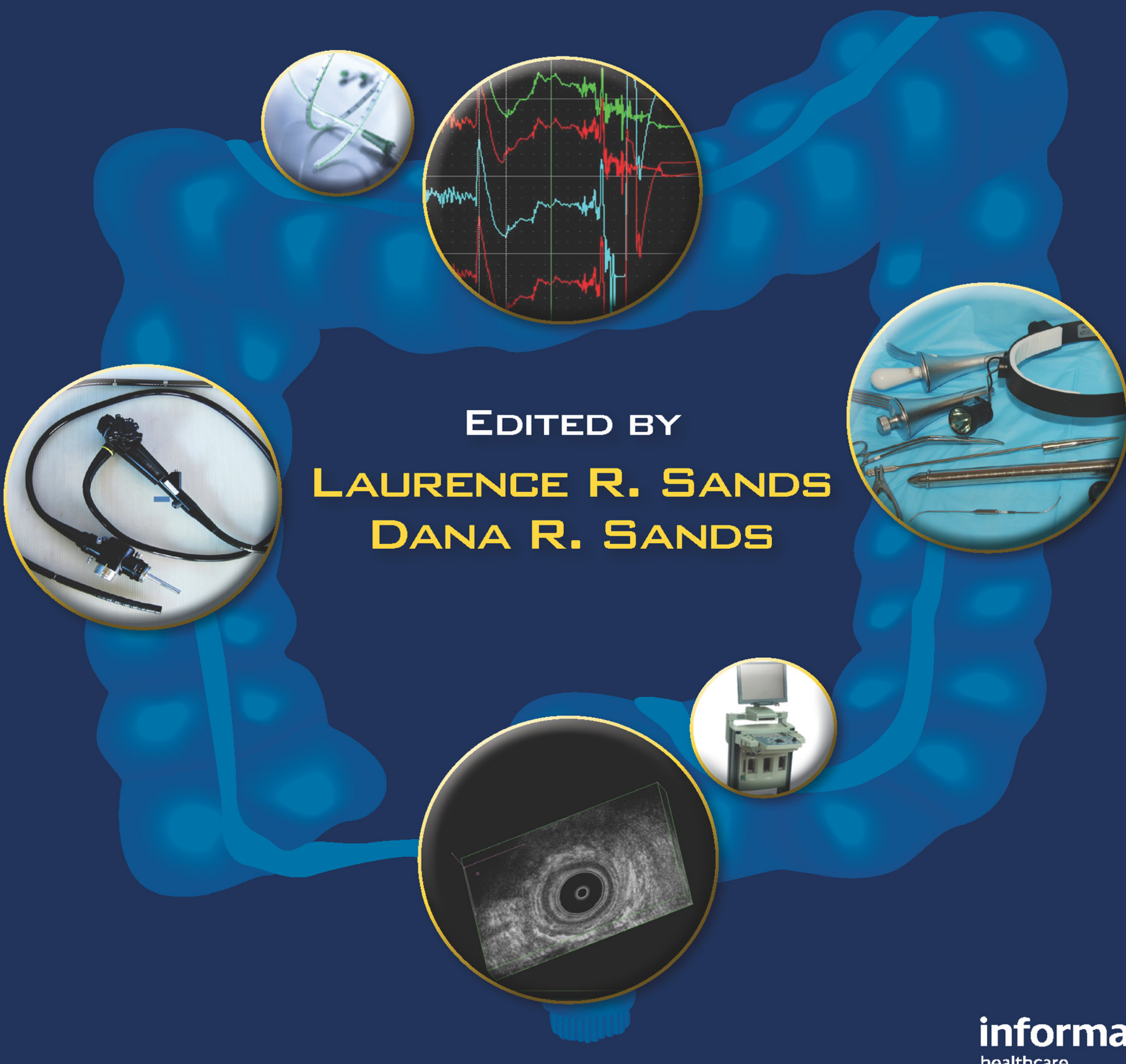
AMBULATORY COLORECTAL SURGERY



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Foreword

The Editors are to be congratulated on their collaborative effort to provide colon and rectal surgeons and their trainees with an excellent resource for the management of anorectal and outpatient problems in colon and rectal diseases. The table of contents is comprehensive and contemporary. The chapters have been authored by young colon and rectal surgeons with experienced senior surgeons as coauthors in certain circumstances. The approach to each topic is well organized with adequate historical comment to provide background to modern therapy. This is a rapidly changing field and the authors have provided evidence for the use of each physiologic test, imagining technique, and therapeutic maneuver (medical or surgical). This is a concise, detailed, and practical treatise, which will be easily used as a reference in the clinic, physiology lab, and outpatient operating room.

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Preface

The face of medicine has changed significantly in the 21st century. Emphasis is placed on minimally invasive techniques and shorter hospitalization. This medical climate has challenged physicians to provide excellent care of increasingly complex problems often in the outpatient setting and frequently using multidisciplinary approaches.

As such, we have been motivated to write a new colon and rectal surgery textbook capitalizing on the shifting practices of medicine in the 21st century. This book represents a compilation of office-based diagnoses, conditions, and treatments that are commonly encountered in general and colon and rectal surgical practices. Attention is paid to all facets of outpatient colorectal surgery including the evaluation and treatment of complex pelvic floor pathology.

Many office-based outpatient conditions and anorectal diseases in general are often poorly understood. This disease spectrum is frequently glossed over in surgical training programs. Most surgical trainees today have limited access to the outpatient office setting, especially within the confines of the restricted working hours of residents. Conditions such as the ones reviewed in this book make up the core of many surgical practices. Therefore, we believe that this book will be useful to all practicing colon and rectal surgeons, general surgeons with an interest in anorectal disease, and particularly those young surgeons just completing their surgical training and starting in practice.

The chapters are listed by condition and include a comprehensive review of the disease entity followed by the available diagnostic modalities and treatment options. The perioperative care is also included in order to provide the reader with a guide to the complete management of these patients. A review of the literature, both classic and new, will help the reader to gain a thorough understanding of each disease process. Prominent authors who have expertise in these areas have been brought together in this effort to bring some simplicity to the treatment of a group of common conditions, which are often ineffectively managed by physicians.

Our hope is that this book will give surgeons the ability to manage the spectrum of diseases encountered in the outpatient setting and make a strong contribution to the welfare of all patients.

The editors are especially thankful to the contributors who have taken time from their busy clinical practices to help in this endeavor and to Elektra McDermott, without whom, this project would not have been possible. We also wish to acknowledge and dedicate this book to our dear children, Ryan and Cory, from whom we have taken much time in the preparation of this project.

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1 Patient Evaluation

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INTRODUCTION

Over the past few decades, there have been vast changes in the practice of surgery. Sutures and sewing have been ever increasingly replaced by stapling devices. Generous incisions are being replaced by small port sites. These advances have also been accompanied by cost-reducing measures. Elective inguinal hernia repair is no longer a three day hospital stay, but rather a three hour experience. During this time period, the concept of ambulatory surgery, surgery not requiring in-patient hospitalization, has become a reality. This includes patients who undergo surgery where they are admitted a few hours prior to surgery and discharged a few hours after surgery, or patients who are admitted for a 23-hour stay. The field of colorectal surgery, especially anorectal surgery, has accepted and welcomed this change.

Ambulatory colorectal surgery has proven to be both safe and cost-effective (1). However, careful preoperative patient assessment and optimization, along with proper surgical planning, are required to ensure a safe outcome.

In addition to a thorough history and physical examination, appropriate laboratory, radiologic, and endoscopic tests are part of the preoperative armamentarium. Moreover, anesthetic and surgical technique must be individualized for every patient and explained to the patient during the office consultation. During this evaluation, a risk-assessment system is also used to better predict the outcome of the procedure to be performed. Furthermore, adequate preoperative education to be provided by the colorectal surgeon or by a member of the surgical team familiar with the procedure will provide comfort and minimize the patient's anxiety.

CHOICE OF PROCEDURE

Despite a growing number of procedures being safely performed at ambulatory centers, there are still limitations. Therefore, the choice of the procedure must be carefully made by the colorectal surgeon prior to determining the setting of the surgery.

In the realm of colorectal surgical procedures, ambulatory surgery is limited predominantly to anal and rectal surgery. Although not comprehensive, a list of acceptable ambulatory procedures is outlined in Table 1. Intra-abdominal colorectal surgery, whether by conventional laparotomy or laparoscopic approach, has not yet made its way to the ambulatory setting. Postoperative issues such as prolonged ileus, intravenous fluid requirements, and postoperative pain management continue to require inpatient care after intra-abdominal colorectal surgery. Table 2 lists some of the relative contraindications to ambulatory surgery.

PATIENT EVALUATION

Patient evaluation for ambulatory surgery begins with a thorough history and physical examination. The history should first focus on the nature of the disease process to assist in making the correct diagnosis. The history should also elicit information that would be important for planning different treatment options. From the history, the physician should be able to assess

Table 1 Acceptable Ambulatory Procedures

Examination under anesthesia
Incision and drainage of peri-rectal abscess
Treatment of anal fistula
Treatment of anal fissure
Treatment of pilonidal sinus
Treatment of anal condyloma
Treatment of hemorrhoidal disease
Transanal excision of rectal lesions
Endoscopy

what type of surgery the patient will require, and also based on the patient's condition and proposed procedure, the appropriate setting for the planned procedure. For example, a 25-year-old healthy female undergoing an elective hemorrhoidectomy will differ greatly from a 65-year-old male with a history of congestive heart failure, recent myocardial infarction, and defibrillator on antiplatelet therapy.

After obtaining a history, a complete physical examination should be performed. The examination should not be limited to the area of pathology so as to not miss associated conditions which may affect the ultimate treatment plan. As surgeons, we are eager to correct our patients' problems quickly and efficiently, but this should not interfere with thoroughness. For example, the treatment plan for a patient with hemorrhoidal disease would be very different if the patient was noted on physical examation to have abdominal distention secondary to ascites. Therefore, all major organ systems should be evaluated, even though the patient's chief complaint only involves an anorectal problem.

Based on the history and physical, and often some diagnostic tests to be discussed later, a variety of risk-assessment scores have been developed (Table 3). The most commonly used is the American Society of Anesthesiologists Classification (ASA) (Table 4) (2). The advantage of the ASA is its ease of use, its lack of other testing needed for use, and its correlation with perioperative morbidity and mortality (2). The disadvantage of the ASA is that it is a subjective and very generalized score. The ASA should not be used as the sole criteria for determining the appropriateness of an ambulatory setting for surgery; however, patients over an ASA of II should strongly be considered for nonambulatory surgery.

Organ-specific risk-assessment indexes are also available. The most widely used is the Goldman cardiac risk index (3). This index assigns point values for different clinical variables and then patients are divided into different classes based on the total score (Table 5). With increasing class, there is an increase in life-threatening complications and cardiac death risk. There are no official guidelines on what class of patient based on the Goldman risk index should not be considered a candidate for ambulatory surgery. However, patients who fall in Class III and IV should definitely be evaluated by the surgeon, cardiologist, and anesthesiologist prior to scheduling a procedure at an ambulatory center.

Table 2 Relative Contraindications to Ambulatory Surgery

Expected ileus
Expected fluid shifts
Expected intravenous fluid requirements
Intravenous analgesics
Expected electrolyte abnormalities

Table 3 Risk-Assessment Scores

American Society of Anesthesiologists Classification
Goldman Cardiac Risk Index
Prognostic Nutritional Index
Pulmonary Complication Risk

Table 4 ASA Classification

I.	Normal healthy patient
II.	Mild systemic disease
III.	Severe, noncapacitating systemic disease
IV.	Incapacitating systemic disease, threatening life
V.	Moribund, not expected to survive 24 hr
VI.	Emergency

Source: From Ref. 2

Scores such as the Prognostic Nutritional Index, although potentially useful for major colon and rectal procedures, do not play a significant role in cases that would be considered for an ambulatory setting. Other physiologic scores including the Acute Physiology and Chronic Health Evaluation (APACHE), APACHE II, and the Physiological and Operative Severity Score for enUmeration of Mortality (POSSUM) do not play a significant role in the evaluation of patients for ambulatory surgery.

SPECIAL PATIENT CONSIDERATIONS

As the decision to proceed with surgery is underway and the decision between ambulatory surgery and hospital admission is being considered, there are certain patient characteristics that require special attention.

There is no official age limit that would be considered safe to undergo ambulatory surgery; however, the literature has shown an increased rate of readmission, morbidity, and mortality for patients undergoing ambulatory surgery over the age of 85 (4). Nonetheless, age alone should not prevent ambulatory surgery, but it should be evaluated in conjunction with associated comorbidities which may lead toward an in-patient setting.

Obesity is another growing problem in the United States and throughout the western world. There is no recommended maximum body mass index or weight that should be considered a contraindication for ambulatory colorectal surgery; however, obese patients should be considered higher risk for surgery from many perspectives, especially from an airway protection standpoint. When obese patients are being evaluated for surgery, the surgeon should be familiar with the capabilities of the operative facility in terms of dealing with obese patients including equipment matters and adequate resources to safely care for this patient population. When surgery is planned for the prone position, as is often the case in anorectal procedures, special consideration should be given to general anesthesia in obese patients for airway protection.

Obstructive sleep apnea (OSA) is another concern when scheduling surgery, whether ambulatory or in-patient. OSA is often associated with obesity; however, normal weight patients may also suffer from OSA. All patients should be questioned about potential symptoms including apneic events during sleep, heavy snoring, or the feeling of fatigue after a full night's sleep.

Table 5 Goldman Cardiac Risk

	# Points
Myocardial infarction within 6 mo	10
Age greater than 70	5
S3 gallop or jugular venous distension	11
Aortic stenosis	3
Nonsinus rhythm or atrial premature contractions	7
Greater than 5 premature ventricular contractions	7
Poor general medical condition	3
Intraperitoneal, thoracic, aortic operation	3
Emergency operation	4
Class I	0–5
Class II	6–12
Class III	13–25
Class IV	$\geq$26

Source: From Ref. 3

The use of a Continuous Positive Airway Pressure (CPAP) device is also an obvious indicator of sleep apnea. OSA is not an absolute contraindication to outpatient procedures; however, the surgeon should ensure that the ambulatory surgery center has adequate monitoring capabilities for a longer than normal recovery and monitoring period. The possibility of in-patient admission should also be considered and arrangements made prior to surgery, especially if the patient is likely to require narcotics for analgesia.

The presence of a pacemaker and/or of a defibrillator is not a contraindication for ambulatory surgery; however, adequate cardiology back-up must be available to handle any issues which may arise, including reprogramming the device both pre- and postoperatively. In our institution, the presence of a defibrillator prohibits surgery at the Ambulatory Surgery Center; however, the patient may have surgery at the main hospital operating room and still be discharged home the same day of surgery.

Malignant hyperthermia is a rare complication of anesthesia. A known history or known family history of malignant hyperthermia should be considered a relative contraindication to ambulatory surgery. If the patient will only have intravenous sedation and local anesthesia, this would be less of a concern; however, this should be discussed with the anesthesia and nursing team prior to surgery.

PREOPERATIVE WORK-UP

Once the decision to proceed with surgery has been made and the appropriate location and setting for surgery has been selected, the patient must undergo a preoperative work-up.

All patients must have a complete history and physical examination prior to surgery. As discussed earlier, all organ systems should be evaluated with a thorough review of systems. Physical examination should also include all organ systems.

The use of "routine" preoperative laboratory tests is becoming a subject of historical interest. Patients undergoing ambulatory colon and rectal surgery, as with all ambulatory surgical patients, should have preoperative laboratory tests, only as needed, specific to the patient, diagnosis, and proposed surgery. Each institution has specific guidelines and requirements for ambulatory and major surgery. The following are guidelines at our institution. These guidelines apply to adult patients undergoing ambulatory colorectal surgery who have no specific comorbidities.

All patients at our institution have a preoperative complete blood count (CBC) within seven days of surgery. The basic metabolic panel (BMP) is officially reserved for all patients over the age of 65; however, many patients over the age of 50 will also undergo a BMP prior to surgery if comorbid conditions are present. Patients who undergo mechanical bowel preparation will also benefit from electrolyte evaluation, especially potassium levels. This is often performed in the morning of surgery. If the potassium is low, it is replaced prior to or intraoperatively. Diabetic patients should undergo fingerstick blood glucose levels on the day of surgery. Routine coagulation studies including prothrombin time (PT) and partial thromboplastin time (PTT) are not necessary unless the patient has a personal or family history of bleeding disorders or the patient is taking anticoagulants such as warfarin. Bleeding time is rarely assessed prior to surgery unless there is a significant concern over the patient's platelet function. Other hematology or chemistry studies are usually not necessary. Despite the clear lack of need for "routine" preoperative laboratory values for all patients, both surgeons and primary care physicians continue to order and anesthesiologists demand these tests with a significant cost to the health-care system. Better education is required for all members of the health-care team to help reduce the number of unnecessary tests and thus reduce costs.

For female patients of child bearing age, a urine or serum pregnancy test should be performed on the day of surgery or within a few days prior to surgery. Exceptions to this testing exist (Table 6); however, many institutions have adopted a policy of mandatory testing, except for the postmenopausal women and women who have had a hysterectomy.

The use of an electrocardiogram (ECG) is based on age and gender. All males over the age of 40 are required to have an ECG as are all females over the age of 50. Any patient with a cardiac history or pulmonary history should also undergo an ECG prior to surgery. Patients with many other comorbidities including obesity and diabetes mellitus should also undergo ECG.

Table 6 Exceptions to Pregnancy Testing

Absolute
Total hysterectomy
Bilateral oopherectomy
Menopause
Relative
Consistent oral contraceptive use and normal menses
Consistent intrauterine device or levonorgestrel implants
Bilateral tubal ligation

Radiologic studies for ambulatory surgery are usually unnecessary except to aid in confirming the diagnosis for the proposed surgery. Preoperative chest X-ray for ambulatory surgery patients should only be performed in patients over the age of 75. Patients with significant cardiac and/or pulmonary disease should also undergo a preoperative chest X-ray.

There is no specific age at which patients should have a medical work-up prior to surgery; however, patients over the age of 40 are usually referred to a primary care physician for evaluation prior to elective surgery. The surgeon should be aware of the proper preoperative work-up of patients.

Cardiac evaluation prior to surgery is determined based on the patient's history. A simplified protocol follows (5). Patients who had a recent cardiac evaluation with either invasive or noninvasive testing which was normal or unchanged compared with prior evaluation should require no further work-up prior to elective ambulatory surgery. Patients who have excellent functional status and report no cardiac or pulmonary symptoms should also require no further work-up other than a normal ECG. Patients with poor functional status and a normal/stable ECG undergoing a low-risk ambulatory procedure should require no further work-up unless deemed necessary by the cardiologist. Patients with cardiac symptoms including congestive heart failure, prior myocardial infarction, valvular disease, or significant arrhythmias should have a full cardiac work-up prior to an elective ambulatory procedure. This work-up should include evaluation by a cardiologist, ECG, noninvasive studies, and cardiac catheterization, if indicated. These guidelines are simplified and should be tailored to each patient individually. High-risk patients would also benefit from the anesthesiologist's evaluation prior to surgery.

All patient medications should be taken into account during the preoperative evaluation. Anticoagulants should ideally be stopped five days prior to surgery, unless contraindicated. Aspirin and other antiplatelet agents should be stopped at least 7 to 10 days prior to the proposed surgery. A history of cardiac drug-eluting stents often requires that the patient remain on the antiplatelet agents, especially for the first 9 to 12 months. If this is the case, surgery should be postponed, if possible. Otherwise, a discussion should be undertaken with the cardiologist regarding the discontinuation of these agents prior to surgery. Based on the risks/benefits of the surgery compared with the risks/benefits of discontinuing these agents, a decision should be made. The use of herbal supplements should also be elicited from the patient as many of these agents can cause increased bleeding tendencies. Thus, depending on the agent, they often must be discontinued prior to surgery.

A very important aspect of the patient evaluation is preoperative counseling relative to postoperative expectations. This is important for all types of surgery; however, even more important in ambulatory surgery as the patient will be discharged home postoperatively. Patients should be given realistic expectations of the level of pain to expect; for example, patients should be told that significant pain should be expected for at least one week after hemorrhoidectomy. Discussion with the patient should include all aspects of postoperative recuperation including wound care, bowel regimes, analgesics, and postoperative follow-up. A detailed discussion with the patient prior to ambulatory surgery will lead to a better postoperative experience and faster recovery. Ideally, the nursing and anesthesia staff should also discuss the expected postoperative course from their perspectives.

In addition to the overall medical evaluation, a dedicated preoperative anorectal assessment is required. This starts with careful inspection of the anus and perianal area followed by a detailed digital examination. Most anorectal pathologies treated as outpatient procedures are diagnosed based on the physical examination, including but not limited to hemorrhoids, pilonidal cyst, condyloma, and chronic anal fissure.

The majority of anorectal abscesses are also diagnosed based on the physical examination. However, supralevator or deep postanal space abscesses may require endorectal ultrasonography or computerized tomography scan for complete evaluation, especially in patients with Crohn's disease or immunosuppressive disorders.

Patients with anorectal fistula should also undergo preoperative and/or intraoprative evaluation to determine the fistulous tract in order to guide the optimum surgical approach and prevent iatrogenic tract creation. This includes anorectal ultrasonography with hydrogen peroxide injection through the external opening, magnetic resonance imaging with or without anorectal probe, and fistulogram. Intraoperatively, injection of hydrogen peroxide, normal saline, or methylene blue via the external opening will aid in the identification of the internal opening allowing the safe introduction of a fistulous probe through the tract and further direct management of the fistula.

CONCLUSION

The cost-effectiveness of ambulatory colorectal surgery has been well established. Nonetheless, these procedures can only be safely performed after adequate preoperative evaluation and cautious patient selection.

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2 Anatomy of the Rectum and Anus

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INTRODUCTION

Concepts concerning the anatomy of the anorectum are constantly changing in light of new scientific methodology. In addition, the anatomy of this region is so intrinsically related to its physiology that many aspects are appreciated only in the living. Therefore, it is a region in which the colorectal surgeon has, as advantages over the anatomist, the experience on "in vivo" dissection, and on both physiological and endoscopic examinations. Recent advances in anorectal physiology, along with the advance of surgical techniques, have renewed the interest in more detailed studies of anatomy (1–8). Conversely, studies matching 3-D reconstructions of specific muscle groups of the anorectum and pelvic floor, with level oriented resting and squeeze pressure profiles, have provided more data to reevaluate concepts of the high-pressure zone or functional anal canal length (9,10).

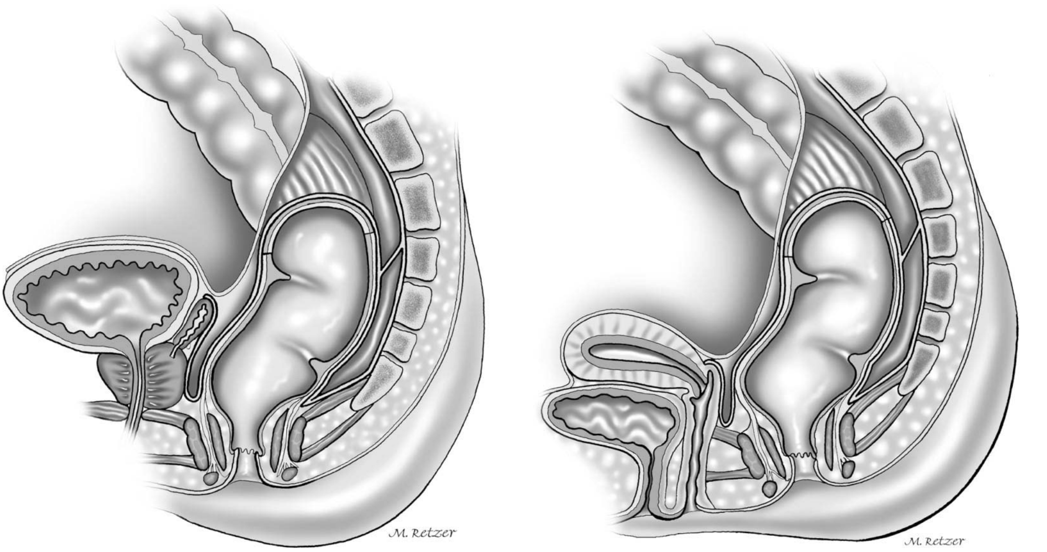
RECTUM

The rectum is a 12 to 15 cm long segment of large bowel involved in the entire process of defecation—its sensibility initiates the process and its capacity makes the patient able to control it, among several other mechanisms involved. It occupies the sacral concavity and ends 2 to 3 cm anteroinferiorly to the tip of the coccyx, where it angulates backward to pass through the levators to become the anal canal (Figs. 1 and 2). The proximal limit of the rectum, the rectosigmoid junction, has been considered as an externally indistinct segment which to most surgeons comprises the last 5 to 8 cm of sigmoid and the uppermost 5 cm of the rectum. However, it is well defined endoscopically as a narrow and sharply angulated segment and, in fact, is the narrowest portion of the large intestine. In a more clear definition, the rectosigmoid junction is the "point" where the tenia libera and the tenia omentalis fuse to form a single anterior tenia and where both haustra and mesocolon terminate, usually situated at 6 to 7 cm below the sacral promontory (Fig. 3) (4). Likewise, the distal limit of the rectum is debatable, regarded as the muscular anorectal ring by surgeons and as the dentate line by anatomists.

Anatomical characteristics of the rectum include a wide and easily distensible lumen and the absence of teniae, epiploic appendices, and haustra. The rectal mucosa is smooth, pink, and transparent which allows visualization of submucosal vessels. This typical "vascular pattern" disappears in inflammatory diseases and melanosis coli. The rectum is characterized by three lateral curves: the upper and lower curves are convex to the right and the middle is convex to the left. These curves correspond on the intraluminal aspect to the folds or valves of Houston. There are usually three folds: two on the left side (at 7–8 cm and at 12–13 cm) and one at 9 to 11 cm on the right side. The middle valve is the most consistent (Kohlrausch's plica) and corresponds to the level of the anterior peritoneal reflection. The valves of Houston must be negotiated during rectosigmoidoscopy, and they disappear after straightening of the rectum, which is attributed to the 5-cm length gained during rectal mobilization; they do not contain all the rectal wall layers and do not have a specific function; however, from a clinical point of view, they are an excellent location for rectal biopsy (11).

Anatomical Relationships of the Rectum

The upper third of the rectum is invested by peritoneum on both its anterior and lateral aspects. The middle rectum is only anteriorly covered by peritoneum, as the posterior peritoneal reflection is usually 12 to 15 cm from the anal verge. Finally, the lower third of the rectum is entirely extraperitoneal, as the anterior peritoneal reflection occurs at 9 to 7 cm from the anal verge, in men, and a little lower at 7.5 to 5 cm from the anal verge in women. The rectum is, therefore,



(**A**) (**B**)

Figure 1 Sagittal diagram of the (**A**) male and (**B**) female pelvis.

entirely extraperitoneal on its posterior aspect. According to anatomists, the rectum is characterized by the absence of a mesorectum. However, the areolar tissue on the posterior aspect of the rectum, containing terminal branches of the inferior mesenteric artery and enclosed by the fascia propria, is often referred to by surgeons as the mesorectum (Fig. 4). A more distinct mesorectum, however, may be noted in patients with complete rectal prolapse. In addition, the mesorectum may be a metastatic site from a rectal cancer and it can be removed without clinical sequelae, as no functionally significant nerves pass through it (12).

Anteriorly, the rectum is related to the cervix uteri and the posterior vaginal wall in women; in men, the rectum lies behind the bladder, vas deferens, seminal vesicles, and prostate. Posteriorly, the rectum is related to the concavity of the sacrum and coccyx, the median sacral vessels, and the roots of the sacral nerve plexus.

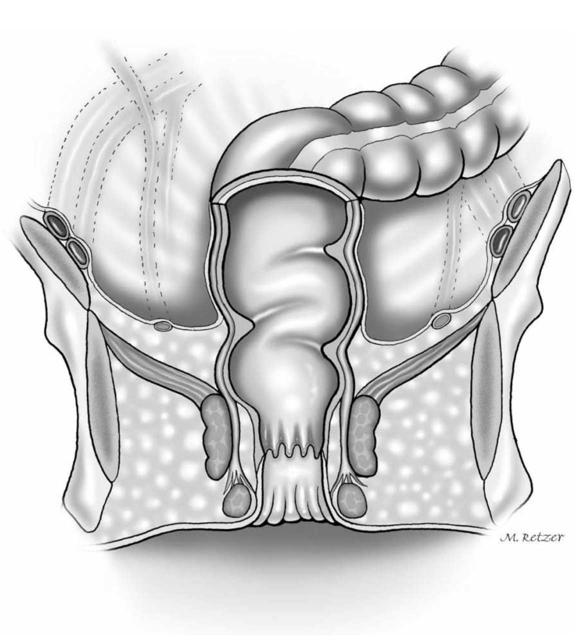


Figure 2 Frontal diagram of the rectum.

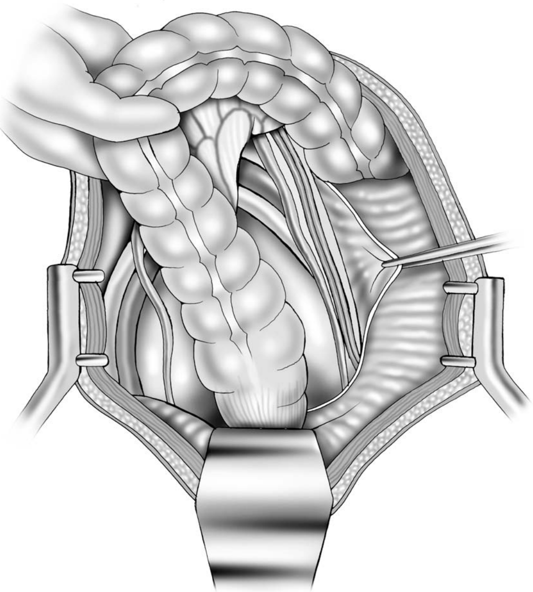


Figure 3 The rectosigmoid junction and its anatomical relationship, after division of the mesosigmoid and medial retraction of the sigmoid colon.

Fascial Attachments of the Rectum

The walls and the floor of the pelvis are lined by the parietal endopelvic fascia, which continues on the pelvic organs as a visceral fascia and attaches them to the pelvic walls. Because the parietal fascia is intimately attached to the pelvic viscera, it is also referred to as the viscero–fascial layer. The fascia propria of the rectum is then an extension of the pelvic fascia that encloses the rectum and fat, nerves and blood, and lymphatic vessels, present mainly in the lateral and posterior extraperitoneal portion of the rectum [Figs. 5(A) and (B)].

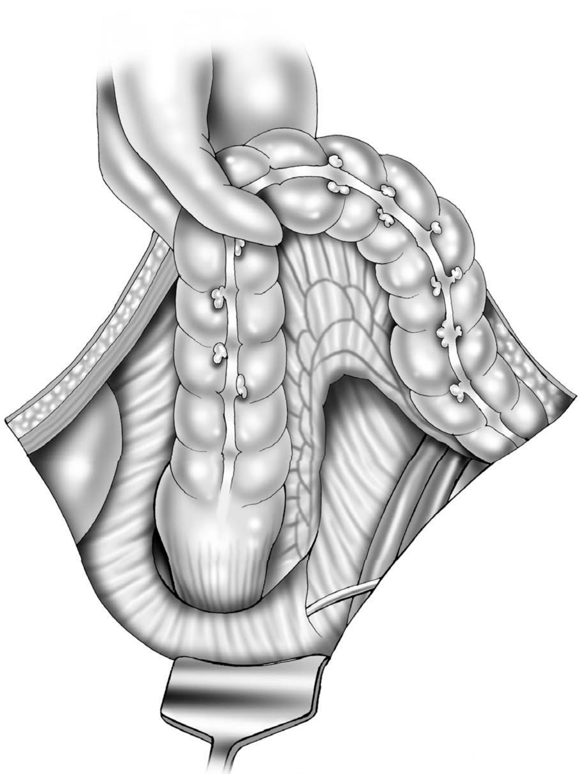
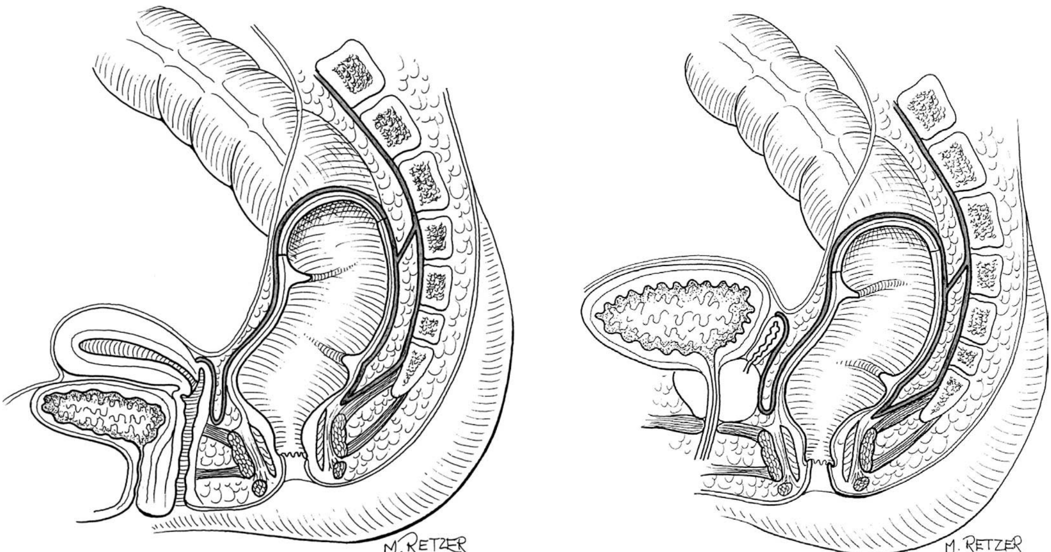


Figure 4 The mesorectum.



(**A**) (**B**)

Figure 5 Fascial attachments of the rectum in the (**A**) female and (**B**) male pelvis.

The rectum is attached to the lateral pelvic wall by distal condensations of the fascia propria of the rectum, known as lateral ligaments or lateral stalks of the rectum (Fig. 6). These ligaments comprise essentially connective tissue and nerves; the middle rectal artery does not traverse the lateral stalks of the rectum but sends minor branches through them, uni- or bilaterally, in approximately 25% of cases (13). Consequently, division of the lateral stalks during rectal mobilization carries out a 1:4 chance of bleeding. However, from a practical point of view the stalks rarely require ligation; electrocautery is sufficient in the vast majority of cases.

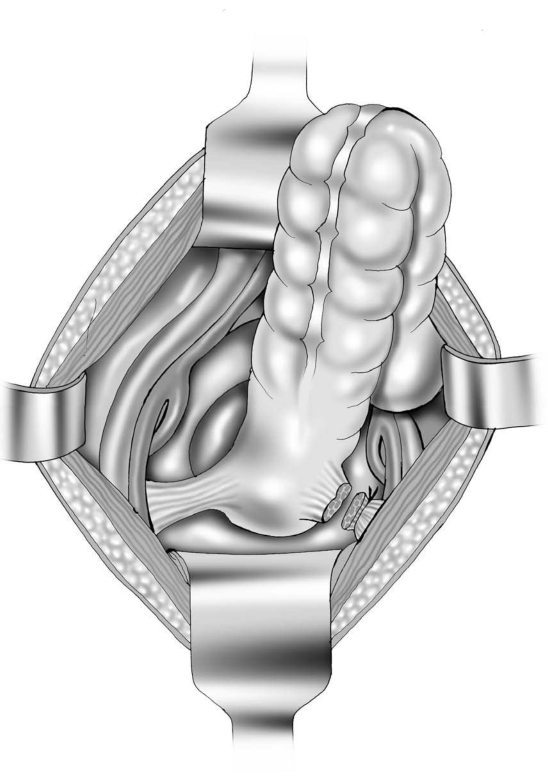


Figure 6 Lateral stalks of the rectum.

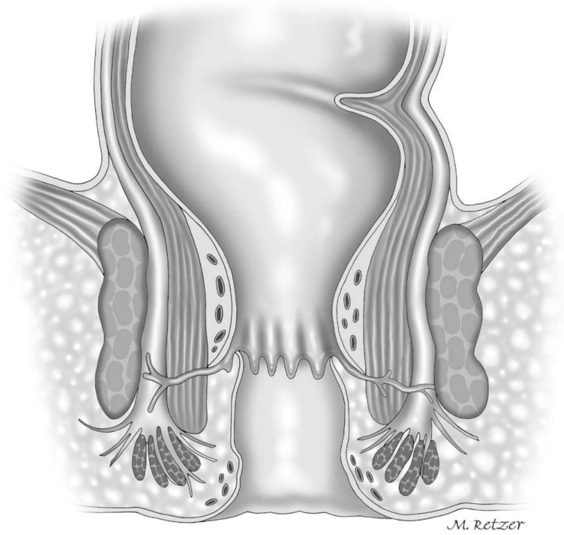


Figure 7 The anal canal.

Furthermore, ligation of the stalks implies leaving behind lateral mesorectal tissue, which may preclude obtaining oncologically adequate lateral or mesorectal margins.

The presacral fascia is a thickened part of the parietal endopelvic fascia that covers the concavity of the sacrum and coccyx, nerves, the middle sacral artery, and presacral veins. Intraoperative rupture of the presacral fascia may cause troublesome hemorrhage, related to the underlying presacral veins, in 4.6% to 7% of cases after surgery for rectal neoplasms (14,15). These veins are avalvular and communicate, via basivertebral veins, with the internal vertebral venous system. This system can attain hydrostatic pressures of 17 to 23 cm H_2O, about two to three times the normal pressure of the inferior vena cava, in the lithotomy position (14). In addition, the adventitia of the basivertebral veins adheres firmly, by structures "in anchor," to the sacral periosteum at the level of the ostia of the sacral foramina found mainly at the level of S3–S4 (14). Consequently, despite its venous nature, presacral hemorrhage can be life-threatening due to the high hydrostatic pressure and difficult to control due to retraction of the vascular stump into the sacral foramen.

The rectosacral fascia is an anteroinferior-directed thick fascial reflection from the presacral fascia at the S4 level, on the upper surface of the anococcygeal ligament to the fascia propria of the rectum, just above the anorectal ring. Although William Waldeyer had described the entire pelvic fascia without specifically emphasizing the rectosacral fascia, this fascia became classically known as fascia of Waldeyer (1). Anteriorly, close to the urogenital diaphragm, the rectum is separated from the prostate and seminal vesicle or the vagina by a condensation of visceral pelvic fascia, known as the fascia of Denonvilliers. Both Waldeyer's and Denonvilliers' fascia are important anatomical landmarks during rectal mobilization [Figs. 5(A) and (B)].

ANAL CANAL

The anal canal has a peculiar anatomy and a complex physiology, which accounts for its vital role in continence and its susceptibility to a variety of diseases. It is distinctly defined by anatomists and surgeons as the "anatomical" or "embryological" anal canal, which is shorter (2.0 cm), extends from the anal verge to the dentate line which corresponds to the procotodaeal membrane, and the "surgical" or "functional" anal canal, which is longer (4.0 cm) and extends from the anal verge to the anorectal ring (Fig 7). The anorectal ring, or the upper end of the sphincter, is more precisely the puborectalis (PR) and the upper border of the internal anal sphincter (IAS) and is an easily recognized boundary of the anal canal on physical examination. Despite lacking embryological significance, the anorectal ring is of clinical relevance since division of this structure, as during surgery for abscesses and fistula, will inevitably result in fecal incontinence. The anterior-directed contraction of the sling of PR can also be easily palpated around the anorectal junction during rectal examination. Anteriorly, the anal canal is related to the urethra in the male and to the perineal body and to the lowest part of the posterior vaginal wall in the female. Posteriorly, the anal canal is related to the coccyx. The ischiorectal fossa is situated on either side and contains fat and the inferior rectal vessels and nerves which traverse it to enter the wall of the anal canal.

Lining of the Anal Canal

The lining of the anal canal consists of an upper mucosal and a lower cutaneous segment. The dentate (pectinate) line represents the "sawtoothed" junction of the ectoderm and the endoderm and, thus, represents an important landmark between two distinct origins of venous and lymphatic drainage, nerve supply, and epithelial lining. Above the dentate line, the intestine has sympathetic and parasympathetic innervation and the venous and lymphatic drainage and the arterial supply are to and from the hypogastric vessels. Distal to the dentate line, the anal canal has somatic nerve supply and its vascularization is related to the inferior hemorrhoidal system.

The pectinate or dentate line corresponds to a line of anal valves, which represent remnants of the proctodeal membrane. Above each valve is situated a small pocket known as the anal sinus or crypt. A variable number of glands, ranging from 4 to 12, are more concentrated in the posterior quadrants and are connected to the anal crypts. More than one gland may open into the same crypt, while half the crypts have no communication. The anal gland ducts, in an outward and downward route, enter the submucosa; two-thirds enter the IAS; and half of these terminate into the intersphincteric plane (16). Obstruction of these ducts, presumably by accumulation of foreign material in the crypts, may cause perianal abscesses and fistulas (17). Above the dentate line, 8 to 14 longitudinal folds, known as the rectal columns (columns of Morgagni), have their bases connected in pairs to each valve at the dentate line. At the lower end of the columns are the anal papillae. The mucosa in the area of the columns consists of several layers of cuboidal cells and acquires a deep purple color due to the underlying internal hemorrhoidal plexus. This 0.5 to 1 cm strip of mucosa above the dentate line is known as the anal transition or cloacogenic zone, and it is the source of some anal tumors. Above this area, the epithelium becomes a single layer of cuboidal columnar cells and macroscopically acquires the characteristic pink color of the rectal mucosa.

Anus and Anal Verge

The anus or anal orifice is an anteroposterior cutaneous slit which, at rest, as well as the anal canal, is kept virtually closed due to both tonic circumferential contraction of the sphincters and the anal cushions. The cutaneous part of the anal canal consists of a modified squamous epithelium, which is thin, smooth, pale, and stretched and devoid of hair and glands. The terms "pectin" and "pecten band" have been used to define this segment (18). However, the round band of fibrous tissue called "pecten band," divided in cases of anal fissure (pectenectomy), represents probably the spastic IAS. The anal verge (linea Alban, anocutaneous line of Hilton) marks the lowermost edge of the anal canal, usually the level of reference for measurements taken during colonoscopy. Others prefer to evert the anus and consider the dentate line as a landmark because it is more precise; the difference between the two is nearly 1 cm. Distal to the anal verge, the lining becomes thicker, pigmented, and arranged in radiating folds around the anus; it then acquires hair folicules, glands including large apocrinal glands, and other features of normal skin. For this reason, perianal hidradenitis suppurative—inflammation of the apocrinal glands—may be excised with preservation of the anal canal.

Muscles of the Anorectal Region

Based on phylogenetical studies, two muscle groups derive from the cloaca—the "sphincter" and "lateral compressor" groups (19). The sphincteric group is present in almost all animals; in higher mammals this group is divided into ventral (urogenital) and dorsal (anal) groups; in primates, the latter forms the external anal sphincter (EAS). The lateral compressor or pelvicaudal group connects the rudimentary pelvis to the caudal end of the vertebral column. This group is more differentiated and subdivided in lateral and medial compartments, but only in reptiles and mammals. The homologue of the lateral compartment is apparently the ischiococcygeus, and the pubo and ileococcygeus in the medial pelvicaudal compartment. In addition, most primates possess a variable-sized group of muscle fibers close to the inner border of the medial

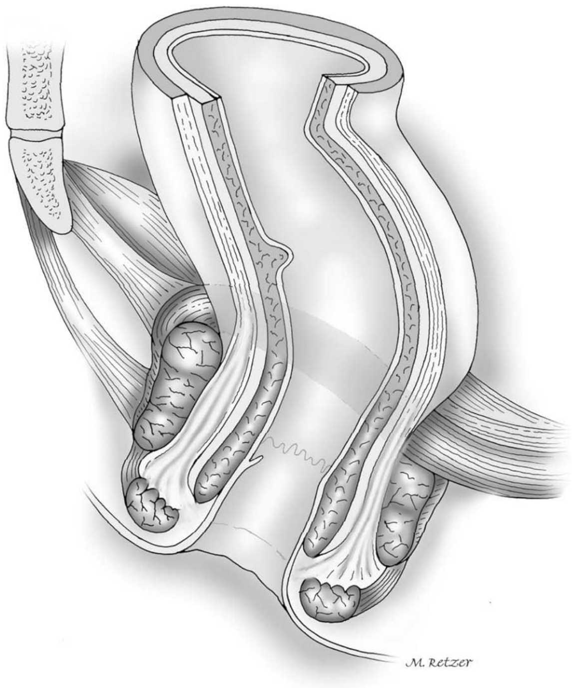


Figure 8 Muscles of the anal canal.

pelvicaudal muscle, which attach the rectum to the pubis; these fibers are more distinct and known in man as the PR muscle.

Internal Anal Sphincter

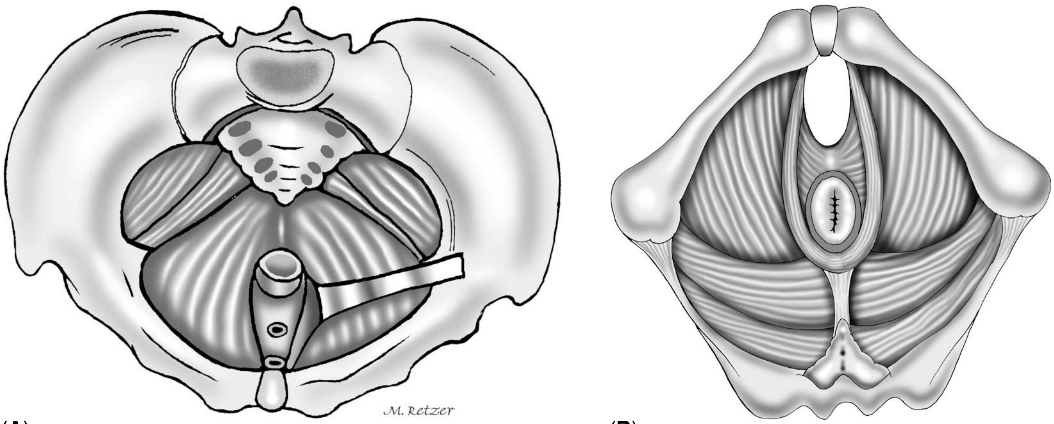
The IAS represents the distal 2.5 to 4 cm long condensation of the inner circular muscle layer of the rectum (Fig. 8). The lower rounded edge of the IAS can be felt on physical examination, about 1.2 cm distal to the dentate line; the groove between it and the EAS, the intersphincteric sulcus, can be visualized or easily palpated. The different echogenic patterns of the anal sphincters facilitate their visualization during endosonography. The IAS is a 2 to 3 mm thick circular band and shows a uniform hypoechogenicity. The PR and the EAS, despite their mixed linear echogenicity, are both predominantly hyperechogenic, and the distinction is made by position of their shape and topography.

Conjoined Longitudinal Muscle

Whereas the inner circular layer of the rectum gives rise to the IAS, the outer longitudinal layer, at the level of the anorectal ring, mixes with some fibers of the levator ani muscle to form the conjoined longitudinal muscle (CLM) (Fig. 8). This muscle descends between the IAS and EAS and ultimately some of its fibers, referred to as the corrugator cutis ani muscle, traverse the lowermost part of the EAS to insert into the perianal skin. There is still controversy regarding the anatomy of the CLM: other sources for the striated component include the PR and deep EAS, the pubococcygeus, and top loop of the EAS and lower fibers of the PR (20–22). On its descending course, the CLM may give rise to medial extensions that cross the IAS to contribute the smooth muscle of submucosa (musculus canalis ani, sustentator tunicae mucosae, Treitz muscle, and musculus submucosae ani) (23). Others have described outward filamentous extensions of the CLM crossing the entire length of the EAS to enter the fat of the ischiorectal fossa (24).

External Anal Sphincter

The EAS is the elliptical cylinder of striated muscle that envelops the entire length of the inner tube of smooth muscle, but ends slightly more distal to the terminus of the IAS. It is a continuous sheet of muscle which forms, along with the PR and levator ani, one funnel-shaped sheet of skeletal muscle; the deepest part of the EAS is intimately related to the PR, which is actually considered a component of both the levator ani and EAS muscle complexes (25). The EAS is also



(**A**) (**B**)

Figure 9 The pelvic floor: (**A**) pelvic or superior view and (**B**) perineal or inferior view.

described as composed of two [(1) deep sphincter and PR and (2) subcutaneous and superficial sphincter] or three [(1) subcutaneous, (2) superficial, and (3) deep] divisions or compartments (Fig. 8) (2,26).

Oh and Kark (26) also noted differences in the arrangement of the EAS according to gender and site around the anal canal. In the male, the upper half of the EAS is enveloped anteriorly by the CLM, while the lower half is crossed by it. In the female, the entire EAS is grossly encapsulated by a mixture of fibers derived from both longitudinal and IAS muscles. Based on an embryological study, the EAS also seems to be subdivided into two parts, superficial and deep, without any connection to the PR (5). Shafik (2) proposed the three U-shaped loop system concept, in which each loop is a separate sphincter with distinct attachments, muscle bundle directions, and innervations and each loop complements the others to help maintain continence. However, clinical experience has not supported Shafik's three part scheme; the EAS is more likely a one muscle unit, not divided into layers or laminae, attached by the anococcygeal ligament posteriorly to the coccyx and anteriorly to the perineal body.

Levator Ani

The levator ani muscle or pelvic diaphragm is a pair of broad symmetrical sheets composed of three striated muscles: iliococcygeus, pubococcygeus, and PR (Figs. 9 and 10). A variable fourth component, the ischiococcygeus or coccygeus, is, in humans, rudimentary and is represented by a few muscle fibers on the surface of the sacrospinous ligament (27). The coccyx, the sacrospinous ligament, and the ischial tuberosities, when palpated during rectal examination, are landmarks for procedures involving the pudendal nerve such as anesthetic block and evaluation of the pudendal nerve terminal motor latencies. The pelvic floor is "defective" in the midline where

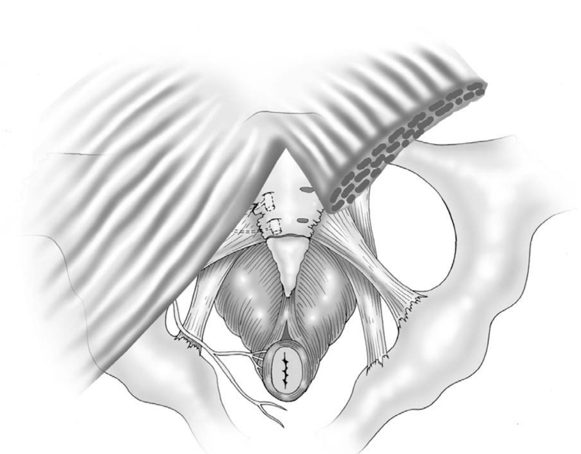


Figure 10 Posterior view of the pelvic floor and sphincteric muscles.

the lower rectum, urethra, and either the dorsal vein of the penis in men or the vagina in women pass through it. This defect is called levator hiatus and consists of an elliptical space situated between the two pubococcygeus muscles (11). The hiatal ligament, originating from the pelvic fascia, maintains the intrahiatal viscera together and prevents their constriction during levator ani contraction.

The ileococcygeus arises from the ischial spine and posterior part of the obturator fascia, and courses inferiorly and medially to insert into the lateral aspects of S 3 and S 4, the coccyx, and the anococcygeal raphe. The pubococcygeus fibers arise from the posterior aspect of the pubis and the anterior part of the obturator fascia, run dorsally alongside the anorectal junction, to decussate with fibers of the opposite side at the anococcygeal raphe and insert into the anterior surface of the fourth sacral and first coccygeal segments. The PR muscle is a U-shaped strong loop of striated muscle which slings the anorectum junction to the back of the pubis. The anorectal angle, the result of the anatomic configuration of the U-shaped sling of PR muscle around the anorectal junction, is thought to maintain gross fecal continence. The PR is the most medial portion of the levator muscle and is situated immediately cephalad to the deep component of the EAS. Since the junction between the two muscles is indistinct and they have similar innervation (pudendal nerve), the PR has been regarded by some authors as a part of the EAS rather than the levator ani complex (26). Anatomical and phylogenetic studies suggest that the PR is either a part of the levator ani (28) or of the EAS (19). Based on microscopic examinations in human embryos, Levi et al. (5) observed that the PR muscle has a common primordium with the ileo and pubococcygeus muscles; the PR is, in various stages of development, never connected with the EAS. Additionally, neurophysiologic studies have implied that the innervation of these muscles may not be the same because stimulation of sacral nerves resulted in electromyographic activity in the ipsilateral PR muscle, but not in the EAS (29). This is, therefore, a controversial issue, and as a consequence of all this evidence, the PR has been considered to belong to both the EAS and levator ani muscular groups (30).

PARANAL AND PARARECTAL SPACES

Potential spaces of clinical significance in the anorectal region include ischiorectal, perianal, intersphincteric, submucous, superficial postanal, deep postanal, supralevator, and retrorectal spaces [Figs. 5(A) and (B)]. The ischiorectal fossa is subdivided by a thin horizontal fascia into two spaces: the ischiorectal and perianal. The ischiorectal space comprises the upper two-thirds of the ischiorectal fossa. It is a pyramid-shaped space situated, on both sides, between the anal canal and lower part of the rectum medially, and the side wall of the pelvis laterally. The apex is at the origin of the levator ani muscles from the obturator fascia, and the base is represented by the perianal space. Anteriorly, the fossa is bounded by the urogenital diaphragm and transverse perinei muscles. Posterior to the ischiorectal fossa is the sacrotuberous ligament and the inferior border of the gluteus maximus. On the superolateral wall, the pudendal nerve and the internal pudendal vessels run in the pudendal canal (Alcock's canal). The ischiorectal fossa contains fat and the inferior rectal vessels and nerves.

The perianal space is the area corresponding to the anal verge that surrounds the lower part of the anal canal. It is continuous with the subcutaneous fat of the buttocks laterally and extends into the intersphincteric space medially. The external hemorrhoidal plexus lies in the perianal space and communicates with the internal hemorrhoidal plexus at the dentate line. This space is a typical site of anal hematomas, perianal abscesses, and anal fistula tracts. The perianal space also encloses the subcutaneous part of the EAS, the lowest part of the IAS and fibers of the longitudinal muscle. These fibers function as septa, dividing the space into a compact arrangement, which may account for the severe pain caused by a perianal hematoma or abscess (11).

The intersphincteric space is a potential space between the IAS and the EAS, where most anal glands end. Therefore, its importance lies in the genesis of perianal abscesses.

The submucous space is situated between the IAS and the mucocutaneous lining of the anal canal. This space contains the internal hemorrhoidal plexus and the muscularis submucosae ani. Cephalad is continuous with the submucous layer of the rectum and, inferiorly, it ends at the level of the dentate line.

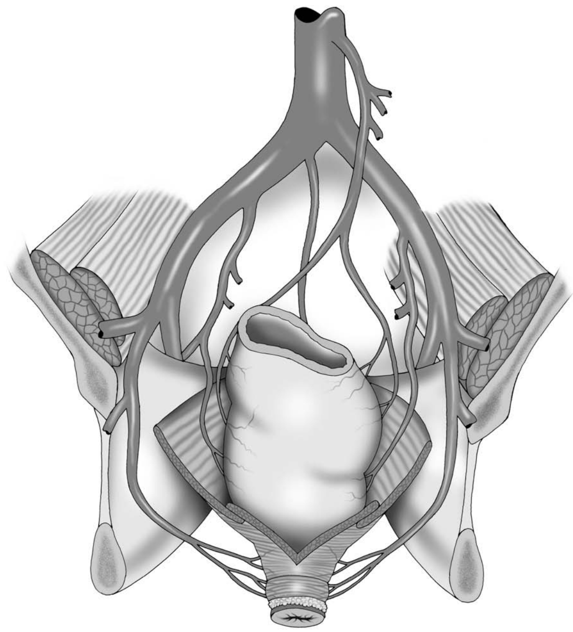


Figure 11 The arterial supply of the anorectum.

The superficial postanal space is interposed between the anococcygeal ligament and the skin. The deep postanal space, also known as the retro-sphincteric space of Courtney, is situated between the anococcygeal ligament and the anococcygeal raphe. Both postanal spaces communicate posteriorly with the ischiorectal fossa, and are potential sites of horseshoes abscesses.

The supralevator spaces are situated between the peritoneum superiorly and the levator ani inferiorly. Medially, these bilateral spaces are related to the rectum and, laterally, to the obturator fascia. Supralevator abscesses may occur as a result of upward extension of a cryptoglandular source or from a pelvic origin.

The retrorectal space is located between the fascia propria of the upper two-thirds of the rectum anteriorly and the presacral fascia posteriorly. Laterally are the lateral rectal ligaments, inferiorly is the rectosacral ligament and, above, it is continuous with the retroperitonium. The retrorectal space is a site for embryological remnants and the rare presacral tumors.

ARTERIAL SUPPLY

The superior and inferior rectal (or hemorrhoidal) arteries represent the major blood supply to the anorectum (Fig. 11). The contribution of the middle rectal artery (middle hemorrhoidal artery) varies inversely with the magnitude of the superior rectal artery, which may explain its variable and controversial anatomy. Some authors report absence of the middle rectal artery in 40% to 88% (31,32), whereas others have identified it in 94% to 100% of specimens (33). It originates more commonly from the anterior division of the internal iliac or the pudendal arteries and reaches the rectum. The middle rectal artery reaches the lower third of the rectum anterolaterally, close to the level of the pelvic floor and deep to the levator fascia; therefore it does not run in the lateral ligaments, which are inclined posterolaterally. The middle rectal artery is more prone to be injured during low anterior resection, when anterolateral dissection of the rectum, close to the pelvic floor, is performed from the prostate and seminal vesicles or from the upper part of the vagina. Although scarce in extramural anastomoses, the anorectum has a profuse intramural anastomotic network, which probably accounts for the fact that division of both superior rectal and middle rectal artery does not result in necrosis of the rectum.

The paired inferior rectal artery (IRA) or inferior hemorrhoidal artery is a branch of the internal pudendal artery, which is a branch of the internal iliac artery. The IRA arises within the pudendal canal and is, on its course, entirely extrapelvic; it traverses the obturator fascia, the ischiorectal fossa, and the EAS to reach the submucosa of the anal canal and ultimately ascend in this plane. The IRA needs to be ligated during the perineal stage of the abdominoperineal resection. Kloesterhalfen et al. (3), based on postmortem angiographic, manual, and histologic preparations, found two topographic variants of the IRA. In the so-called type I, which is the most common (85%), the posterior commissure is less perfused than the other sections of the anal canal. In addition, the blood supply may be jeopardized by contusion of the vessels passing vertically through the muscle fibers of the IAS during increased sphincter tone. These authors postulated that, in a pathogenetic model of the primary anal fissure, the resulting decrease in blood supply would lead to a relevant ischemia at the posterior commissure.

VENOUS DRAINAGE

Blood from the rectum along with the left colon, via the inferior mesenteric vein, reaches the intrahepatic capillary bed through the portal vein. The anorectum also drains, via middle and inferior rectal veins, to the internal iliac vein and then to the inferior vena cava. Although it is still a controversial subject, the presence of anastomoses among these three venous systems may explain the lack of correlation between hemorrhoids and portal hypertension (34).

The paired inferior and middle rectal veins and the single superior rectal vein originate from three anorectal arteriovenous plexuses. The external rectal plexus, situated subcutaneously around the anal canal below the dentate line, constitutes the external hemorrhoids when dilated. The internal rectal plexus is situated submucosally around the upper anal canal, above the dentate line. The internal hemorrhoids originate from this plexus. The perirectal or perimuscular rectal plexus drains to the middle and inferior rectal veins.

LYMPHATIC DRAINAGE

The lymphatic drainage of the large intestine, similar to the venous drainage, basically follows its arterial supply. The lymph nodes in the rectum, however, are particularly more numerous as compared to the other parts of the large bowel. The nodes situated between the peritoneum and the bowel wall, equivalent to the epicolic group in the colon, are known as "nodules of Gerota." Lymph from the upper 2/3 of the rectum drains exclusively upward, via superior rectal vessels, to the inferior mesenteric nodes and then to the paraortic nodes. Lymphatic drainage from the lower third of the rectum occurs not only cephalad, along the superior rectal and inferior mesentery arteries, but also laterally along the middle rectal vessels to the internal iliac nodes. Studies using lymphoscintigraphy failed to demonstrate communication between inferior mesenteric and internal iliac lymphatics (35). In the anal canal, the dentate line is a landmark for two different systems of lymphatic drainage: above, to the inferior mesenteric and internal iliac nodes and, below, along the inferior rectal lymphatics to the superficial inguinal nodes, or, less frequently, along the IRA. Block and Enquist (36) have demonstrated that, in the female, after injection of dye 5 cm above the anal verge, lymphatic drainage may also spread to the posterior vaginal wall, uterus, cervix, broad ligament, fallopian tubes, ovaries, and cul-de-sac. After injection of dye at 10 cm above the anal verge, spread occurred only to the broad ligament and cul-de-sac, and at the 15 cm level, no spread to the genitals was seen.

INNERVATION

Rectum

The sympathetic and parasympathetic components of the autonomic innervation of the large intestine closely follow the blood supply (Fig. 12). The sympathetic supply arises from L1, L2, and L3. Preganglionic fibers, via lumbar sympathetic nerves, synapse in the preaortic plexus, and the postganglionic fibers follow the branches of the inferior mesenteric artery and superior rectal artery to the upper rectum and left colon. The lower rectum is innervated by the presacral nerves, which are formed by fusion of the aortic plexus and lumbar splanchnic nerves. Just below the sacral promontory, the presacral nerves form the hypogastric plexus (or superior hypogastric plexus). Two main hypogastric nerves, on either side of the rectum, carry sympathetic innervation from the hypogastric plexus to the pelvic plexus. The pelvic plexus lies on the lateral side of the pelvis at the level of the lower third of the rectum, adjacent to the lateral

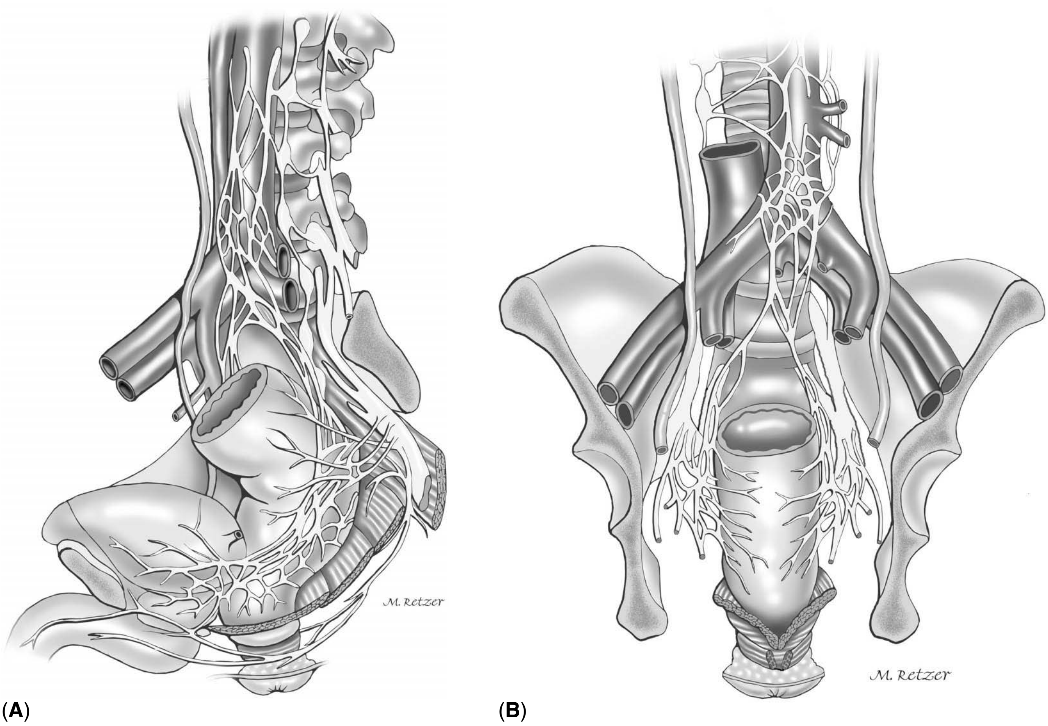


Figure 12 The parasympathetic and sympathetic nerve supply to the rectum: (**A**) sagittal and (**B**) coronal diagrams.

stalks. The term inferior hypogastric plexus has been used to mean the hypogastric nerves or the pelvic plexus; therefore it is inaccurate.

The parasympathetic supply derives from S2, S3, and S4. These fibers emerge through the sacral foramen and are called the nervi erigenti. They pass laterally, forwards, and upwards to join the sympathetic hypogastric nerves at the pelvic plexus. From the pelvic plexus, combined postganglionic parasympathetic and sympathetic fibers are distributed to the upper rectum and left colon, via inferior mesenteric plexus, and to the lower rectum and upper anal canal. The periprostatic plexus, a subdivision of the pelvic plexus situated on the Denonvilliers'fascia, supplies the prostate, seminal vesicles, corpora cavernosa, vas deferens, urethra, ejaculatory ducts, and bulbourethral glands.

Sexual function is regulated by cerebrospinal, sympathetic, and parasympathetic components; locally the latter plays the main role. Erection of the penis is mediated by both parasympathetic (arteriolar vasodilatation) and sympathetic (inhibition of vasoconstriction) inflow. Sympathetic activity is responsible for emission and parasympathetic activity for ejaculation. Urinary and sexual dysfunction is commonly seen after a variety of pelvic surgical procedures, including low anterior resection and abdominoperineal resection. Permanent bladder paresis occurs in 7% to 59% of patients after abdominoperineal of the rectum (37). The incidence of impotence is approximately 15% and 45% and that of other ejaculatory dysfunction is 32% and 42% after low anterior resection and abdominoperineal resection, respectively (38). The overall incidence of sexual dysfunction after proctectomy may reach up to 100% for malignant disease (39,40); however, these rates are much lower (0–6%) for benign conditions, such as inflammatory bowel disease (40–43). This occurs because dissection performed for benign disease is closer to the bowel wall and avoids nerve injury (44).

All pelvic nerves lie in the plane between the peritoneum and the endopelvic fascia and are endangered during rectal dissection. Injury to the autonomic nerves may occur at several points: during flush ligation of the IMA, close to the aorta, the sympathetic preaortic nerves may be injured. Lesion of both the superior hypogastic plexus and hypogastric nerves may occur during dissection at the sacral promontory or in the presacral region; in this case, sympathetic denervation with intact nervi erigentes results in retrograde ejaculation and bladder dysfunction. The nervi erigentes are located in the posterolateral aspect of the pelvis and, at the point of fusion with the sympathetic nerves, they are closely related to the middle hemorrhoidal artery. An isolated injury of these nerves may completely abolish erectile function. The pelvic plexus may be damaged either by excessive traction on the rectum, particularly laterally, or during division of the lateral stalks, when it is performed closer to the pelvic lateral wall. Finally, dissection near the seminal vesicles and prostate may damage the periprostatic plexus (mixed parasympathetic and sympathetic injury) resulting in erectile impotence and flaccid neurogenic bladder; sexual function may preserved by dissection below the Denonvilliers'fascia. Sexual complications after rectal surgery predominate in men, but are probably underdiagnosed in women (45). Some discomfort during intercourse is reported in 30% (46) and dyspareunia in 10% (47), after proctocolectomy and ileostomy.

Anal Canal

The IAS is supplied by sympathetic (L5) and parasympathetic (S2, S3, S4) nerves following the same route as the nerves to the rectum. The levator ani is supplied by sacral roots (S2, S3, and S4) on its pelvic surface and by the perineal branch of the pudendal nerve on its inferior surface. The PR receives additional innervation from the inferior rectal nerves. The EAS is innervated on each side by the inferior rectal branch (S2, S3) of the pudendal nerve and the perineal branch of S4. Despite the fact that the PR and EAS have somewhat different innervations, these muscles seem to act as an indivisible unit. After unilateral transection of a pudendal nerve, the EAS function is still preserved due to the crossover of the fibers at the spinal cord level.

Sensory Innervation

The upper anal canal contains a rich profusion of both free and organized sensory nerve−endings, especially in the vicinity of the anal valves. Organized nerve-endings include Meissner's corpuscles (touch), Krause's bulbs (cold), Golgi–Mazzoni bodies (pressure), and genital corpuscles (friction). Anal sensation is carried in the inferior rectal branch of the pudendal nerve and is thought to play a role in anal continence (27).

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3 Anorectal Physiology

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INTRODUCTION

Anorectal physiology is complex and relies on a delicate interplay of the neuromuscular function and structural integrity of the pelvic floor. Alterations in pelvic floor physiology result in an increasing number of visits to colorectal surgeons from patients complaining of functional disorders. It has been estimated that more than four million people complain of constipation every year, representing a prevalence rate of 2% of the total population. This is associated with more than 3 million prescriptions, and over 200 million spent, for cathartics and over-the-counter laxatives (1). Conversely, fecal incontinence is estimated to occur in more than 6.5 million Americans with a prevalence of up to 11% (2).

While the spectrum of disease is often not life-threatening, pelvic floor pathology has a significant impact on quality of life. The physician with a comprehensive understanding of anorectal physiology and the available diagnostic modalities will be able to offer relief to many patients with an accurate diagnosis and appropriate therapeutic recommendations.

Determination of the etiology of constipation, fecal incontinence, rectal prolapse, and anorectal pain can be facilitated in the anorectal physiology laboratory. Often, the cause of functional disorders is multifactorial. Physiologic testing after a careful history and physical examination can provide the physician with the needed insight to offer the most effective treatment regimen.

This chapter will present the most widely used diagnostic modalities with emphasis on their underlying principle, technique, interpretation, and clinical application.

ANORECTAL MANOMETRY

Background and Basic Concepts

Since the classic experiments of Denny-Brown and Robertson (3) in 1935, explaining the mechanisms underlying human defecation based on a manometric study, anorectal manometry (ARM) has become widely used for studying anorectal functional disorders (3). Measurements are obtained by inserting a pressure-sensitive device into the anal canal, which is connected via a nondistended tubing system to a transducer. The transducer transforms the pressure signals into electronic ones that are transformed and processed through an amplifier and subsequently presented as measurements (4).

Instrumentation

There are three basic systems used to perform ARM: Fluid or air-filled balloon systems, Water perfused systems, and Microtransducers.

Fluid or Air-Filled Balloon Systems

In 1965, Schuster et al. (5) described a method for measuring anal sphincter pressures. The air-filled balloon device consisted of a latex balloon was tied around a hollow cylinder, through which another balloon could be passed, thus creating two compartments. Both of the balloons are connected to pressure transducers (5). After placing the probe in the anal canal, one balloon is in the region of the internal anal sphincter (IAS) while the other is encircled by the superficial portion of the external sphincter (EAS).

Although, theoretically, both regions of the anal sphincter could be separately assessed, the considerable overlap of both IAS and EAS does not allow this method to accurately differentiate the two sphincters. Therefore, the pressure readings obtained represent the sum of all forces acting upon the balloon (4).

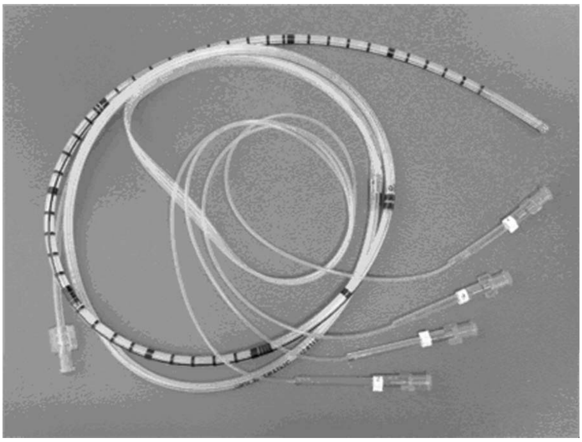

Figure 1 Four-channel water-perfused manometry catheter.

Since the size of the catheter introduced into the anal canal can alter the sphincter tone, which in turn results in artifactual distortion of the resting pressure, the smaller the size of the catheter the more accurate the results (6). However, smaller catheters allow a relatively smaller area of the anal canal to be measured (7). The pressure distribution inside the anal canal is asymmetric along its longitudinal as well as radial axes. As the pressure increases gradually from proximal to distal, there are unequal forces acting from each sidewall. The balloon system does not take into account the radial asymmetry of the anal canal sphincter and recording regions are restricted to two regions—the upper and lower anal canal.

Air or water can be used to distend the balloon, but since air is distensible, using water provides lower variation in pressure measurements. This requires complete evacuation of air bubbles to avoid damping of the recorded pressures, which can be a challenging task (3).

Water-Perfused Systems

Water-perfused systems are the most commonly used in North America and are considered reliable methods for performing ARM (Fig. 1) (8). Originally, developed by Arndorfer et al. (9) in the late 1970s for esophageal manometry, the principle of this method depends on continuous water flow in a constant rate through the catheter. By means of measuring the resistance to this water outflow exerted by the surrounding anal sphincters, pressures can be eventually recorded (Fig. 2) (10).

While the catheter is properly situated inside the rectum, there is a potential space between the catheter and the anal canal wall. Once this space is filled by perfusate, the water flows cephalad toward the rectum or outside the anal canal. The pressure required to overcome the initial resistance after the space has been filled is termed the "yield pressure" (4,11,12).

A constant flow rate, usually 0.3 mL/channel/min is required to enable the sensors to measure the outflow resistance or pressure (13). The greater the sphincter strength, the more resistance impeding the water flow, the higher the pressure recorded. Low flow rates may interfere with accuracy of detecting pressure changes, whereas high rates are associated with more fluid accumulation in the rectum, which can then affect the reproducibility of the procedure (8,14).

Microtransducers

Microtransducers have a fixed location on the anorectal probe, from which measurements are provided with respect to radial pressures. The use of microtransducers is convenient as they

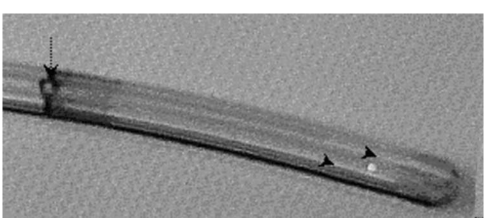

Figure 2 Tip of the catheter showing one of the four openings for the water outflow (*arrow*) and two of the channels (*arrow heads*).

are easy to set up and calibrate. They require the use of relatively small-size catheters, thus minimizing the amount of artifactual stimulation, and there is no water leak. Since there is no hydraulic transmission, pressures measured are thought to be more accurate than those from perfused catheters. (3,4) Furthermore, microtransducers eliminate concerns regarding positioning, thereby allowing ambulatory measurements and recordings to be taken in the sitting position, creating a more physiologic evaluation. Drawbacks associated with these transducers, however, are that they are expensive and very fragile, and require handling with great amount of care (15–17).

Manometry Catheters

Sleeve catheters consist of a thin silastic membrane adhered to a catheter formed of a silastic tube with a second tube formed on one side. Water flows between the two silastic interfaces along the sphincter, thus any resistance to the water flow would be recorded in terms of pressure (4,18). As with the balloons system, sleeves provide an assessment of the global pressures of the anal canal but cannot provide information regarding pressures at a specific location within the sphincter complex.

Water-perfused catheters are the most commonly used. The outer diameter of the catheter ranges from 4 to 8 mm, which helps reduce the artifactual distortion from larger catheters when inserted into the anal canal. While rigid catheters are easy to insert and orient in the anal canal, the more flexible catheters cause less distortion (8).

The commonly used catheters have multiple channels, ranging from 2 to 8 mm with the channel ports opening on the side of the catheter. These openings can be displayed in a radial or a stepwise pattern.

Catheters are irrigated with sterile water and are connected to a transducer via a low compliance, nondistensible capillary tubing system. This feature is important for transmitting any small pressure changes occurring inside the anal canal. Unlike microtransducers, water-perfused catheters cannot be used in an ambulatory setting as any movements of the patient will result in considerable pressure artifacts (4).

Measurements

Resting Pressure

Resting pressure represents the sphincter tone during the resting state, which is produced mainly by the IAS. This is a smooth muscle, which is in a state of continuous involuntary contraction as a result of both intrinsic myogenic and extrinsic autonomic supply, and it provides a natural barrier to the involuntary loss of stool (19).

The IAS is responsible of 50% to 85% of the resting tone, while the EAS accounts for 25% to 30%. This extra pressure is essential to minimize voluntary attention to the anal sphincters. Finally, anal cushion expansion makes up the remaining 5% to 15%, which seems to be essential for perfect anal control (19–22). As pressure increases gradually in anal canal from proximal to distal, the highest resting pressure is recorded generally 1 to 2 cm proximal to the anal verge. This corresponds anatomically to the condensation of distal fibers of the IAS.

The mean anal canal resting pressure in healthy volunteers is generally in the range of 50 to 70 mmHg. This is lower in women as well as in the elderly (Fig. 3) (8,23,24).

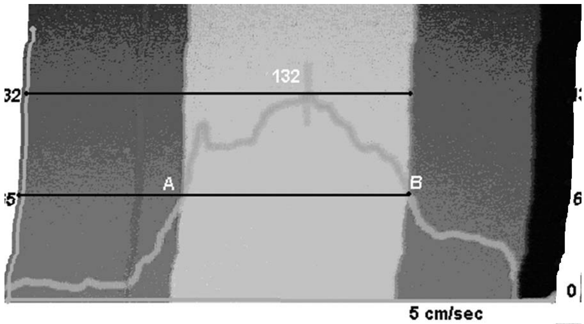

Figure 3 Schematic representation of a “resting” pressure. Points A and B represent the 50% of maximum pressure. Distance A–B represents “high pressure zone.”