A prospective analysis. *J. Amer. Coll. Surg.* 1998; **187:** 58-63.

8. Demetriades D., Murray J.A., Chan L., *et al.* Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. *J. Trauma.* 2001; **50:** 765-775.

9. Gonzalez R.P., Merlotti G.J. and Holevar M.R. Colostomy in penetrating colon injury: Is it necessary? *J. Trauma.* 1996; **41:** 271-275.

10. Miller P.R., Fabian T.C., Croce M.A., *et al.* Improving outcomes following penetrating colon wounds - Application of a clinical pathway. *Ann. Surg.* 2002; **235:** 775-781.

11. Singer M.A. and Nelson R.L. Primary repair of penetrating colon injuries - A systematic review. *Dis. Colon Rect.* 2002; **45:** 1579-1587.

12. Kamwendo N.Y., Modiba M.C.M., Matlala N.S. *et al.* Randomized clinical trial to determine if delay from time of penetrating colonic injury precludes primary repair. *Brit. J. Surg.* 2002; **89:** 993-998.

13. Eshraghi N., Mullins R.J., Mayberry J.C., *et al.* Surveyed opinion of American trauma surgeons in management of colon injuries. *J. Trauma.* 1998; **44:** 93-97.

14. Demetriades D. Colon injuries: New perspectives. *Int. J. Care Injured.* 2004; **35:** 217-222.

15. Dufour D., Kromann Jensen S., Owen-Smith M., *et al.* Surgery for Victims of War. 3rd ed. Geneva. *Int. Comm. Red Cross.* 1998; 103-124.

16. Khoury D.A., Beck D.E., Opelka F.G., *et al.* Colostomy closure. Ochsner clinic experience. *Dis. Colon Rect.* 1996; **39:** 605-609.

17. Riesener K.P., Lehnen W., Hofer M., *et al.* Morbidity of ileostomy and colostomy closure: Impact of surgical technique and perioperative treatment. *World J. Surg.* 1997; **21:** 103-108.

18. Mealy K., O'Broin E., Donohue J., Tanner A. *et al.* Reversible colostomy — what is the outcome? *Dis. Colon Rect.* 1996; **39:** 1227-1231.

19. Berne J.D., Velmahos G.C., Chan L.S., *et al.* The high morbidity of colostomy closure after trauma: further support for the primary repair of colon injuries. *Surg.* 1998; **123:** 157-164.

20. Chandramouli B., Srinivasan K., Jagdish S., *et al.* Morbidity and mortality of colostomy and its closure in children. *J. Paed. Surg.* 2004; **39:** 596-599.

21. Sitzler P.J., Stephenson B.R. and Nicholls R.I. On-table colonic lavage: An alternative. *J.R. Coll. Surg. Edinb.* 2003; **43:** 276-277.

22. Trillo C., Paris M.F. and Brennan J.T. Primary anastomosis in the treatment of acute disease of the unprepared left colon. *Amer. Surg.* 1998; **64:** 821-825.

23. Goozen A.W., Tollenaar R.A.L.E.M., Geelkerken R.H., *et al.* Prospective study of primary anastomosis following sigmoid resection for suspected acute complicated diverticular disease. *Brit. J. Surg.* 2001; **88:** 693-697.

24. Salem L. and Flum D.R. Primary anastomosis or Hartmann's procedure for patients with diverticular peritonitis? A systematic review. *Dis. Colon Rect.* 2004; **47:** 1953-1964.

25. Whetsone D., Hazey J., Pofahl W.E., *et al.* Current management of diverticulitis. *Cur. Surg.* 2004; **61:** 361-365.

26. Reemst P.H.M., Kuijpers H.C. and Wobbes T. Management of left-sided colonic obstruction by subtotal colectomy and ileocolic anastomosis. *Eur. J. Surg.* 1998; **164:** 537-540.

27. Edino S.T., Mohammed A.Z. and Anumah M. Intraoperative colonic lavage in emergency surgical treatment of left-sided large bowel lesions. *Trop. Doc.* 2005; **35:** 37-38.

28. Harris G.J.C., Senagore A.J., Lavery I.C., *et al.* The management of neoplastic colorectal obstruction with colonic endolumenal stenting devices. *Amer. J. Surg.* 2001; **181:** 499-506.

29. De Salvo G.L., Gava C., Pucciarelli S., *et al.* Curative surgery for obstruction from primary left colorectal carcinoma: Primary or staged resection? The Cochrane Database of Systematic Reviews 2004, Issue 2. Art. No.: CDOO21O1.pub2. DOI: 10.1002/14651858. CDOO21O1.pub2.

30. Kuzu M.A., Aslar A.K., Soran A., *et al.* Emergent resection for acute sigmoid volvulus - results of 106 consecutive cases. *Dis. Colon Rect.* 2002; **45:** 1085-1090.

31. De U. and Ghosh S. Single stage primary anastomosis without colonic lavage for left-sided conlonic obstruction due to acute sigmoid volvulus: A prospective study of one hundred and ninety-seven cases. *ANZ J. Surg.* 2003; **73:** 390-392.

32. Raveenthiran V. Restorative resection of upreparaed left-colon in gangrenous vs. viable sigmoid volvulus. *Int. J. Colorectal. Dis.* 2004; **19:** 258-263

33. Demetriades D., Murray J.A., Chan L.S., *et al.* Handsewn versus stapled anastomosis in penetrating

colon injuries requiring resection: A multicenter study. *J. Trauma.* 2002; **52:** 117-121.

34. Lustosa S.A.S., Matos D., Atallah A.N., *et al.* Stapled versus handsewn methods for colorectal anastomosis surgery. The Cochrane Database of Systematic Reviews 2001, Issue 3. Art.No.: CD003144. DOI: 10.1002/1465 1858. CDOO3 144.

35. van Geldere D., Fa-Si-Oen P., Noach L.A., *et al.* Complications after colorectal surgery without mechanical bowel preparation. *J. Amer. Coll. Surg.* 2002; **194:** 40-47.

36. Zmora E., Mahajna A., Bar-Zakai B., *et al.* Colon and rectal surgery without mechanical bowel preparation - a randomized prospective trial. Ann. Surg. 2003; **237:** 363-367.

37. Ram E., Sherman Y., Weil R., *et al.* Is mechanical bowel preparation mandatory for elective colon surgery? - A prospective randomized study. Arch. Surg. 2005; **140:** 285-288.

38. Bucher P., Mermillod B., Gervaz P., *et al.* Mechanical bower preparation for elective colorectal surgery - a meta-analysis. *Arch. Surg.* 2004; **139:** 1359-1364.

Updated Reference List

1. Cleary R.K., Pomerantz R.A. and Lampman R.M. Colon and rectal injuries. Review [203 refs]. *Dis. Colon & Rectum.* 2006; **49:** 1203-1222.

2. Richter S., Lindemann W., Kollmar O., *et al.* One-stage sigmoid colon resection for perforated sigmoid diverticulitis (Hinchey stages III and IV). *World J. Surg.* 2006; **30:** 1027-1032.

3. Constantinides V.A., Tekkis P.P., Athanasiou T., *et al.* Primary resection with anastomosis vs. Hartmann's procedure in nonelective surgery for acute colonic diverticulitis: a systematic review. Reviewi [50 refs]. *Dis. Colon & Rectum.* 2006; **49:** 966-981.

4. Oren D., Atamanalp S.S., Aydinli B., *et al.* An algorithm for the management of sigmoid colon volvulus and the safety of primary resection: experience with 827 cases. *Dis. Colon & Rectum.* 2007; **50:** 489-497.

5. Hsu T.C. Comparison of one-stage resection and anastomosis of acute complete obstruction of left and right colon. *Amer. J. Surg.* 2005; **189:** 384-387.

6. Patriti A., Contine A., Carbone E., *et al.* One-stage resection without colonic lavage in emergency surgery of the left colon. *Colorectal Dis.* 2005; **7(4):** 332-338.

7. Villar J.M., Martinez A.P., Villegas M.T., *et al.* Surgical options for malignant left-sided colonic obstruction. *Surg. Today.* 2005; **35:** 275-281.

8. Zmora O., Mahajna A., Bar-Zakai B., *et al.* Is mechanical bowel preparation mandatory for left-sided colonic anastomosis? Results of a prospective randomized trial. *Techniques in Coloproctol.* 2006; **10:** 131-135.

9. Jung B., Pahlman L., Nystrom P.O., *et al.* Mechanical Bowel Preparation Study Group. Multicentre randomized clinical trial of mechanical bowel preparation in elective colonic resection. *Brit.J. Surg.* 2007; **94:** 689-695.

10. Fa-Si-Oen P., Roumen R., Buitenweg J., *et al.* Mechanical bowel preparation or not? Outcome of a multicenter, randomized trial in elective open colon surgery. *Dis. Colon & Rectum.* 2005; **48:** 1509-1516.