EVALUATION OF MANOMETRY AND DEFECOGRAPHY ASSESSMENT FOR CONSTIPATION AND INCONTINENCE

By

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ABSTRACT

This thesis examines the sensitivity and specificity of manometry and defecography assessments; the relationship between function and symptoms; and the relationship between age and parity and patient assessments.

The manometry assessments of 72 incontinent and 50 constipated female patients were compared to 86 healthy volunteers using discriminant function and classification analysis (DFA). The defecography assessments of a subset of these patients, 21 incontinent and 25 constipated, were compared to 22 healthy female volunteers. These data were used to examine the factors age, parity, severity of symptoms and rectal wall morphology on function.

The results show that the variables of total squeeze pressure and resting pressure have a sensitivity of 79% for the incontinent patients and 32% for the constipated patients. The specificity was 87%. The manometry variables resting pressure, squeeze pressures, volume to urgency were significantly different in the patient groups. Aging was a significant factor for lower resting pressures and increased parity was a significant factor for lower squeeze pressures in the patient groups.

The sensitivity of the combination of the defecography variables, lift and strain angles and junction levels, was 90% for the incontinent patients and 88% for the constipated patients. The specificity was 95%. The defecography variables were not significantly different in the patient groups. Rest and lift angles were significantly wider with increased age and parity.

Neither the defecography and manometry variables nor rectal wall morphology changes were associated with varying severity of either constipation or incontinence.

The manometry and defecography assessments are presented in graphs, which may enhance the clinical usefulness of the assessments by demonstrating the difference between patient values and healthy controls. The manometry data are also presented in an index which makes areas of specific impairment more obvious.

DFA of the manometry and defecography variables provides probability rates which may be useful in predicting patient outcomes. The discriminant scores from the analysis of the defecography and manometry variables can be used to develop a continuum from health to incontinence.

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CHAPTER ONE

INTRODUCTION

Constipation and faecal incontinence are common clinical problems, but the mechanisms underlying the problems are not clearly understood. There is no consensus for either the assessment or the treatment of these disorders. This reflects the complexity of the neural and muscle control of continence and defecation as well as the contribution of the patient's diet, exercise, cognitive awareness, bowel habit and training and other medical history.

Faecal incontinence is age and sex related. The incidence of incontinence is eight times higher in women than in men in the 45 years and older age group (Henry, 1987). Incontinence occurs in about 10 percent of hospitalized elderly (Tobin and Brocklehurst, 1986) and 5% of the elderly in the community setting (Gray, 1986). Incontinence is often under reported because of the patient's embarrassment (Read et al., 1979; Gray, 1986). A recent Canadian study in a long-term care hospital by Borrie and Davidson (1992) found incontinence added a cost of $9771 a year per patient in nursing care and supplies. Although it is generally thought of as a problem of the elderly, many younger people are also incontinent. A US householder survey by Drossman et al. (1993) shows an average of 50.1 missed work or school days a year because of gross faecal incontinence.

Constipation generally relies on the subjective reporting of the patient. For some patients constipation is having less than three bowel movements a week, for others it is hard stools or straining at stool. This results in difficulty in defining constipation in objective terms. Sonnenberg and Koch (1989) review several surveys and show that frequent constipation was reported by 2% of the American population. Constipation increases with age for a variety of reasons including: changes in diet, multiple drug therapies for other medical conditions, immobility, and postponment of bowel movements. The exact role of the patient's psyche in constipation is unclear. Although emotions such as fear and anxiety can cause changes in gastrointestinal function, neither the emotions nor the gastrointestinal changes are predictable or in many cases measurable (Bartolo et al., 1988a). Patients with constipation are often concerned about having undiagnosed cancer and for this reason seek advice from their physicians. In the United States three million patients are treated yearly for constipation with laxatives and cathartics. The cost of diagnosis and treatment for constipation has not been evaluated, but must be a burden on the medical system (Fleshman et al., 1992b). Drossman et al. (1993) shows 21.9 missed work or school days a year because of functional constipation.

Despite years of examination of the anorectal reflexes and pelvic floor function, by a variety of methods, the relationship of function to patient symptoms is poorly understood. Manometry and defecography are the two techniques used most commonly to assess anal sphincter and pelvic floor function in patients with constipation and incontinence. Although both techniques reveal pathologies in the patients, there is a great deal of overlap between the measurements of variables between constipated and incontinent patients and healthy control values. None of the assessments has been shown to be sensitive and specific for either constipation or incontinence. The usefulness of defecography and manometry in the assessment of anorectal dysfunction is under continuous discussion.

The aim of this thesis is to show that constipation and incontinence are not unrelated problems, but are symptoms reflecting differing degrees of pelvic floor and anorectal muscle and nerve dysfunction. To meet this goal, this thesis will examine the clinical usefulness of manometry and defecography in patients with constipation and fecal incontinence.

The objectives are:

- to evaluate the sensitivity and specificity of manometry and defecography assessments,
- to evaluate the relationship between symptoms and function

- to evaluate the relationship between patient's age and parity and the assessments,
- to design clinically useful ways of reporting patient assessments,
- to formulate a hypothesis on prediction of patient's outcomes.

In this thesis, papers which describe anorectal physiology, manometry and defecography will be reviewed. Five studies are described, which show the contribution of defecography and manometry assessments to the understanding of anorectal dysfunction.

CHAPTER TWO

ANORECTAL PHYSIOLOGY AND PATHOPHYSIOLOGY

Essential to continence and defecation is a physiological balance between the aggressive force of the movement of the bowel contents and defensive strength of the anal sphincters. This balance depends on a complex interaction between a number of functional units in addition to cognitive awareness and stool consistency. The first report on anorectal physiology was in 1877, when Gowers (1877) described the anal reflex relaxation with rectal distention. Since the 1960's, with the introduction of various techniques to accurately measure sphincter muscle responses, understanding of the mechanisms of continence and defecation has grown, but is not complete. There is by no means agreement amongst investigators as to the importance of the various components of this complex function. This review will briefly describe the physiology, the neural control and the pathophysiology of the musculature of the pelvic floor and anorectum.

THE SMOOTH MUSCULATURE

The Rectum

The rectum is a 10 - 15 cm section at the end of the distal bowel. It is made of smooth muscle and the longitudinal muscle layer is much thinner than the sigmoid colon, giving the rectum more elasticity (Fry and Kodner, 1985). The innervation of the rectum is via the enteric nervous system, and the sympathetic (thoracolumbar) and parasympathetic nerves (S-2 S-3 S-4 the nervi erigentes). The sympathetic innervation is excitatory and parasympathetic is inhibitory. The neural afferent pathways for rectal sensation, cognitive and reflex, are still unclear. The location of sensory receptors sensitive to distention of the rectum has not been established (Whitehead and Schuster, 1987). Early studies suggested that the neural pathways were through the pelvic nerves, but children with myelomeningocele have normal rectal sensation unless the lesions are at L-2 or higher (Whitehead et al., 1986). Ihre (1974) found that the sensory pathway travelled through the sympathetic ganglia and entered the cord at L-3.

The elasticity of the rectum enables the storage of large quantities of stool and the postponement of defecation until an appropriate time. In healthy individuals the rectum has a capacity to hold 1500 ml of saline (Shafik, 1975) or a 400 cc of air in a balloon (Heppell et al., 1982).

In some patients with constipation the rectum becomes extremely distended with stool resulting in megacolon (Meunier et al., 1976). Patients with dementia, stroke or sensory neuropathies have increased sensory thresholds and have increased incidence of faecal impaction and overflow incontinence (Schiller, 1986; Read and Abouzekry, 1986a; Allen et al., 1988). Studies have found no difference (Ihre, 1974) or a significant decrease (Read et al., 1983b; Allen et al., 1988) in rectal compliance in incontinent patients. In patients with ulcerative colitis the decrease in rectal compliance is associated with increased feelings of urgency (Denis et al., 1979). Rectal ischemia presents with decreased rectal compliance and symptoms of incontinence (Devroede et al., 1982), but is rare and accounts for only a few patients.

The Internal Anal Sphincter

Fry and Kodner (1985) describe the internal anal sphincter as the inner muscular tube of the anal canal which is completely surrounded by the external anal sphincter. It is separated from the external anal sphincter by the inter-sphincteric plane. Fibres that are a continuation of the longitudinal muscle layer of the rectum run through this plane. The internal anal sphincter is a thickened continuation of the circular smooth muscle surrounding the rectum. At the top of the junction of the rectum and the anal canal is a zone called the dentate line where the rectal epithelium changes and joins the epithelium of the anal canal.

The innervation of the internal anal sphincter is via the enteric nervous system. The sympathetic and parasympathetic nervous systems act to regulate the activity of the enteric nervous system (Meunier and Mollard, 1977; Burleigh and D'Mello, 1983; Gordon, 1987). Below the dentate line receptors for the sensations of temperature, pain and touch are carried by the afferent fibres in the inferior rectal nerves. Touch sensation above the dentate line is relatively insensitive and carried by the parasympathetic fibres (Fry and Kodner, 1985).

At rest the internal anal sphincter is tonically contracted. The resting pressure measured by manometry is about 90 mm Hg in healthy individuals (McHugh and Diamant, 1987). Fifty to ninety percent of the resting pressure is from the tonic activity of the internal anal sphincter (Duthie and Watts, 1965; Frenckner and Euler, 1975). Rectal distention causes inhibition of tone in the internal anal sphincter. Rectal balloon volumes between 5-20 cc cause a brief small reflex relaxation of the internal anal sphincter as measured by manometry. Larger balloon volumes cause longer and larger relaxation of the internal anal sphincter (Schuster et al., 1965). The internal anal sphincter resting pressure acts as a barrier, preventing the contents leaking from the rectum. During defecation the sphincter is inhibited by the stimulus of the rectal contents.

Lack of the reflex inhibition of the internal anal sphincter is a marker for agangionosis of the enteric nervous system as in Hirschsprung's disease. The internal sphincter in patients with Hirschsprung's disease is in a state of permanent contraction and usually the patient is constipated (Whitehead and Schuster, 1987). Internal anal sphincter weakness is often associated with incontinence (Read et al., 1984). One cause of internal anal sphincter weakness is the chronic use of laxatives which damage the myenteric nervous system (Haubruch, 1985). Slow recovery of the internal anal sphincter tone after relaxation has been found in some patients with incontinence (Buser and Miner, Jr. 1986; Sun et al., 1989a; Sun et al., 1990). Changes in the sensitivity of the upper anal canal to rectal contents have been described in incontinent patients (Miller et al., 1987).

THE STRIATED MUSCULATURE

The Levator Ani

The levator ani muscles form most of the pelvic floor and consists of a broad thin sling between the inner surface of the pubis, the obturator fascia and the ischial spine. The levator ani consists of three parts: the iliococcygeus, the pubococcygeus and the puborectalis. These muscles, with outlets for the urogenital organs and rectum, form the funnel shaped pelvic floor. The iliococcygeus is the posterior and lateral part of the levator ani and terminates in the coccyx and anococcygeal raphe. It is not connected to the anal canal. Part of the pubococcygeus muscle fibres run straight back from the pubis to the coccyx and part cross over in front and behind the rectum to form the rectal opening in the pelvic floor. Garavoglia et al. (1993), describe the connection of the pubococcygeus and the rectal wall at this opening. They found on dissection that the muscles fuse with the fascia of the rectum in the ascending component and with the longitudinal muscles of the rectum in the descending component. The puborectalis is a sling of muscle which is attached to the lower back part of the pubis and loops around the rectum at the junction of the anal canal.

The efferent innervation of the levator ani is controversial. Innervation is either from direct branches from the spinal cord of the sacral nerves, S-3 S-4 (Whitehead and Schuster, 1987) or via the S-2 and the pudendal nerve (Snooks et al., 1986) or both (Felt-Bersma et al., 1990). Matzel (1990) shows that the innervation is by direct branches of the sacral nerves which run in plane between the intra pelvic fascia and the levator ani muscles.

The External Anal Sphincter

The external anal sphincter has at least two and perhaps three components (Goligher et al., 1955; Shafik, 1975). The top portion is partially fused to posterior part of the puborectalis and then forms a sleeve around the anal canal. The subcutaneous portion is divided into discrete muscle bundles by the longitudinal fibres from the rectum. Garavoglia et al. (1993), describe the subcutaneous muscle as running from the perineal body to the anococcygeal raphe with some medial fibres crossing over in front and behind the anal canal.

The superficial part is located between the lowest part of the internal anal sphincter and the perianal skin.

The external anal sphincter is innervated by the pudendal nerve which originates from the sacral nerves mainly S-2 with some contribution from S-3, but the branch is distal to the levator ani branches. Branches of the pudendal nerve innervate the external anal sphincter, perineal and perianal skin and urethral sphincter (Shafik, 1975; Schuster, 1968; Snooks et al., 1986).

In healthy individuals these muscle groups work in a coordinated fashion. The levator ani and the external sphincter are tonically partially contracted and are capable of voluntarily increasing the amount of contraction. The pelvic floor is normally positioned above the plane of the ischial tuberosities (Shorvon et al., 1989a). The puborectalis muscle maintains a sharp angle of about 90 degrees, between the rectum and the anal canal, preventing the passage of stool. Voluntary contraction of the anal sphincter decreases the angle to about 75 degrees. Contraction of the anal sphincter is a learned conditioned response and prevents stool loss with increases in intra-abdominal pressure such as those due to coughing or lifting heavy objects. The puborectalis relaxes during defecation and the angle widens to about 135 degrees, allowing the contents of the rectum to pass. The external sphincter tonic contraction contributes 10 - 50% of the resting pressure of the anal canal (Duthie and Watts, 1965). Voluntary contracting of the external anal sphincter increases the resting pressure of the anal canal by 2 to 3 fold.

Anomalies in puborectalis muscle and external anal sphincter function are most often identified, as possible causes of constipation and incontinence. Kuijpers et al. (1986a) found some constipated patients were unable to relax the pelvic floor muscles and in particular the puborectalis during straining. Failure to relax the external anal sphincters during straining has been described in constipated patients, but the cause is unknown (Read et al., 1986b; Shorvon et al., 1989a).

Weakness of the pelvic floor muscles and external anal sphincter muscles is shown in patients with incontinence. Low squeeze pressure has been found in incontinent patients compared to continent (Hiltunen et al., 1986). Read and Abouzekry (1986a) found increased anorectal angles, but no difference in resting and squeeze pressure in elderly incontinent impacted patients compared to controls. Lower anorectal junction levels, resting and squeeze pressure were associated with incontinence in the Bartolo et al. (1983a) study.

Several factors contribute to weak pelvic floor and external anal sphincter musculature. Ageing has shown to be associated with lower resting pressures, and thinner pelvic floor muscles (McHugh and Diamant, 1987; Garavoglia et al., 1993). Other factors are: difficult deliveries (Snooks et al., 1984; Snooks et al., 1990), spinal cord injuries (Whitehead and Schuster, 1987), and straining at stool (Snooks et al., 1985a), diabetic and other neuropathies (Ihre, 1974). Pelvic floor weakness is reflected in wider angles as measured at defecography (Bartolo et al., 1983a), descending perineum at rest (Womack et al., 1985) and changes in electomyography results (Snooks et al., 1985a). Pudendal nerve neuropathy is widely implicated because straining is thought to cause traction trauma to the nerves and in the course of time may lead to incontinence (Henry et al., 1982). Manometric studies show weaker voluntary squeeze pressure with aging and in females (McHugh and Diamant, 1987; Felt-Bersma et al., 1989).

One of the problems with studies of the striated musculature is the difficulty is determining exactly which set of muscles is being evaluated, because the muscles have some overlap in both structure and innervation (Read et al., 1983a). None of the tests of pelvic floor or external sphincter muscle function have shown to reliably discriminate amongst patients with incontinence and constipation and controls.

In summary all these muscle groups work in a synergistic way to maintain continence. The pelvic floor muscles support and anchor the rectum and anal canal, the puborectalis and external anal sphincter exert a tonic force from several directions to keep the sphincter closed and this force can be voluntarily increased if called upon. The rectum is sensitive to distention and signals the need for defecation and acts as a compliant reservoir to store stool, until an appropriate time. The internal anal sphincter tone acts as a barrier to prevent leakage from the rectum. There are several external factors which influence the function of the anorectum and pelvic floor musculature. Aging, diet, exercise, medications and the presence of other diseases all impact on the physiology of motility and the basic mechanisms that contribute to continence.

CHAPTER III

METHODS OF ASSESSMENT OF PELVIC FLOOR DYSFUNCTION

There are many ways to assess anorectal function: digital examination, manometry, radiology, electromyography, tests of thermal or electro sensitivity, saline infusion test to name a few. The most widely accepted techniques for patient assessment at the clinical level are digital examination, anorectal manometry and radiological studies of defecation. These tests examine different aspects of anorectal and pelvic floor function, but are not often used in a systematic way to either evaluate or make treatment decisions for patients with incontinence and constipation. This chapter will give an overview manometry and radiology assessments and describe briefly the findings for controls.

Manometry Assessment

Manometry assessment is used to evaluate the function of the voluntary and involuntary components of the internal and external anal sphincter tone, the integrity of reflex inhibition to rectal distention and rectal sensitivity.

Manometry is performed with the patient in the left lateral position. A lubricated pressure sensitive device is gently inserted into the patient's anal canal. The patient is allowed to rest for a few moments and a recording is made of the baseline or resting pressure. The patient is instructed to voluntarily contract the anal sphincters a number of times. Some techniques include the use of a rectal balloon, which is positioned in the patient's rectum. The balloon is inflated to various sizes while the pressure in the anal canal and the patient's responses are recorded.

The Manometry Variables

Many studies have been reported describing the pressures of the anorectum at rest and with stimulation from rectal distention (Schuster et al., 1965; Kerremans, 1969; Ihre, 1974). At rest in healthy individuals the anal canal has a baseline or resting pressure of 60-100 mm Hg. This resting pressure is largely due to the tonic contraction of the internal anal sphincter and to a lesser degree the tonic contractile activity of the external anal sphincter. During the assessment the patient is asked to tighten or squeeze the anus closed several times. The average of these pressures is called the squeeze pressure and is about 150-200 mm Hg in healthy controls. The squeeze pressure variable is a measure of the strength of the voluntary component of the external anal sphincter. It is reported as maximum squeeze pressure which includes the resting pressure or with the resting pressure subtracted. When the rectum is distended by a 50 ml balloon the anal sphincter relaxes briefly and then returns to baseline levels. The decrease in pressure is caused by the relaxation of the internal anal sphincter. If the relaxation reflex is absent it is an indication of Hirschsprung's Disease, which is a lack of ganglion cells in the myenteric plexus (Whitehead and Schuster, 1987). Often there is a brief spike of increased pressure at the start of the balloon inflation. This brief increase is called the 'guard reflex' and is a contraction of the external anal sphincter. Rectal distention caused by inflation of the balloon with 150 ml of air, causes inhibition of the internal anal sphincter muscles and the external anal sphincter muscles contract strongly. Maximum distention of the rectum causes complete relaxation of the internal and external anal sphincter, which slowly recovers tone. Superimposed on the pressure records are slow waves of pressure with frequencies usually ranging between seven and 20 cycles per minute. On some records ultra slow pressure waves of around one cycle per minute can be seen (Pedersen and Christiansen, 1989). Another component of the manometry assessment is the patient's verbal responses to the balloon inflations. Patients are asked to report their sensations of feeling the balloon for the first time, urgency and discomfort.

Manometry Techniques

There is no generally accepted standardized method of performing anal sphincter manometry. This accounts for much of the inconsistency reported in the literature. The methods used to evaluate anorectal pressure include: water or air filled balloons of various sizes (Schuster et al., 1965; Hallan et al., 1989), perfusion catheters of differing diameter, rigidity and flow rates (Taylor et al., 1984; Bannister et al., 1989), and strain gauges of different configurations and sensitivity (Schouten and van Vroonhoven, 1983; Vela and Rosenberg, 1982). The diameter of the recording probe is known to change the outcome measures of anorectal pressures (Gutierrez et al., 1975). The methods used in anorectal assessment also differ, including: stationary probes (Sun et al., 1989a), pull through probes (McHugh and Diamant, 1987) and probes with ports oriented in different directions (Williamson et al., 1990). The subjects' interpretation of the instructions to "squeeze" range from breath holding, tightening their thighs, buttocks and abdomen to tightening the anus.

Because there is no standard technique, the range between the studies is very large for all the variables. All of these factors contribute to the great variation reported as "normal" responses in the literature. There is also a wide range of values within the studies indicating a large variation in function in the healthy population (McHugh and Diamant, 1987; Felt-Bersma et al., 1989).

Several authors have reported the results of manometry studies using a small diameter (4-7 mm) multi-port (4-8) catheter. The catheter is made up of several micro-tubes with openings or ports in various patterns along the catheter designed to cover the axial area or the longitudinal distance of the anal canal. There is often an inflatable balloon attached to the distal end of the catheter for rectal stimulation. The ports are side holes which are continuously perfused with water at about 0.4 ml per minute, by a low compliance perfusion system. Water filled pressure transducers are used to measure anal pressures. The catheter is perfused slowly with water at a constant rate. Contraction or relaxation of the muscles of the anorectum effects the rate of flow of the water from the catheter and this is translated into pressure changes by the transducers. This system is reliable, easily calibrated and well tolerated by patients.

Reliability of Anorectal Manometry

There have been three reliability studies of anorectal manometry reported in the literature. Pedersen and Christiansen (1989) measured the day to day variation in 10 subjects. The subjects were measured ten times in one day, on three different occasions over 3 to 24 months. They found a variation of about 20% for resting and squeeze pressure, which was not significant. Felt-Bersma (1989) measured 14 patients twice in a one to three week period, and found the variation to be around 10% for resting and squeeze pressure.

The difference between the two studies can be accounted for in part by the different manometry techniques used. Pedersen and Christiansen used the perfused catheter with the pull through method. The pull through method is performed by placing the catheter so that all ports are in the patient's rectum. The catheter is then pulled at a constant rate through the anal passage while recording the pressure. This method gives a pressure profile for the length of the canal. The stationary method used by Felt-Bersma is done by placing the catheter in the anal canal so that one port is in the rectum and the remaining ports are oriented longitudinally along the anal canal. The catheter remains stationary throughout the recording. The stationary catheter measures the pressure at each port over time and the slow waves and ultra slow waves of pressure are recorded. The pull through method does not record the slow waves of pressure. Pedersen and Christiansen made some recordings with a stationary catheter and report that much of the variation they found was accounted for by the presence of the slow and ultra slow waves of pressure. McHugh and Diamant (1984) compared the pull through technique to the stationary profile in 22 subjects and found no significant differences for resting pressure measurements. They found the pull through technique to be stable by evaluating multiple measures over intervals of 1.5 seconds. Resting pressure was not significantly affected by rate of infusion.

Besides the variation due to different techniques, several authors have reported age and sex as factors affecting manometry values. Men have higher resting and squeeze pressures compared to women of the same age in some studies (Loening-Baucke and

Anuras, 1985; McHugh and Diamant, 1987; Gibbons et al., 1986; Pedersen and Christiansen, 1989; Sun et al., 1989a; Poos et al., 1986), but not in the Taylor et al. (1984) study. Older individuals have lower squeeze and resting pressures in some studies (McHugh and Diamant, 1987; Bannister et al., 1987; Laurberg and Swash, 1989; Poos et al., 1986); this was not found in Pedersen and Christiansen (1989), but the sample was small. Parity may be a factor for the lower squeeze pressure measured in patients. Taylor et al. (1984) found lower squeeze pressure to be a trend with increased parity. McHugh and Diamant (1987) did not find parity to influence squeeze pressure in healthy controls. Damage done to the external anal sphincter during prolonged and difficult delivery may contribute to the cause of some patient's symptoms and healthy women had better deliveries or had the capacity for better recoveries (Snooks et al., 1984).

Manometry is a reliable, inexpensive and low risk method of assessing the internal and external sphincter tone, strength, and reflex activity, as well as the patient's cognitive awarness of rectal stimulation.

Radiological Assessment of Pelvic Floor Function

In recent years the radiological assessment techniques of defecography and proctography have been developed and are important tools for diagnosing physical abnormalities of the rectal wall and in the assessment of the functioning of the pelvic floor muscles. The usefulness of the measurement of anorectal junction levels and anorectal angles in the assessment of pelvic floor disfunction is under continuous discussion.

Anorectal radiology with the patient in the left lateral position is usually called proctography (Bartram et al., 1988). Defecography or evacuation proctography is a radiological assessment that attempts to mimic normal defecation (Burhenne, 1964). The defecography assessment begins with the patient in the left lateral position, liquid barium is inserted into the rectum to coat the rectal mucosa and then barium paste is introduced into the patient's rectum until a feeling of fullness is reported. The patient is then seated on a specially constructed commode and examined by remote control fluoroscopy. Spot films are taken at rest and during voluntary contraction of the anal sphincter, straining without defecating and during the act of defecation.

THE DEFECOGRAPHY VARIABLES

The defecography variables are measured on the spot films taken during the procedure. The variables measured are the anorectal angle and the anorectal junction level as well as unusual changes in rectal wall morphology. The anorectal angle is formed at the junction of the anal canal and the rectum. The angle is changed by the relaxation or contraction of the puborectalis muscle which loops around the junction. The angle is measured between a line drawn through the central axis of the rectum and anal canal or from a line drawn along the posterior rectal wall and the axis of the anal canal. The junction of the anal canal and the rectum is measured from a reference point, which is usually the ischial tuberosities or a line drawn from the pubus to the coccyx. Pelvic floor movement movement in proctography and defecography is measured using the pubo-coccygeal or the ischial tuberosities as a reference. Lift movement is caused by the voluntary contraction of the anal sphincter and descent by increasing the intra-abdominal pressure through straining or by defecation. Rectocele, intussusception and enterocele are changes in rectal wall mophology that form during defecation can be assessed from the films.

The anorectal angle is considered the most important component in maintaining continence (Parks, 1975); however, the importance of the angle has been challanged. Comparison of studies measuring angles and junction levels is difficult because of the lack of standard technique and evaluation. Angles on proctography are measured from the central axis. The defecography angles are measured either from the central axis or from the posterior border of the rectum. Skomorowska et al. (1987) concluded that "one should refrain from measuring angles in men, since little is gained from it. No clinical importance should be attached to the result". Bartram et al. (1988) and Felt-Bersma et al. (1990) show that using the central axis of the rectum to make angle measurements on defecography films overestimates the angle width. Angle measurements using the posterior boarder of the rectum also present measurement difficulties if rectal wall abnormalites distort the configuration of the rectum (Jorge et al., 1992). Many studies emphasise the size of the strain angle. If the angle does not widen on strain it is an indication of a non-relaxing puborectalis muscle, which is implicated in symptoms of constipation (Kuijpers et al., 1986a). Angle changes have a lot of inter-subject variation not only because of differences in function but also in the patient's ability to perform the manoeuvres.

The junction level is usally referenced from the ischial tuberoisties or other bone structures. Bartram et al. (1988), found that the ischial tuberosities are more clearly visualized on spot films than the pubis ramus and the junction of the coccyx and sacrum and may be the better reference point. Some studies have used references external to the patient, such as the chair edge, which have no physiological meaning (Skomorowska et al., 1987). Most studies examine descent of the junction from the reference structure. Descent measurements referenced from resting levels may yield more information about muscle function. Lift movement of the junction level during contraction of the anus is seldom assessed and is not reported in most studies. Like descent, lift is usually referenced from a bone structure and not from resting levels which may reveal more information about muscle function.

Bernier et al. (1988) reviews the design problems of the commodes used for defecography. Most authors have designed their own commodes and this may account for some of the differences in reported studies. Some commode constuction materials interfere with the clarity of the radiology films.

Patients are often embarrassed by the defecography procedure and although every attempt is made to make them feel comfortable, this embarrassment may inhibit defecation in some patients. The patients' ability to understand instructions to contract the anus or strain without defecation may also influence the accuracy of the results of the measurements.

Defecography Control Subjects

Because of the radiation exposure involved in defecography there are very few studies with a healthy control group. The 'normal' controls in most studies are patients of both sex awaiting surgery or being evaluated for some disorder thought to be unrelated to anorectal function.

A recent study by Shorvon et al. (1989a) is the first comprehensive study describing defecography observations in healthy volunteers. The angle values in healthy females varied widely. At rest the angle was 95 degrees and the angle was consistently decreased on squeeze on average to 71 degrees, showing the normal functioning pelvic floor musculature. The junction level at rest also varied in control group, but was usually above the ischial tuberosties with an average of 0.4 cm. On squeeze all subjects raised the junction level about 1 cm. These data show how the pelvic floor muscles work in healthy young female subjects and suggest that angle and junction level measurements are useful in the assessment of pelvic floor function in patients.

Reliability of Defecography Assessment

The lack of reliability between different radiologists on measuring the anorectal angle has been a criticism of defecography assessments (Penninckx et al., 1990). The Penninckx study involved 3 observers who measured 14 films 2 times. No data for within rater reliability is given. In the Penninckx study, it is inferred that only qualitative measures of angle and junction level can be used as indicators of pelvic floor dysfunction in defecography assessment. Jorge et al. (1992) examined intra-observer reliability of angle measurements by having 100 patient films assessed twice in a two to twelve month period by the same observer. They found a good correlation between the two ratings; however, there was only one observer in the study. Evaluation of reliabilty should focus on the relationship of the individual patient scores given by different observers (Streiner et al., 1989). More studies need to be carried out in order to validate measurements derived from defecography films.

Complicating measurement even further are the findings that there are significant sex and age differences in anorectal angle and descent in healthy volunteers (Skomorowska et al., 1987; Shorvon et al., 1989a; Jones et al., 1987b; Laurberg and Swash, 1989), which may account for some differences in reported studies (Bartolo et al., 1986; Womack et al., 1986).

Grouping males and females together in the same study makes the results of defecography difficult to interpret because the bony structures used as references are different and heavier in males.

Even though there are many methodological difficulties to be resolved, defecography has proven to be useful in characterizing specific disorders such as spastic floor syndrome (Kuijpers et al., 1986a), and in detecting anatomical abnormalities (Shorvon et al., 1989a).

RESEARCH DESIGN

The subjects were 122 consecutive female patients who were referred to the motility clinic for anorectal manometry assessment of constipation or incontinence. Exclusion criteria were males, less than 16 years of age, colostomy or ileostomy, anorectal surgery in the past 5 years, ulcerative colitis and Crohn's disease.

Patient history included age, number of children, duration of symptoms, type of symptoms, history of surgeries, bladder control, medications and the presence of other medical disorders. The patients are described in Table I. Normal values from 86 healthy female controls aged 20 to 89 were obtained from the original data of work previously published (McHugh and Diamant, 1987). None of the volunteers had anorectal complains, postanorectal surgery, previous fecal incontinence. None were taking medications that are known to affect anorectal function. The volunteers had between 0 and 11 childbirths with an average parity rate of 1.5. These control data were also used to determine the manometry index for controls.

Pressures in the anal canal were recorded on a Grass polygraph by a stationary technique (Buser and Miner, Jr. 1986). The chart recorder was calibrated so that a full pen deflection equalled 100 mm Hg. For measurements greater than 100 mm Hg the sensitivity of the preamplifiers was adjusted. The probe consisted of six low compliance water perfused catheters with distal side openings arranged longitudinally 1 cm apart, and connected to a Mui Scientific perfusion system. A balloon was secured to the probe 7 cm from the first recording site.

Each patient was interviewed and the chart reviewed to obtain a medical and symptom history. The patient was made comfortable in the left lateral position in a hospital bed in the motility lab. The probe was lubricated and gently positioned so that the balloon and at least one recording site were placed in the rectum. The patient was given a few minutes to relax. A baseline recording was made and then the patient was asked to tighten the anus as though trying to prevent a bowel movement. This manoeuvre was repeated three times.

The anorectal reflex was stimulated by inflating the balloon with a syringe of air. The patient was instructed to report the first sensation of something in the rectum, the feeling of urgency, and any discomfort. The balloon was quickly inflated and remained inflated for 60 seconds and then deflated for sixty seconds with each increment in volume. Inflations started with 10 cc and increased by ten cc increments to 50 cc. From 50 cc the inflations increased by 25 cc increments until maximum tolerable volume was reported by the patient (Read et al., 1986b). The transducers were open to air when the pen baseline position was set. At the end of each study the catheter was held in position at the level of the anus to make a reference record. The chart recorder ran continuously through out the study.

Manometry variables include maximum basal resting pressure, maximum squeeze pressure, balloon volume to first perception, sphincter relaxation of 10 mm Hg, feeling of urgency and maximum tolerable volume. Measurements made of resting pressure and squeeze pressure from the chart record were referenced to air (the final catheter position at the level of the anus). Balloon volumes were measured using a 60 cc syringe used to inflate the balloon. The variables measured were: resting pressure, squeeze pressure and balloon volume to first perception, urgency, and discomfort. Squeeze pressure is the increase in pressure above resting pressure with voluntary contraction of the external anal sphincter. Total squeeze pressure is measurement from reference to maximum pressure which includes the resting pressure. This is an important distinction as many studies report only total squeeze pressure which is inflated because it also contains the resting pressure.

The patients in the defecography studies are a subset of the patients in the manometry study. The patients' history data are described in Table II. These patients had both manometry and defecography assessments at McMaster Hospital. The medical history of the defecography patients is described in Table II. Twenty-one incontinent and twenty five constipated patients were evaluated. The control data were obtained from the twenty-two healthy young female subjects reported in the Shorvon et al. (1989a) study.

The defecography technique used in these studies is outlined by Shorvon and Stevenson (1989b). All measurements were made by one radiologist to reduce observer measurement error. The spot films were taken at rest, during voluntary contraction of the sphincter and lift of the pelvic floor muscles and straining without defecating. Defecography parameters included the posterior anorectal angle and the anorectal junction level measured from the ischial tuberosities. The anorectal angle was measured from the posterior rectal wall and the axis of the anal canal. The lift and strain angle and junction level were also evaluated by comparison to resting levels between and within the study groups. Rectocele, intussusception and enterocele during defecation were graded using the method described in the Shorvon et al. (1989a) study.

STATISTICAL METHODS

Univariate Analysis

Univariate analysis is the most common type of statistial analysis used in studies of manometry and defecography. The selection of the variables is based on the investigators criteria of importance. Analysis of variance was chosen to compare group means. A significant F statistics indicates that the group means are different. If there are more than two groups, it does not reveal where the differences are. Calculating t-tests for all possible pairs of means runs the risk that some of the tests will be significant when they are not. Multiple comparison tests determine which population means are different from each other and set more stringent criteria than t-test to protect against calling too many differences significant. Oneway analysis of variance with the range test Student-Newman-Keuls (SNK) was used to examine where the group differences occurred. Student-Newman-Keuls is a multiple comparison test that reports significance at the $p<0.05$ level. Factorial analysis of variance was used to deal with multiple factors which affected the group means and any interactions between the factors.

Multivariate Analysis

The patients' symptoms in this study range from complete lack of control over bowel movements to the inability to initiate bowel movements. In order to assess the patients' dysfunction a number of variables which reflect muscle function and cognitive awareness are measured. These measures, individually, can only describe one specific aspect of a complex function. What we need to know is: Are constipated and incontinent patient groups truly different from each other and from controls, and if so, how different and why are they different? The answers to these questions are important because they have the potential to help us understand the underlying mechanisms of anorectal dysfunction. Several studies have implicated various aspects of function as critical factors. Sensory awareness (Rogers et al., 1988), timing of the anorectal reflex (Buser and Miner, Jr. 1986), resting pressure (Harris et al., 1966), squeeze pressure (Katz et al., 1967), anorectal junction levels (Bartolo et al., 1983a) and angles (Skomorowska et al., 1987) have all been suggested as variables which explain the difference between constipation, continence and incontinence. Other studies show almost complete overlap between the controls, the constipated and the incontinent patients on many of the variables (Felt-Bersma et al., 1990; Read et al., 1984; Bartolo et al., 1983b; Womack et al., 1986).

Pelvic floor and anorectum muscles work together in a coordinated way to maintain continence. What is measured during assessments are parts of that complex physiology. What is needed is a way to look at the variables in combination to see which are important in explaining the difference between continence and incontinence. The variables which differentiate between the groups are likely the ones which will reflect the pathophysiology of the disorder. The ideal statistical method to examine this problem is discriminant function analysis.

Discriminant function analysis is a statistical method which analyses the variables by weighting and combining them and making predictions based on the combination. Instead of using **group membership** to look at differences in the variables as in analyis of variance, discriminant function analysis uses the **variables** to *predict* group membership. These predictor variables in this thesis are the measurements taken from the manometry and defecography assessments. The importance of the predictor variables in the function can be used to understand the contribution they make to the physiological differences between the groups (Tabachnick et al., 1989).

The mathematical objective of discriminant function analysis is to weight and combine the variables so that the groups are forced to be as statistically separate as possible. Analysis of the discriminant function reveals on which variables the groups differ, which variables contribute the most to the discriminating function and uses the function to classify the groups (Norman et al., 1986). Discriminant function analysis is a statistical procedure that creates an equation (or function) by examining all the variables and determining on which ones the groups differ. This is done by statistically forming a single dimension or linear combination of the variables so that the groups are forced to be as distinct as possible.

The variables in the function are weighted and combined for each subject. Each subject's combined score is the subject's discriminate score. The equation is formed like this:

Discriminant score = (importance of the variable's ability to separate the groups (weight)) (the standardized score of the variable) + (weight) (standardized score of the next variable) +

... and so on until all the variables have been considered.

Because the variables are standardized, the function overall will have a mean of zero and a standard deviation of one. The mean of the discriminant scores for each group is called the group centroid. The further the centroids are apart and the less overlap in the discriminant scores for the groups, the better the separation of the groups along the dimension.

Only variables which explain the most of the variance between the groups are used. Variables left out of the function may be significant in univariate analysis, but do not add to the function's ability to explain more of the variance between the groups and are not used in the equation. This may seem illogical, but the purpose of the analysis is to explain the greatest amount of variance in the function by the groups. If a variable does not add any more to the already explained variance, it is not used.

The experimenter has the option of choosing how the variables are entered into the equation. The stepwise procedure selects only the most useful variables and examines the variables one at a time. The first variable chosen is the one that explains the most of the variance (has the most ability to discriminate between the two groups). The second variable is chosen from the remaining ones because it is the variable that most improves the discrimination ability of the equation. The most efficient variables have been selected, when either no variables remain or the ones that do, do not explain any more of the variance between the groups.

How good is the group separation or discriminant function? The Wilk's lambda statistic is used to determine if the equation accounts for a significant amount of the variance between the groups (Tatsuoka, 1970). The larger the lambda the less discriminating power the function has. The Chi square test is used to show how reliable the relationship is between the groups and the predictor variables (Tabachnick et al., 1989). The canonical correlation squared gives the proportion of the variance explained by the groups. The weighting coefficients identify the variables which contribute most to the differentiation along the function.

Each subject has one discriminant score which represents the combination of all the variables entered into the analysis. This score indicates exactly how close or how far the subject is from the function mean. The classification procedure creates a function for each group and this function is used to calculate a probability score of how close the individual subject is to membership in each of the groups. The subjects can then be classified using the discriminant scores and a Chi-square can be done to show whether the classification is better than chance (Tabachnick et al., 1989). The rule dividing the probability classification is strict; a .51 probability places a subject in the correct group, .49 probability does not and the subject is misclassified. Some subjects can therefore be considered marginal based on their probability scores.

Of course subjects tested on a function which is based on the subjects' own variables is more likely to be significant. In order to compensate for this the data have to be cross-validated. This can be done by randomly selecting part of the subject population and withholding them. The function is then formed on the remaining subjects and then the withheld subjects are tested on the function. Another method of validation is called the jackknife procedure. During jackknife each subject's data are left out of the equation when that subject is classified. This gives a less biased estimate of the predictive ability of the function.

We used the computer program from SPSS Inc. to analyze the data. The Discriminant function program using stepwise variable entry to examine each variable's discriminating power and Wilk's Lambda (SPSS 1986) which uses the overall multivariate F ratio to test the differences between the groups' centroids were chosen because together they produce the largest multivariate F (Tabachnick et al., 1989). We used the computer program from BMDP Statistical Software Inc. to jackknife the data (BMDP 1990).

Five studies were designed to evaluate the relationship between the symptoms of constipation and incontinence and defecography and manometry assessments. The first examines manometry assessment and the patients age and parity and explores ways of presenting the data. The second study uses discriminant function analysis to evaluate the sensitivity and specificity of manometry assessments. The third study is an evaluation of the sensitivity and specificity of defecography and presents a method of reporting assessments. The fourth study combines the defecography and manometry variables to examine if the assessments are complementary. The fifth and last study is an exploration of the relationship of rectal wall morphology and the defecography and manometry variables.

TABLE I

PATIENT HISTORY MANOMETRY STUDIES

	INCONTINENT	CONSTIPATION
N	72	50
AGE	55.9 (±14.5)	45.3 (±16.9)
PARITY	2.6 (±1.5)	1.6 (±1.5)
ANORECTAL SURGERY	19	3
haemorrhoids	5	2
prolapse	5	0
fistula	3	0
sphincter repair	4	1
pelvic floor repair	2	0
BLADDER REPAIR/DYSFUNCTION	34	19
HYSTERECTOMY	34	16
IRRITABLE BOWEL SYNDROME	13	6
DIAGNOSIS OF PROLAPSE	9	3
HISTORY OF PAIN	23	34
MULTIPLE SCLEROSIS	2	3
POLIO	1	0
STROKE	2	0
DIABETES	3	0
CEREBRAL PALSY	0	1

TABLE II

PATIENT HISTORY DEFECOGRAPHY STUDIES

	INCONTINENT	CONSTIPATION
N	21	25
AGE	54.3 (±16.6)	50.1 (±15.7)
PARITY	2.3 (±1.3)	2.2 (±1.5)
ANORECTAL SURGERY	4	1
haemorrhoids	2	1
fistula	1	0
sphincter repair	1	0
BLADDER REPAIR/DYSFUNCTION	9	10
HYSTERECTOMY	8	9
IRRITABLE BOWEL SYNDROME	3	3
DIAGNOSIS OF PROLAPSE	1	1
HISTORY OF PAIN	6	15
MULTIPLE SCLEROSIS	0	1
STROKE	1	0
CEREBRAL PALSY	0	1

CHAPTER FOUR

MANOMETRY ASSESSMENT OF ANORECTAL FUNCTION

ABSTRACT

One hundred and twenty-two consecutive female patients were assessed with anorectal manometry. Seventy-two patients were incontinent and 50 were constipated and the manometry results were compared to 86 healthy female controls.

The significantly, important differences between the patient groups and controls were reflected in resting pressure, squeeze pressure and total squeeze pressure (all $p<0.0001$).

We designed a method of reporting that makes these relationships easier to interpret. In addition, a four category index of high and low resting and squeeze pressures was developed to describe the patients and controls. The distribution of patients and controls within the index was significantly different ($p<0.0001$). Ninety-two percent of the incontinent patients had low squeeze pressures. Ninety-three percent of controls and eighty percent of constipated patients had high resting pressures. Older patients were described by the low resting pressure categories ($p<0.0006$) and patients with high parity rates were described by the low squeeze pressure categories ($p<0.0002$). Fifty-one percent of controls, forty-eight percent of the constipation patients and forty-two percent of the incontinent patients were in the high resting, low squeeze category.

The manometry index describes if the patient has problems with the internal anal sphincter (resting tone), the external anal sphincter (squeeze pressure), both or none. It can be used to make management decisions for the treatment of constipation or incontinence. The index can be used to identify patients at risk for incontinence as well as patients who may be amenable to treatment or need further assessment for surgery.

Constipation and incontinence are symptoms which cannot be seen as disorders with

unique functional impairments. The manometry assessments of both constipated and inconstipated patients as a group reflect a continuum from normal to severely impaired as a result of a combination of sensory and muscle and nerve dysfunction.

INTRODUCTION

Patients with anorectal dysfunction present with challenging problems that have diverse etiology. They have a wide variety of symptoms, ranging from complete incontinence of stool to severe constipation. These symptoms not only have a negative psychosocial impact on the patients, but also carry high health care costs. One of the problems in understanding the mechanism underlying the symptoms is the wide range and overlapping values found on manometry assessment of anorectal function of patients and controls. Another problem is that the focus of many research studies has been to find on one mechanism to explain incontinence and another mechanism to explain constipation. The relationships between patient symptoms, severity of dysfunction and data from objective assessments of function are complex and there are a variety of factors influencing each part of the relationship. Age, diet and neurological disease are factors known to affect bowel movement frequency and consequently, the majority of patients cannot be classified easily. As a result of the complexity of the problem, many of the treatments for constipation and incontinence, such as medication or surgery, have not been shown to improve the patient's outcome in the long term.

Manometry assessment is used to evaluate the function of the voluntary and involuntary components of the internal and external anal sphincter tone, the integrity of reflex inhibition to rectal distention and the patient's cognitive awareness of rectal sensation. At rest in healthy individuals, the anal canal has a tone of 60-100 mm Hg (Schuster, 1968; Kerremans, 1969; Ihre, 1974; Taylor et al., 1984). When the rectum is distended by a 50 ml balloon the internal anal sphincter relaxes briefly and the external anal sphincter increases in tone. Consequent to rectal distention induced by a 150 ml balloon, the internal anal sphincter is inhibited and the external anal sphincter contracts. Maximum distention of the rectum causes complete relaxation of the internal and external anal sphincters which recovers slowly. The external anal sphincter is under tonic contraction and contributes 10 to 50% to the resting tone of the internal anal sphincter (Duthie and Watts, 1965; Lestar et al., 1989; Frenckner and Euler, 1975). The external anal sphincter can be voluntarily contracted to increase the pressure within the anal canal. The internal anal sphincter is also tonically contracted and relaxes with rectal distension. Duthie (1982) describes the various components and their relationship to normal functioning. Maintenance of continence and defecation involves the coordination of these muscles as well as sensory awareness of rectal filling. The musculature of the anorectum and its innervation is complex and trauma or neural damage to any part will affect function.

There are two important factors to consider when examining the literature on anorectal manometry. One, there are large variations and overlaps in the manometric measurements of incontinent and constipated patients and controls, and two, there is no correlation between the severity of symptoms and manometric assessment (Delechenaut et al., 1992; Elliot et al., 1987). However, in general, patients with anorectal dysfunction have manometric results which are different from the normal population. In patients with constipation there may be a decreased sphincter response to balloon distention (Read et al., 1986b; Waldron et al., 1988) and impaired sensation in the rectum (Buser and Miner, Jr. 1986; Read et al., 1986b; Shouler and Keighley, 1986). Faecal incontinent patients may have reduced rectal compliance (Whitehead and Schuster, 1987), low anal canal resting pressures (Read et al., 1983b; Schiller, 1986) and weak external anal sphincter voluntary squeeze pressures (Rogers et al., 1988).

Studies of patient groups reported in the literature present conflicting data. Several confounders lead to these mixed results. First, there is no accepted standardized method of performing anal sphincter manometry (Coller, 1987). Second, several studies report significant differences in the manometry results with gender and/or age (McHugh and Diamant, 1987; Read et al., 1979; Felt-Bersma et al., 1989; Loening-Baucke and Anuras, 1985); many manometry studies do not take these age and gender differences into account when forming their study groups. Third, many studies include a variety of disorders in the patient groups as well as the controls. Combinations of pelvic floor neural or muscle dysfunction interacting with other factors such as central nervous system disorders will result in markedly different symptoms. Diet is also of crucial importance, for example a patient with weak sphincters will be constipated or incontinent depending on stool consistency.

Manometry assessment for patients with anorectal dysfunction has been seen by clinicians as unsatisfactory because the results usually, fail to help the physician to make a prognosis on the patient's outcome (Elliot et al., 1987). The objective of this study was to examine the *relationships* between some of the manometry variables and patient history and to develop a method to characterize the patients in a clinically useful way. We will show that anorectal dysfunction is a continuum and that patients with constipation may be at risk for future incontinence.

METHODS

The subjects were 122 consecutive female patients who were referred to the motility clinic for anorectal manometry assessment of constipation or incontinence. Exclusion criteria were males, less than 16 years of age, colostomy or ileostomy, ulcerative colitis and Crohn's disease.

Patient history included age, number of children, duration of symptoms, type of symptoms, history of surgeries, bladder control, medications and the presence of other medical disorders. Normal values from 86 healthy female controls aged 20 to 89 were obtained from the original data of work previously published (McHugh and Diamant, 1987). These control data were also used to determine the manometry index for controls. Subjects are described in detail in Chapter III.

The manometry variables measured were: resting pressure, squeeze pressure and balloon volume to first perception, urgency, and discomfort. Squeeze pressure is the increase in pressure above resting pressure with voluntary contraction of the external anal sphincter.

Total squeeze pressure is measurement from reference to maximum pressure which includes the resting pressure. Details of manometry assessment measurements are in Chapter III.

Statistical analyses were done using the SPSS Inc. (1986), to describe the manometry variables. Comparisons were made between patient groups and controls for the manometry variables resting and voluntary squeeze pressure. Within each patient group the manometry variables were analyzed to examine the effects of symptom severity. The constipated patients were divided into two groups based on reported symptoms: one or more bowel movements a week, and bowel movements less than once a week (without the use of laxatives or enemas) and a history of faecal impaction. The incontinent patients were divided into two groups: patients with frequent soiling, and patients having involuntary losses of large amounts of stool. The patient groups were reclassified according to age and parity to examine the effects of these variables. The data were examined comparing the controls to the patient groups, and the patient groups to each other.

RESULTS

Patients Compared to Controls

The manometric data are summarized in table I. The resting and squeeze pressures are important variables because there are significant differences between the patient groups and controls for these measures, and the measures are objective. To understand the values of squeeze pressure in the context of function it is important to relate them to resting values when comparing healthy persons with patients. We designed a method of reporting which makes this relationship easy to assess, see figure I.

The most important observations were: (a) There were significant differences between the constipated patients, the incontinent patients and controls for resting pressure, squeeze pressure and total squeeze pressure; b) The mean pressure generated by voluntary contraction of the sphincters in the incontinent patients was less than the resting pressure of the control group.

The controls and patients were divided into groups by age: under fifty years and over fifty years of age. Age was a significant factor in reduced resting and squeeze pressure in the control group (McHugh and Diamant, 1987), but not in the constipated patients. Resting pressure was significantly lower in incontinent patients over age fifty ($p<0.04$).

Comparison of Patient Groups

The constipated patients had significantly higher pressures than the incontinent for all three measures, (all $p<0.0001$).

The anorectal reflex and perception of rectal stimulation were tested with inflation of the rectal balloon with measured volumes. The patient groups did not differ in volumes necessary to cause sphincter relaxation of 10 mm Hg, sustained relaxation, or the volume to first perception (table II). Significantly lower balloon volumes were needed to elicit sensations of urgency and discomfort in the incontinent group ($p<0.0001$).

When the incontinent and constipated patients were reclassified by symptoms there were no significant differences in the manometry, age or parity variables.

Age and Parity

The mean age of the patient groups was significantly different ($p<0.0001$) 45.3 ±16.9, for the constipated group (N=50), and 55.9 ±14.5 for the incontinent group (N=72). The mean parity was 1.6 ±1.5 for the constipated group and 2.6 ±1.5 for the incontinent ($p<0.0004$).

In order to examine the effects of age and parity on the manometry variables, the patient groups were combined and analyses of variance with age and parity were performed. The patients were grouped as over or under 50 years of age and with zero to one child or two or more children. Age ($p<0.01$) and parity ($p<0.05$) were significant factors affecting resting pressure. Age was not a significant factor, but parity significantly contributed to decreased squeeze pressure ($p<0.002$) and total squeeze pressure ($p<0.001$).

Index of Resting and Squeeze Pressures

The manometry assessment gives two important measures: 1) resting pressure, which is a combination of internal and external sphincter tone and 2) squeeze pressure, which is a measure of external sphincter function. A method to utilize these measurements to categorize the patients was developed similar in concept to the study done by Hiltunen (1985) with incontinent patients. To code the resting and squeeze pressures, an index of anorectal function was given to each patient: high and low scores were assigned on the basis of resting pressure greater or less than 40 mm Hg and squeeze pressure of more or less than 60 mm Hg. This index has four categories which describe the combination of resting and squeeze pressure: 1) low resting, low squeeze pressures, 2) high resting, low squeeze pressures, 3) low resting, high squeeze pressures, and 4) high resting, high squeeze pressures. The fourth category describes resting and squeeze pressure as reported in the literature for healthy controls (Read et al., 1986b; Hiltunen, 1985; Bannister et al., 1989; Penninickx et al., 1992). The distribution of the controls and patients in the index was significantly different, ($p<0.0001$; table II).

Ninety-three percent of the normal controls were classified into the high resting pressure sectors. The distribution for normal controls was: 51 percent in the low squeeze high resting pressure sector, and 42 percent in the high resting high squeeze pressure sector (table III). Table IV shows the distribution of the constipation patients in the index. Eighty percent of constipated patients were characterized by high resting pressure with 32 percent in the high and 48 percent in the low squeeze pressure sectors. Ninety-two percent of the incontinent patients were characterized by low squeeze pressure and these patients were equally distributed between high and low resting pressure categories (table V).

To further characterize the patients in the index categories, a oneway ANOVA with a range test was used to examine the anorectal reflex and rectal sensitivity variables, age and parity of the patients comparing each of the categories in the index. The results are presented in Table VI. Patients in the low resting pressure categories were significantly older than the patients in the high resting high squeeze pressure category. Patients in the low resting low squeeze pressure category had significantly higher parity rates than patients in the high squeeze pressure categories. Patients in the low resting low squeeze pressure category also had significantly lower volumes to discomfort than those in the high resting high squeeze pressure category.

Parity is a significant factor for squeeze pressure and this is reflected in the distribution of the patients with fewer children in the high squeeze pressure categories ($p<0.0002$). Age is a factor in resting pressure and the patients in the low resting pressure categories were significantly older than those in the high resting pressure categories ($p<0.0006$).

The patients in the high resting low squeeze pressure category are especially interesting because about half are incontinent and half constipated. Further descriptive analyses were done for this category to examine the variables for group differences. Oneway analysis of variance was used to analyze the data and table VII presents the results. Within the high resting low squeeze pressure category the incontinent patients had significantly lower squeeze pressures, volumes to urgency and discomfort and a higher parity rate than the constipated patients (all $p<0.05$). There was no significant difference in age of the patient groups in this category.

DISCUSSION

The manometry index.

This study presents two methods of using the anorectal manometry assessment to characterize patients and gain greater insight into understanding each patient's problem. The first method demonstrates anorectal muscle function of patients by illustrating the mean resting and squeeze pressures on a graph, so that the amount of pressure generated by the internal anal sphincter (resting pressure) and the external anal sphincter (squeeze pressure) can be compared to healthy controls. The manometry assessment can be reported by comparing the patient's assessment values to the mean of healthy controls, with the differences described in standard deviations from the mean values of the young and older healthy controls. This method of reporting manometry results may clarify the patient's specific area of muscle impairment as well as indicating risk and management strategies. (see Appendix 1)

The second method provides an anorectal function index which places patients into categories of high and low resting and high and low squeeze pressures based on their manometry assessments. In this index patients show four different combinations of sphincter muscle function, 1) weak internal and external sphincters, 2) weak internal and normal external sphincters, 3) normal internal and weak external sphincters and 4) normal internal and external sphincters. By combining the variables of resting pressure and squeeze pressure, the index enables the physician to categorize the patient in a context that clarifies the specific dysfunction and allows comparison to patients with similar dysfunctions. This type of comparison is not possible with an examination of only separate averaged manometry values for groups of incontinent and constipated patients. From the data presented in this study we conclude that the most important factor in maintaining continence is the strength of the external anal sphincter. The second factor is the tone of the internal anal sphincter. All the patients with a resting pressure of less than 40 mm Hg and a squeeze pressure of less the 20 mm Hg were incontinent. None of the constipated patients or controls had values this low. Eighty-five percent of the incontinent patients were characterized by low squeeze pressures and forty-nine percent had a squeeze pressure of less than 20 mm Hg. There was no relationship between symptom severity and the manometry index categories for the incontinent patients in this study.

Hiltunen (1985) examined 25 incontinent patients and used a manometry index to show that patients with gross incontinence were in the low resting low squeeze category and patients with incontinence to flatus and watery stools were in the high resting low squeeze pressure category. The distribution of the age and sex matched controls within the index was not discussed. The cut off point for high and low resting pressure was similar to this study, but the cut off point for squeeze pressure was about 25 mm Hg compared to 60 mm Hg in this study.

Eighty percent of the constipated patients were characterized by high resting pressures and of these forty percent had high squeeze pressures. Eighteen percent of the constipated patients had squeeze pressures of less than 20 mm Hg, but none of these had resting pressures below 40 mm Hg. These patients may be at risk for incontinence when factors such as aging come into effect. Twelve percent had squeeze pressures between 20 and 40 mm Hg and resting pressure less than 40 mm Hg. These are the patients that are potentially at greatest risk for future incontinence.

Ninety-three percent of the controls were characterized by high resting pressures and of these 45% had high squeeze pressures. Only two percent of the controls had low resting and low squeeze pressures.

The use the index in the reporting of manometry assessments will facilitate physicians' understanding of individual patient's anorectal muscle function. By comparing each new patient to other patients and healthy controls, more rational decisions can be made for the appropriate tests, referral path or management. The manometry index is a useful tool in describing whether the patient has problems with the internal anal sphincter (resting tone), the external anal sphincter (squeeze pressure), both or none.

Internal Anal Sphincter

Age over 50 years is associated with lower resting pressures in both patient groups in this study, similar to the findings of McHugh and Diamant (1987) and Felt-Bersma et al. (1989). Increased parity was also associated with lower resting pressures in this study. Cali et al. (1992), found resting pressures significantly lower in multiparous compared to nulliparous healthy women; however, the multiparous women were also significantly older and this confound their results. Felt-Bersma et al. (1989), found lower resting pressures with age in controls, but parity was not examined. The main effect of parity is on the external anal sphincter, but because resting pressure is a combination of the tone of both the internal and external anal sphincters there is some association between parity and resting pressure.

Damage to the internal anal sphincter can be caused by trauma, psychotropic drugs and the chronic use of anthraquinone laxatives, a culturally important influence in the early 1900's (Preston and Lennard-Jones, 1985; Brocklehurst, 1985).

External Anal Sphincter

Higher rates of parity in this study are associated with lower squeeze pressures. Pudendal nerve impairment and/or external anal sphincter muscle trauma due to difficult childbirth are reflected in the patients with low squeeze pressure who had more children than patients in the high squeeze categories. Prolonged and difficult vaginal delivery causes pudendal nerve damage particularly in multiparous patients (Snooks et al., 1984). Taylor et al. (1984), discusses the idea that the majority of damage resulting from childbirth is to the puborectalis muscle and would not be reflected in resting pressures. The significantly lower squeeze pressures with two or more deliveries found in this study confirms that components of the external sphicter are affected by childbirth. The additional stress of childbirth may contribute to the further weakening of an already compromised musculature in patients with constipation and incontinence. Snooks et al. (1984), show that pudendal nerve injury measured soon after vaginal delivery recovers in 60% of the women, two months later. Parity is not a variable which affects squeeze pressure in healthy controls (McHugh and Diamant, 1987).

Weakening of the external anal sphincter through damage to the pudendal nerves which innervate the external anal sphincter can occur in a number of ways. The most important factor is excessive and prolonged straining at stool which stretches the distal part of the pudendal nerves (Henry et al., 1982; Kiff et al., 1984; Whitehead and Schuster, 1987). Percy et al. (1981), and Snooks et al. (1985a), also found evidence that the pelvic branches of the third and fourth sacral motor roots, which innervate the puborectalis muscles, are damaged in patients who have a history of excessive straining at stool. Thirty percent of the incontinent patients in this study had a history of constipation. Patients, particularly women whose muscles are thinner than those of men, should be cautioned against excessive straining at stool.

Age as a factor

There are few studies reporting changes in smooth muscle of humans with ageing.

Morphological and histological studies of the esophagus (Meciano Filho et al., 1995), small intestine (de Souza et al., 1993) and colon (Koch et al., 1991) show age related nerve cell loss in the myenteric plexus. de Sousa also found an increase in collagen with ageing and Filho found increases in nerve size associated with ageing. How these changes affect muscle function is not known. These and other areas such as age related changes in intercellular Ca^{2+} movement or changes in neurotransmitters need more study (Szurszewski et al., 1989).

Age was not a significant factor effecting squeeze pressure in either the incontinent or constipated patient groups. The amount of impairment to the external anal sphincter muscles in these patients may have overshadowed the effects of ageing. In this study the young patients were functioning below the levels of the older healthy controls. However, ageing is a significant factor in low squeeze pressures in healthy controls (McHugh and Diamant, 1987). Garavoglia et al. (1992) found hypertrophy of both the levator ani and the external anal sphincter muscles in patients over 65 years old. The reduction in estrogen after hysterectomy has been examined by Roe (1988) as a contributing factor to decreased sphincter muscle strength, but no association has been found. Muscle strength in general is reduced in women after the age of 50 which Seely et al. (1995), found to be independent of the levels of estrogen.

The Continuum

Several authors suggest that there is a continuum of dysfunction represented in patients with constipation and incontinence (Lubowski and Nicholls, 1988; Skomorowska et al., 1987; Bartolo et al., 1988a), but studies have not been done to examine this hypothesis in a way which would give predictive ability to the anorectal assessments.

The present study supports of the continuum theory as a pattern of increasing impairment from health to incontinence for anal pressures and for rectal function (figure 1). For all the variables, the mean values for the constipated patients fall between the mean values of the controls and the incontinent patients. We found significant differences between the control group, the constipated and incontinent patients for resting and squeeze pressure.

The incontinent patients had lower resting and squeeze pressures compared to the control and constipated groups, indicating that internal and external muscle weakness are major contributors to the symptoms of incontinence, similar to the conclusion of Read et al. (1979). We also found significant differences between the control and constipated groups related to weakened muscles, but not to the extent of the incontinent group.

Unlike Allen et al. (1988), we found a higher threshold for the perception of rectal sensation for both patient groups. Both patient groups have higher thresholds to perception and reflex relaxation and lower thresholds to urgency and discomfort than those reported in the literature for normal controls. The constipated patients had significantly higher thresholds for discomfort than the incontinent patients. These changes in the inhibitory reflex and the sensitivity thresholds are indicators that there is some impairment in the afferent fibres in the rectum in both patient groups, but more in the incontinent patients. The incontinent patients may have a different cognive awareness of rectal sensation than the constipated. These patients learn not to ignore rectal sensations through fear of involuntary stool loss.

Other support for the continuum theory is shown by the distribution of the patients within the index. Within each category the incontinent patients had values reflecting more dysfunction than the constipated patients. The incontinent patients were significantly older, had higher parity rates and often a history of constipation. Regardless of the patient's symptoms, the older the patient the lower the resting pressure and the higher the patient's parity rate the lower the squeeze pressure. One can predict that without management to prevent further muscle weakness, as the constipated patients continue straining at stool, age and have more children they will continue to weaken the sphincters and may be at risk for future incontinence.

Symptom severity was not reflected in significant differences in the values of the manometry variables. This is similar to finding of others (Infantino et al., 1995; Delechenaut et al., 1992; Read et al., 1979).

There is a gradual change from health to incontinence for many patients with anorectal dysfunction. Increasing age contributes to lower resting tone and increased parity contributes to lower squeeze pressures. Constipation and incontinence are not unrelated disorders but symptoms which reflect pelvic and anorectal muscle impairment of varying degrees. More attention needs to be paid to the prevention of pelvic and anorectal muscle damage in all women, especially through the management of constipation and childbirth. Damage to the pelvic floor innervation during difficult and prolonged labour and delivery is a risk, especially in multiparae (Snooks et al., 1986). Special care needs to be taken during labour and delivery to avoid the use of forceps, perineal tears and prolonged labour. In general, moderate dysfunction is exhibited by constipation and severe dysfunction is exhibited by incontinence.

Value for prediction and assessment

The patients in this study represent a continuum of dysfunction from health to incontinence and the index can be used to identify patients at risk for incontinence as well as patients who will be amenable to treatment. Taking into consideration age, history, symptoms and parity, the patient's position in the index can give insight into the effectiveness of treatments such as biofeedback, education or surgery.

TABLE I

MANOMETRY VARIABLES PATIENTS AND CONTROLS

	CONTROLS	CONSTIPATION	INCONTINENCE
n	86	50	72
Pressure (mm Hg)			
Rest	81.3 ± 27.7*	60.8 ± 26.9	41.3 ± 20.2
Squeeze	65.9 ± 44.8*	53.8 ± 35.1	34.2 ± 34.5
Total squeeze	147.1 ± 52.4*	114.9 ± 46.1	75.5 ± 38.3

Controls compared to each patient group. * $p<0.0001$

TABLE II

MANOMETRY VARIABLES

	CONSTIPATION	INCONTINENCE
n	50	72
Pressure (mm Hg)		
Rest	60.8 ± 26.9*	41.3 ± 20.2
Squeeze	53.8 ± 35.1*	34.2 ± 34.5
Total squeeze	114.9 ± 46.1*	75.5 ± 38.3
Volume (cc)		
Perception	29.8 ± 24.2	25.6 ± 30.8
Relaxation	20.6 ± 19.1	20.9 ± 14.2
Sustained relaxation	84.4 ± 60.7	59.1 ± 24.6
Urgency	126.5 ± 73.3*	78.5 ± 52.0
Maximum	171.6 ± 94.0*	117.7 ± 52.9
Age	45.3 ± 17.0**	55.9 ± 14.5
Parity	1.6 ± 1.5**	2.6 ± 1.5

Constipation compared to incontinence. * $p<0.0001$
** $p<0.0004$

TABLE III

PERCENT DISTRIBUTION OF CONTROLS IN MANOMETRY INDEX

		RESTING PRESSURE Low	RESTING PRESSURE High	Row Totals
SQUEEZE PRESSURE	Low	1	51	52
	High	6	42	48
Column Totals		7	93	

N = 86

RESTING PRESSURE Low >40 mm Hg
High <40 mm Hg

SQUEEZE PRESSURE Low >60 mm Hg
High <60 mm Hg

TABLE IV

PERCENT DISTRIBUTION OF CONSTIPATED PATIENTS IN MANOMETRY INDEX

		RESTING PRESSURE		
		Low	High	Row Totals
SQUEEZE PRESSURE	Low	12	48	60
	High	8	32	40
Column Totals		20	80	

N = 50

RESTING PRESSURE Low >40 mm Hg
High <40 mm Hg

SQUEEZE PRESSURE Low >60 mm Hg
High <60 mm Hg

TABLE V

PERCENT DISTRIBUTION OF INCONTINENT PATIENTS IN MANOMETRY INDEX

		RESTING PRESSURE Low	RESTING PRESSURE High	Row Totals
SQUEEZE PRESSURE	Low	43	42	85
	High	7	8	15
Column Totals		50	50	

N = 72

Distribution of controls, constipated and incontinent patients within the index, p<0.0001, Chi-square 56.2, degrees of freedom 6.

RESTING PRESSURE Low >40 mm Hg
High <40 mm Hg

SQUEEZE PRESSURE Low >60 mm Hg
High <60 mm Hg

TABLE VI

DESCRIPTION OF ALL PATIENTS BY INDEX CATEGORY

SQUEEZE PRESSURE	RESTING PRESSURE: Low		RESTING PRESSURE: High	
	PRESSURE *(mm Hg)*		**PRESSURE** *(mm Hg)*	
	Rest	26.9 ± 7.8	Rest[1,3]	59.3 ± 18.4
	Squeeze	26.3 ± 15.5	Squeeze	24.5 ± 15.0
	Total squeeze	53.2 ± 16.4	Total squeeze[1]	84.1 ± 23.3
	VOLUME (cc)		**VOLUME***(cc)*	
	Perception	33.4 ± 41.9	Perception	25.5 ± 22.8
Low	Relaxation	23.4 ± 16.1	Relaxation	17.3 ± 10.8
	Sustained relaxation	58.5 ± 22.9	Sustained relaxation	76.7 ± 53.5
	Urgency	91.3 ± 73.8	Urgency	90.8 ± 59.1
	Maximum	118.6 ± 58.3	Maximum	137.7 ± 81.1
	AGE [4]	55.7 ± 14.9	**AGE**	50.6 ± 14.3
	PARITY [3,4]	2.8 ± 1.2	**PARITY**	2.5 ± 1.5
	PRESSURE *(mm Hg)*		**PRESSURE** *(mm Hg)*	
	Rest[4]	19.1 ± 10.1	Rest[1,2,3]	69.0 ± 25.5
	Squeeze	91.1 ± 32.2	Squeeze[1,2]	90.0 ± 34.9
	Total squeeze[1,2]	110.0 ± 34.9	Total squeeze[1,2,3]	159.0 ± 42.1
	VOLUME *(cc)*		**VOLUME** *(cc)*	
	Perception	23.8 ± 11.9	Perception	24.0 ± 16.2
	Relaxation	26.0 ± 15.2	Relaxation	24.8 ± 25.8
High	Sustained relaxation	67.5 ± 39.5	Sustained relaxation	68.8 ± 46.8
	Urgency	107.1 ± 57.4	Urgency	121.2 ± 91.3
	Maximum	141.3 ± 40.6	Maximum	173.1 ± 94.6
	AGE [4]	63.9 ± 20.1	**AGE**	43.8 ± 18.2
	PARITY	0.6 ± 0.9	**PARITY**	1.3 ± 1.5

Superscripts indicate which categories are significantly different, $p<0.05$
Legend of superscripts for categories

[1] Low rest low squeeze
[2] High rest low squeeze
[3] Low rest high squeeze
[4] High rest high squeeze

TABLE VII

MANOMETRY VARIABLES FOR CATEGORY
HIGH RESTING-LOW SQUEEZE PRESSURE

	CONSTIPATION	INCONTINENCE
n	48	42
Pressure (mm Hg)		
Rest	63.0 ± 20.9	56.2 ± 15.8
Squeeze	28.8 ± 14.8	20.9 ± 14.5
Total squeeze	92.6 ± 23.5*	77.0 ± 21.1
Volume (cc)		
Perception	1.6 ± 30.7	20.3 ± 11.3
Relaxation	5.2 ± 7.1*	19.0 ± 13.0
Sustained relaxation	98.9 ± 70.8	57.6 ± 18.9
Urgency	25.3 ± 66.1**	66.3 ± 38.6
Maximum	165.2 ± 91.6*	114.0 ± 63.3
Age	47.8 ± 15.4	53.0 ± 13.0
Parity	2.0 ± 1.5	2.9 ± 1.5

Constipation compared to incontinence. * $p<0.05$
** $p<0.0003$

Figure 1

RESTING AND SQUEEZE PRESSURES

CONTROLS	*R——————————S*
CONSTIPATION	+R——————————S+
INCONTINENCE	R——————S
pressure mm Hg	30—40—50—60—70—80—90—100—110—//—150

Controls compared to each patient group * $p<0.0001$
Constipated patients compared to incontinent + $p<0.0001$

Legend R resting pressure
S squeeze pressure

CHAPTER FIVE

ABSTRACT

Discriminant function analysis with classification was used to test the sensitivity and specificity of manometry assessment and to examine the strengths and weaknesses of manometry in the evaluation of anorectal dysfunction. The subjects were 72 incontinent, 50 constipated female patients and 86 healthy female controls reported in the previous study.

Manometry assessment had a sensitivity of 79% and a specificity of 87% in correctly identifying incontinent patients and the controls ($p<0.0001$). For identifying the constipated patients and the controls the sensitivity was 32% and the specificity was 87% ($p<0.0001$). The discriminating variables were total squeeze pressure and resting pressure. Classification analysis was accurate 89% of the time for incontinent patients and 65% of the time for constipated patients ($p<0.0001$). The discriminating variables in classifying the patient groups in order of importance were total squeeze pressure, volume to urgency, parity, resting pressure and age. The discriminant scores indicate that the patients are on a continuum from health to incontinence. There was a significant correlation between the patients' discriminant function scores and the manometry index score (r.58 $p<0.0001$), showing a strong relationship between the two methods of analysis. Classification analysis, using the manometry variables age and parity, predicts that a third of the constipated patients are at risk for incontinence. They can be identified either by the manometry index or through discriminant function analysis. Patients misclassified by discriminant function analysis as controls may be most amenable to therapy. The strengths of manometry assessment are that it can identify specific impairment of the internal and external anal sphincter musculature as well as sensory deficits. A limitation of manometry assessment is the overlapping values in the variables of the controls and patient groups. Manometry assessment does not explain the degree of severity

of the patients' symptoms.

INTRODUCTION

In order for a diagnostic test to be valid it must be able to discriminate between patients and controls; however, there is no agreement in the literature about the ability of manometry to distinguish between patients with incontinence, or constipation. Clinicians find manometry assessment inadequate because the results seldom help the physician to make a prognosis (Elliot et al., 1987). The purpose of this study is to evaluate manometry assessment as a means of diagnosing anorectal dysfunction.

Several studies have examined the ability of manometry assessments to discriminate between different disorders. Harris et al. (1966) found complete discrimination with resting pressure and squeeze pressure between incontinent patients and controls. Bielefeldt et al. (1990) found a sensitivity of 80% for resting pressure and 67% for squeeze pressure in incontinent patients. Resting pressure correctly identified 80% of incontinent patients and missed 20%, and squeeze pressures identified 67% of the incontinent patients and missed 33%. Katz et al. (1988) found discrimination for squeeze pressure alone. Felt-Bersma et al. (1988) found no discrimination, but showed that squeeze pressure was the best predictor. Read et al. (1877; 1984), Rogers et al. (1988), and Bartolo et al. (1983b), did not find that manometry variables could discriminate between continent and incontinent patients. Felt-Bersma et al. (1989) used the statistical method of receiver operating characteristic (ROC) curves to evaluate the effectiveness of squeeze and resting pressure as diagnostic tests. Their results show that a squeeze pressure of less than 40 mm Hg as a cut point would pick up 80% of the incontinent patients, miss 20% and correctly identify 65% of the continent.

In the usual examination of test validity there is a single measure, on which to base predictions (Streiner et al., 1989). Manometry assessment gives several measures such as sphincter tone and strength, reflexes, and rectal sensitivity. Researchers have used several statistical methods to examine the ability of the manometry assessment to discriminate between different patient groups. The use of univariate statistics implies a separate analysis for each dependant variable, for example using analysis of variance or t-tests. The disadvantage of univariate statistics is that although there may be a significant relationship between the independent and dependent variables, the cause of the relationship is not clarified. Furthermore, multiple dependent variables on the same sample increases the risk of error in the results. The manometry variables are interrelated in a complex way and univariate analysis is not sensitive to complexity.

Multivariate statistics have two advantages, 1) they are designed to analyze several dependant variables without increasing the error rate, and 2) the analysis examines the variables in combination. Discriminant function analysis can determine significance of inter-group differences, show the contribution of individual variables to group discrimination, and with classification analysis give a prediction on group membership.

Bielefeldt et al. (1990), is the only study to report using cluster and discriminant analysis to compare male and female incontinent patients to young male controls. Their study shows resting pressure to have a sensitivity of 80% and a specificity of 84%. The other manometry variables did not significantly improve the discrimination.

The objectives of this study are to evaluate the usefulness of manometry assessment in offering clinicians specific information for the management of patients with constipation and incontinence and to test the hypothesis that patients with constipation and incontinence represent a continuum of the same dysfunction.

METHODS

The subjects were 122 consecutive female patients who were referred to the motility clinic for anorectal manometry and the controls were 86 healthy females reported in McHugh and Diamant (1987). The subjects, manometry assessment and the data collected are described in chapter III.

The patients were grouped into categories by symptom severity to examine if discriminant function analysis could differentiate between varying degrees of dysfunction. The constipated patients were grouped as 1) one or more bowel movements a week (n = 23) or

2) less than one bowel movement a week (n = 27). The incontinent patients were divided into two groups 1) daily soiling (n = 23) and 2) involuntary loss of large amounts of stool (n = 49).

Discriminant Function Analysis

Stepwise discriminant function analyses with jackknife were done using the computer program SPSS Inc. (1986) and BMDP Statistical Software Inc., (1990). Wilk's lambda and stepwise variable entry were chosen for discriminant analysis because they produce the largest multivariate F for showing if the function explains a significant amount of the variance between the groups (Tabachnick et al., 1989). The program uses the Chi-square statistic to test the reliability of the relationship between the groups and the predictor variables. The data were jackknifed to cross-validate the results (Tabachnick et al., 1989). Classification analysis was done to examine the probabilities of each subject's group membership.

Discriminant function analysis was used to find which combination of variables best described the differences between the groups or group separation. A discriminant score was calculated for each patient and these data were used to examine where the patient was positioned on a continuum between continence and incontinence. Classification probability scores were used to measure the amount of risk each patient had for misclassification.

RESULTS

Controls and Patient Groups

The variables resting, total squeeze pressure and squeeze pressure were used in a stepwise discriminant function analysis with classification to compare the patient and control groups.

The discriminant function analysis determined that the resting and squeeze pressure were the variables which contributed to the discrimination of the incontinent patients and the controls. The Chi-square statistic used to test the reliability of the relationship between the grouping and the predictor variables was significant with a Chi-square of 97.3, degrees of freedom: 2, $p<0.0001$. Eighty-seven percent of the controls and 79% of the incontinent were correctly classified by the discriminant function (table I). This gives manometry a sensitivity of 79% and specificity of 87% in correctly identifying the incontinent patients.

The discriminant function analysis was significant in separating the controls and the constipated patients, with a Chi-square of 18.9, degrees of freedom: 2, $p<0.0001$. The analysis determined that total squeeze pressure and resting pressure were the discriminating variables. The function correctly classified eighty-seven percent of the controls, but only thirty-two percent of the constipated patients. Sixty-eight percent of the constipated patients were misclassified as controls (table II). The classification analysis was fair for discriminating controls, but not sensitive in diagnosing constipation.

Constipated and Incontinent Patient Groups

Discriminant analysis was done with the manometry variables resting pressure, total squeeze pressure, squeeze pressure, balloon volumes for sensation and relaxation. A second analysis was done to include age and parity for the two patient groups.

The equation was made from the following variables in order of their contribution to the function: total squeeze pressure, volume to ugency and resting pressure. The function was significant with a Chi-square of 43.0, degrees of freedom: 3, $p<0.0001$. Eighty-seven percent of the incontinent and 54 percent of the constipated were correctly classified, for an overall accuracy of 74 percent. When age and parity were included, the equation was made from total squeeze pressure, volume to urgency, parity, resting pressure and age. The function was significant, with a Chi-square 57.7, degrees of freedom: 5, $p<0.0001$. Classification was correct for eighty-seven percent of the incontinent and sixty-eight percent of the constipated, for an overall accuracy of 80 percent (table III). Including age and parity variables in the analysis improved the classification of the constipated patients.

Characterization of Patients with Classification Analysis

Figure 1 shows the histogram of the patients' discriminant function scores. The area of group overlap shows the patients with values in the range between the two group centroids. In this range constipated patients who are closest to the group centroid of the incontinent patients are classified as incontinent. Incontinent patients whose values are closer to the constipation group centroid are classified as constipated.

The patients were recoded into new groups based on misclassification by discriminant function and classification analysis to examine which variables contributed to the misclassification. There were four new groups: incontinent correct classification, incontinent incorrect classification, constipated correct classification and constipated incorrect classification. A oneway analysis of variance on the discriminant scores was used to test the distribution of the new groups in the discriminant function. The discriminant scores of these new groups were significantly different ($p<0.0001$). Analyses of variance on the variables shows that the misclassified constipated patients were older and had lower volumes to urgency than the correctly classified constipated patients ($p<0.0001$). The misclassified incontinent patients had higher thresholds for maximum volume than the other incontinent patients ($p<0.0001$).

Manometry Index and Discriminant Function Scores

The four index categories (described in the previous chapter), were rated as: (1) low resting-low squeeze pressure, (2) high resting-low squeeze pressure, (3) low resting- high squeeze pressure and (4) high resting-high squeeze pressure. There was a significant correlation between the ratings of the index and the discriminant function scores of the patients, $r=0.58$, $p<0.0001$). Analysis of variance on the discriminant scores grouped by the manometry indices showed the scores to be significantly different, $p<0.0001$ (table IV). The a posteriori test Newman-Keuls shows that the discriminant scores for the low resting-low squeeze pressure (-0.88 ± 0.91) and the low resting-high squeeze pressure categories (-0.35 ± 1.40) were not significantly different from each other. These categories had significantly lower discriminant scores than the two high resting pressure categories ($p<0.05$). The high resting-high squeeze pressure category had significantly larger discriminant scores than all the other categories ($p<0.05$). The discriminant scores for the incontinent patients were lower than the constipated patients in all but the low resting-low squeeze pressure section of the index where the scores were the same (table V). Six of the twenty-four constipated patients in the high resting low squeeze pressure category were misclassified as incontinent (table VI).

For discriminant function analysis with the four severity categories symptom as the grouping factor, the first function was significant with a Chi square of 77.1, $p<.0001$. None of the other functions were significant. The variables in order of importance in the function were total squeeze pressure, age, volume to urgency, parity, squeeze pressure and resting pressure. Classification analysis correctly predicted group membership for 90% of the patients who had involuntary stool loss and 70% of the patients who had fewer than one bowel movement a week. Eighty-three percent of the patients in the soiling group and 43% of the constipated patients in the more than one bowel movement a week groups were misclassified into the involuntary stool loss group. Oneway analysis of variance with range test for the discriminate scores and symptom groups was significant ($p<.00001$). The constipated patients with bowel movements less than once a week had significantly higher discriminant scores than the other three symptom groups, ($p<.05$). Both constipation symptom groups had significantly higher discriminant scores than the two incontinent symptom groups ($p<.05$). The discriminant scores of the stool loss and soiling groups were not significantly different.

DISCUSSION

Discriminant function and classification analysis of the manometry variables shows the assessment to have a specificity of 83.3% and a sensitivity of 83.8% for incontinent patients, but only a sensitivity of 59.2% for constipated patients. Classification analysis shows that 68% of the constipated patients are similar to controls and 32% have manometry assessments which indicate anorectal dysfunction. The inclusion of the variables age and parity with the mamometry variables improved the functions ability to classify the constipated patients. This improved the accuracy of the classification analysis from 74 to 80 percent, and increased the sensitivity and specificity of the assessment. Using the manometry measures in combination with the patient's age and parity, discriminant function analysis can discriminate between patients with incontinence and constipation and can predict outcomes for these patients. This method of using the manometry data and patient history variables in discriminant function analysis shows where the patients are in relationship to one another and to the patient groups. The classification of the patients using the function equation gives a probability for membership in the incontinent and constipation groups for each patient. These probabilities may reflect the degree of risk for future incontinence or the likely success of treatment. It is our hypothesis that the patient's probability score derived from discriminant function analysis will have predictive value for prognosis and treatment outcome. Long term follow up can test this hypothesis.

In the analysis of the two patient groups, constipated patients who were correctly classified by the analysis are most similar to controls. Constipated patients with high probabilities for classification in the correct group who are young and have a history of impaction and hospitalization, should be assessed for slow gastrointestinal transit, and the others might benefit from dietary and bowel habit training and counselling. Incontinent patients with high probabilities for classification into the incontinent group have the most dysfunction. Assessment for rectal wall and external anal sphincter defects may indicate a need for surgical repair. Patients whose probability scores are around 0.50 are marginal and could change either in the direction of continence or incontinence. Some of the patients with marginal probabilities had diagnoses of irritable bowel syndrome with a alternating bowel habit and overflow incontinence and patients with loose stools. Regardless of the severity of their symptoms, these patients have assessments that are borderline between incontinence and constipation. Management aimed at controlling stool consistency may help to alleviate the symptoms in some of these patients. Women who have a history of difficult deliveries may be candidates for surgical repair of the sphincters and require further investigation.

Patients with a higher than 0.50 probability for the wrong patient group are misclassified. The misclassification of patients by discriminant function analysis may provide a basis for prognosis and treatment. The patients misclassified by the discriminant function with probabilities over 0.80 in this study had underlying pathologies such as multiple sclerosis, polio and stroke. Most of these patients were constipated, misclassified as incontinent. To avoid putting them at risk for losing control of their bowels, special care needs to be taken to prevent straining at stool which will further weaken the anorectal muscles. These constipated patients might be incontinent were it not for their constipation. Luboski et al. (1988), suggest that in patients with pelvic floor nerve damage "continence is maintained presumably because the stool is usually solid and hard". The discriminant function would be improved by excluding these patients, but their inclusion tells us that patients with severe muscle impairment can maintain continence, the question is how.

The Continuum

Discriminant function analysis uses the patient's variables to place the patient on a mathematically precise location on a linear dimension or continuum.

The variables used in the discriminant function determine the patient's position on the continuum. The weighted value of the specific variables cause individual patient's position to move back and forth along the continuum until all the variables contributing to group separation are in the function. The more important variables cause the greatest shift. High squeeze pressures, volume to urgency and resting pressures move the patient's score in the direction of continence and greater parity and age move the patient in the direction of incontinence.

The position of the constipated patients, incontinent patients and controls on this continuum indicates the degree of the patient's dysfunction, with the controls at one end and the incontinent patients at the other end of the continuum. This study supports the theory that there is a continuum of dysfunction between constipation and incontinence, and that it can be assessed by manometry. In this study, it is the constipated patients with bowel movements more than once a week who are closer to the incontinent end of the continuum, not the constipated patients with less than one bowel movement a week. About a third of the constipated patients are predicted to be at risk for incontinence.

The Manometry Index and Discriminant Function Scores

The comparison of the index of resting and squeeze pressures (described in the previous chapter) to the patients' discriminant function scores showed that the categories of the index followed the same pattern of dysfunction reflected in the patients' discriminant scores. The low resting-low squeeze category had the lowest discriminant score and the largest proportion of incontinent patients. And the high resting high squeeze category had the highest discriminant score.

Discriminant function analysis has an advantage in that it includes more patient data and makes predictions which can be tested. The index method which categorizes the patients on the basis of resting and squeeze pressures has advantages in that it is simple and reveals which muscle system is impaired. The two methods of classification complement each other and have specific and useful applications because they place the individual patient into a context whereby he/she can be compared to other patients and controls.

In summary, the usefulness of manometry assessment is not in the diagnosis of constipation or incontinence, the patients can describe their symptoms, but in giving physicians valid and reliable information on which to make treatment decisions. This study shows that most patients with constipation and incontinence reflect different degrees of the same underlying anorectal muscle and nerve pathology. Long term follow up studies of patients with anorectal dysfunction will determine if discriminant function and classification analysis of the results of the manometry assessment can make a prognosis for these patients.

The classification analysis shows that about a third of the constipated patients have sphincter pressures, age and parity rates similar to those of the incontinent patient group. Our hypothesis is that the probabilities for these patients indicate a risk for future incontinence. The incontinent patients have the most muscle and nerve damage as reflected in their manometry results, low discriminant scores and high classification rate into the incontinent group. The overlap in discriminant scores of some of the incontinent patients with the constipated patients indicates that some of these patients may be able to regain continence with treatment.

A large data base of manometry assessments and patient histories would be a useful resource for clinicians and researchers. Firstly, the building up of a data base which includes many patients would give researchers more information and help understanding of the complexity of anorectal dysfunction so that possible mechanisms can be explored. This type of data base would allow researchers to be more specific in selecting criteria for studies examining the efficacy of treatments. Secondly, new patients can be assessed using manometry and discriminant function analysis and a prognosis made based on the patient's assessment and history combined with the histories of previous patients. The data collected for the data base should be standardized and tested for reliability between sources. The method of collecting and measuring the manometry variables should be the same at the different contributing laboratories. Data from patient histories should be collected on the same information form at each centre and there should be agreement amongst the investigators about the meaning of any descriptive variables. The type of variables that are collected for the data base will be dependent on the research questions being asked.

FIGURE 1. HISTOGRAM OF DISCRIMINANT FUNCTION SCORES

```
Cases         INCONTINENCE
      16 +                                         +
         |                                         |
         |                                         |
         |                                         |
      12 +                                         +
         |                 1                       |
         |                 1                       |
         |                 1                       |
       8 +              1  1                       +
         |              1  1                       |
         |             111 11                      |
         |             1111111  1                  |
       4 +            11111111  1                  +
         |            11111111 11                  |
         |         11 11111111111     1            |
         |        111111111111111 1 111            |
         X----+----+----+----+----+----+----+----X
              CONSTIPATION
       8 +                                         +
         |                                         |
         |                                         |
         |                                         |
       6 +                         2               +
         |                         2               |
         |                         2               |
         |                         2               |
       4 +                     2 2 2               +
         |                     2 2 2               |
         |                   22222 222     2       |
         |                   22222 222     2       |
       2 +                   2222222222 22 2       +
         |                   2222222222 22 2       |
         |          2   222 2222222222222222 22   2|
         |          2   222 2222222222222222 22   2|
         X----+----+----+--*-+----*----+----+----X
            -3.0 -2.0 -1.0   .0  1.0  2.0  3.0
 Class    11111111111111111111111222222222222222222
Centroids                   1      2
```

Histogram for the classification analysis of the incontinent (1) and constipated patients (2). * marks the group centroid. These plots demonstrate the large overlap in the discriminant scores of the two patient groups.

TABLE I

DISCRIMINANT FUNCTION CLASSIFICATION RESULTS - CONTROLS AND INCONTINENT PATIENTS

Actual Group	Number of Cases	Predicted Group Membership	
		Control	Incontinent
Control	86	75 (87.2%)	11 (12.8%)
Incontinent	72	15 (20.8%)	57 (79.2%)

Percent of cases correctly classified - 83.5%

Sensitivity = $\frac{57}{57+15} = .79$

Specificity = $\frac{75}{75+11} = .87$

TABLE II

DISCRIMINANT FUNCTION CLASSIFICATION RESULTS - CONTROLS AND CONSTIPATED PATIENTS

Actual Group	Number of Cases	Predicted Group Membership	
		Control	Constipation
Control	86	75 (87.2%)	11 (12.8%)
Constipation	50	34 (68.0%)	16 (32.0%)

Percent of cases correctly classified - 66.9%

Sensitivity = $\frac{16}{16+34} = .32$

Specificity = $\frac{75}{75+11} = .87$

TABLE III

DISCRIMINANT FUNCTION CLASSIFICATION RESULTS - INCONTINENT AND CONSTIPATED PATIENTS

Actual Group	Number of Cases	Predicted Group Membership	
		Incontinent	Constipation
Incontinent	72	63 (87.5%)	9 (12.5%)
Constipation	50	16 (32.0%)	34 (68.0%)

Percent of cases correctly classified - 79.5%

Sensitivity = $\frac{63}{63+9} = .88$

Specificity = $\frac{34}{34+16} = .68$

TABLE IV

DISTRIBUTION OF DISCRIMINANT SCORES FOR ALL PATIENTS IN THE MANOMETRY INDEX

		RESTING PRESSURE Low	RESTING PRESSURE High
SQUEEZE PRESSURE	Low	-0.88 ± 0.91	0.03 ± 0.93
	High	-0.35 ± 1.40	1.32 ± 1.38

RESTING PRESSURE — Low >40 mm Hg; High <40 mm Hg

SQUEEZE PRESSURE — Low >60 mm Hg; High <60 mm Hg

Analysis of Variance F 21.79, degrees of freedom 3, p<0.0001

TABLE V

DISTRIBUTION OF DISCRIMINANT SCORES OF INCONTINENT PATIENTS IN THE MANOMETRY INDEX

		RESTING PRESSURE	
		Low	High
SQUEEZE PRESSURE	Low	0.95 ± 1.63	0.43 ± 0.74
	High	0.15 ± 1.04	0.40 ± 0.87

RESTING PRESSURE	Low >40 mm Hg High <40 mm Hg
SQUEEZE PRESSURE	Low >60 mm Hg High <60 mm Hg

TABLE VI

DISTRIBUTION OF DISCRIMINANT SCORES OF CONSTIPATED PATIENTS IN THE MANOMETRY INDEX

SQUEEZE PRESSURE	RESTING PRESSURE: Low	RESTING PRESSURE: High
Low	0.95 ± 1.63	0.54 ± 0.64
High	0.83 ± 0.97	1.68 ± 1.03

RESTING PRESSURE	Low >40 mm Hg High <40 mm Hg
SQUEEZE PRESSURE	Low >60 mm Hg High <60 mm Hg

CHAPTER SIX

DEFECOGRAPHY IN THE DIAGNOSIS OF PELVIC FLOOR DYSFUNCTION

ABSTRACT

The sensitivity and specificity of defecography assessment for patients with incontinence and constipation was tested using discriminant function and classification analysis. Classification analysis was used to examine the probabilities of patient membership for the constipated, incontinent or control groups. The subjects were 46 consecutive female patients, 21 had incontinence and 25 had constipation. They were compared to 22 healthy female controls. The variables measured were: anorectal junction levels referenced from the ischial tuberosities, at rest, and during lifting and straining; junction movement during lifting and straining referenced from resting levels; anorectal angles measured using the posterior border of the rectum, at rest and during lifting and straining.

The controls were significantly different compared to patients for resting and lift junction levels and resting and strain angles (all $p<0.0001$). The data are presented in graphs which show the extent of muscle impairment in patients compared to controls. Discriminant function analysis distinguished between the incontinent and constipated patients and controls ($p<0.0001$). The discriminating variables were lift angle and junction level and strain junction level and angle. The rest and lift anorectal angles were significantly wider with age ($p<0.05$) and parity ($p<0.02$).

Discriminant function and classification analysis are useful in the diagnosis, prognosis and management of patients with incontinence and constipation. Each patient's discriminant function score can be used to describe where the patient is positioned on a continuum of dysfunction from health to incontinence. The classification probability can be used to estimate risk of future incontinence or outcome of therapies.

INTRODUCTION

Since the defecography technique was first described by Burhenne (1964), there has been increasing interest in using the procedure to investigate defecation disorders and related anorectal function. Measurements of the patient's ability to use the pelvic floor muscles reveals information about the pathophysiology of defecation disorders. The results of the few defecography studies performed to investigate clinical differences between control subjects and patients suffering from defecation disorders have not provided a clear insight into the usefulness of defecography to detect physiological abnormalities. Skomorowska et al. (1987) compared the defecography assessments of 25 female controls and 48 incontinent and constipated patients. They found the resting angle and descent measurements in the incontinent patients significantly different from controls. The constipated patients were similar to the controls and their mean values fell in the range between the control and the incontinent group. Descent was measured as the distance between the anal opening and the chair and could have been influenced by body movements. Bartolo et al. (1988b) compared 27 male and female constipated patients to 20 control subjects and found no difference in anorectal angle or junction level at rest or during lifting. The patients had significantly lower junction levels with straining compared to controls. Bartolo et al. (1988a) studied 49 patients and 25 controls and found no differences for angles, but there were significantly lower values for straining and lifting anorectal junction level, but not for resting levels.

Turnbull et al. (1988) compared the defecography assessments of 58 constipated patients and 20 controls and found no significant differences for resting angles or descent. Womack et al. (1985) also found no differences between 16 constipated patients and 6 controls for angles at rest and during straining. Goei (1990) compared the defecography assessments of 19 constipated patients 13 incontinent patients to age and sex matched control subjects. No significant differences were found for angle or junction level. Penninckx et al. (1990) and Ferrante et al. (1991), comparing measurements made by different radiologists from the same defecography films, have not found defecography measurements of angle to be reliable.

If defecography is to be a useful diagnostic tool several criteria have to be met including the ability to determine which patients have a disorder and which do not. Diagnostic data obtained must be reliable in that the measures are the same with different observers or the same observers at different times. The measurements must be valid or shown to measure the intended function and not a some unrelated factor. Reliability and validity are essential for a diagnostic test to be useful in making judgements about the cause and severity of the disorder, to predict the clinical course of the disorder and make a prognosis, to predict the patient's responsiveness to therapy or to determine the patient's response to therapy (Sackett et al., 1985).

The aim of this study is to examine the validity of defecography as a diagnostic tool for patients with faecal incontinence and constipation. Criterion validity will be examined by comparing patients to controls. Predictive validity will be investigated using discriminant analysis. The study will describe the patients' defecography characteristics by comparing patients with constipation and incontinence to controls and to each other.

METHODS

Forty-six female patients consecutively referred to the gastrointestinal clinics at McMaster University Medical Centre for evaluation of anorectal dysfunction with defecography were assessed. Twenty-one patients suffered from faecal incontinence with symptoms ranging from daily soiling to involuntary loss of large amounts of stool. Twenty-five patients were diagnosed as having constipation with symptoms ranging from less than two bowel movements a week to no bowel movements without enemas or laxatives. The mean age of the incontinent group was 54.3, ± 16.6 years and the mean age of the constipated patients was 50.1, ± 15.7 years. The patient groups were compared to the data from twenty-two healthy female volunteers from a study published previously by Shorvon et al. (1989a). The volunteers had a mean age of 21.0 ± 1.6 years and all were nulliparous.

The defecography technique used in this study is outlined by Shorvon and Stevenson (1989b). All measurements were made by one radiologist to reduce observer measurement error. The spot films were taken at rest, during voluntary contraction of the sphincter and lift of the pelvic floor muscles (lift) and straining without defecating (strain). Defecography parameters included the posterior anorectal angle and the anorectal junction level measured from the ischial tuberosities. The anorectal angle was measured from the posterior rectal wall and the axis of the anal canal. The lift and strain angle and junction level were also evaluated by comparison to resting levels between and within the study groups. The presence or absence of enterocele was determined from the shape of the posterior vaginal and anterior rectal wall shape. Intussusception was graded from one to seven based on the thickness and position of the infolding in the wall of the rectum after defecation. Rectocele were evaluated by measuring the maximum depth of any anterior bulge appearing on the anterior rectal wall beyond the expected line on the video recordings of defecation (Shorvon et al., 1989a).

A oneway analysis of variance was used to compare canal length, age, parity and pelvic floor movement. Multiple regression was used to examine the influence of age and parity on the defecography variables.

Discriminant function analysis (DFA) is a multivariate statistic which uses several variables in combination to construct an equation which can then be used to predict from an individual subject group membership based on the relationship of the variables (Tabachnick et al., 1989). Discriminant function analysis was used to classify and predict group membership and to rank the defecography variables in order of discriminating ability. The SPSS Discriminant program was used, (SPSS Inc. 1986). In univariate statistics the study groups are the categorical independent variable used to examine the effects on the measured variables. In discriminant function analysis the measured variables are the independent variables used to predict the dependent variable of study groups. The predictor variables were the defecography measurements and the grouping variables were the controls, incontinent and constipated patient groups.

RESULTS

CONTROLS AND PATIENT GROUPS

The anorectal resting ($p<.0001$) and lift ($p<.00001$) junction levels were significantly higher in controls compared to the patient groups (table I). Data are usually shown with reference to the ischial tuberosities; however, when loss of muscle function is evaluated a reference to control values and resting values is important. Our data are expressed in relationship to the ischial tuberosities, resting values and controls as shown in figure 1 and 2. The results show that the patients have half the range of movement compared to the controls and that the resting values for both angle and junction level are significantly different from the control values (table II).

The anorectal angles at rest ($p<.004$) strain ($p<.001$) and lift ($p<.00001$) were significantly narrower in the controls compared to the patient groups (table III). Figure 2 illustrates the range of angle changes. The mean change in angle with lift was 24 ± 15 degrees for the controls compared to 12 ± 9 degrees for the constipated and 9 ± 9 degrees for the incontinent patients.

The anal canal length was similar in the constipated (1.8 cm), incontinent (1.7 cm) and the controls (1.6 cm). Eighty-three percent of the patients and 81% of the controls had some morphological changes in the rectal wall. There were no clear differences between the groups in grade of intussusception or depth of rectocoeles (table IV). Eight patients and two controls had a widening of the postvaginal-anterior rectal wall space compatible with a enterocele.

CONSTIPATED AND INCONTINENT PATIENT GROUPS

The only variable that was significantly different between the patient groups was descent movement from rest ($p<.04$). The constipated patients on average had little or no descent movement.

To examine the effects of severity of symptoms the patient groups were subdivided. The constipated patients were divided into two groups: 1) less than one bowel movement week (without enemas or laxatives), 2) one or more bowel movements a week. The incontinent patients were also divided into two groups: 1) daily soiling, 2) involuntary major stool loss.

The movement of the anorectal junction level with squeezing was significantly different between the symptom groups ($p<.02$). The constipated patients with less than one bowel movement a week had greater lift than the major stool loss and more than one bowel movement a week group ($p<.05$). None of the remaining defecography variables was significantly different for the symptom groups.

The patients in the incontinent and constipated groups were not significantly different in age or parity. However, in the combined patient groups multiple regression analysis showed that with all the other variables taken into account age was a significant influence on resting ($p<0.05$) and lift anorectal angles ($p<0.04$). Parity also has a significant influence on resting ($p<0.01$) and lift ($p<0.02$) angles. Neither parity nor age was a significant influence on anorectal junction levels.

DISCRIMINANT FUNCTION ANALYSIS:

Discriminant function analysis classified the incontinent and control groups with a 93% accuracy. The order of importance for the variables included in the DFA equation were lift angle and junction level and strain junction level and angle ($p<0.0001$). The classification analysis of the discriminant function accurately classified the faecal incontinent patients 90.5% (sensitivity) and the healthy controls 95.5% (specificity) (table V).

Discriminant function analysis for the constipated and control groups showed that lift angle, and lift and descent movement of the junction level are the variables in the discriminant equation ($p<0.0001$), and the discriminant function classified the groups with an accuracy of 91.5%. The sensitivity of defecography variables in discriminant function classification analysis for constipation was 88.0% and the specificity was 95.5% (table VI).

Discriminant function analysis comparing the patient groups used descent to form the discriminant equation ($p<0.04$), but could not successfully classify the patient groups. The classification accuracy was 38 percent for the incontinent patients and 68 percent for the constipated patients, (table VII). Figure 3 illustrates the position of the groups compared to their group centroid. Patients in the area where the groups overlap have discriminant scores which indicate the distinction between the groups is not clear cut, such scores can be considered marginal for classification.

DISCUSSION

Defecography is a sensitive and specific tool in the diagnosis of a weakened pelvic floor musculature. Using the combined variables of the defecography assessment in discriminant function analysis comparing each patient group with the control group gives defecography a 90.5% sensitivity in diagnosing incontinent patients and 88.0% sensitivity in diagnosing constipated patients. The overall specificity was 95.5% in both analyses. This is reflected in wider angles and low junction levels in the patients compared to the controls. Patients with constipation and incontinence are correctly classified using defecography parameters 90% of the time (sensitivity) and controls are classified as negative 96% of the time (specificity).

This study shows that the patients have lower anorectal junction levels, wider angles and impaired ranges of movement compared to the controls.

Defecography can be seen as a 'stress test' for the anorectal and pelvic floor muscles. The first part, when the rectum is loaded with barium paste, shows how the muscles perform under a 'normal load'. These measurements are called the resting condition. The controls have angle of about 90 degrees and a junction level above the ischial tuberosities at rest. The second challenge is to lift the junction level by voluntarily squeezing the anorectal sphincters closed contracting the levator ani. The controls can lift the junction level well above the ischial tuberosities and narrow the angle about 20 degrees. The third challenge is the strain manoeuvre. The subjects are asked to strain down (increase the intra-abdominal pressure) without defecating (this is accomplished by simultaneously tightening the voluntary muscles of the anal sphincter). The strain measurements show how well the musculature can cope with the added stress. During strain both patients and controls lower the pelvic floor to the same position, but the controls can prevent significant angle widening.

The incontinent patients show muscle weakness under the first challenge by lower junction levels and wider angles at rest. The incontinent patients fail the second challenge and show their inability to either narrow the angle or raise the pelvic floor. They also fail the third challenge, because their angle widens with increased intra-abdominal pressure. The measurements which are used by discriminant function analysis to classify the incontinent patients from healthy controls in order of importance are: lift angle, lift junction level, strain junction level and strain angle. The constipated patients show weakness in the resting measurements. They also show puborectalis muscle weakness in the lift angle changes. In the constipated patients lift anorectal angle is the most discriminating variable followed by descent and lift movement from resting levels. Goei (1990), is the only study we found which compares lift in patient and control groups. We feel that this challenge is important in the examination because under ordinary circumstances this is what people do when they feel urgency at an inconvenient time. The results are an indication of how well the patient can maintain control of the anal sphincters. Strain in most studies is an attempt at defecation. In our study it is similar to the challenge the patient faces when they pick up something heavy or sneeze. It is important because it demonstrates the patient's ability to maintain continence under the stress of increased intra-abdominal pressure.

By looking at the relationship of the defecography variables at rest to those at lift and strain both patient groups have muscle impairment as shown by the low resting values compared to controls. The incontinent have the most dysfunction, demonstrated by the poor responses to the defecography challenges and lack of junction movement with lifting. The constipated have low junctions at rest, but still retain the same amount of lift movement as the controls. By reporting a patient's defecography results in a graphic form comparing them to the mean of the healthy young controls, the amount of change is made obvious. Individual values can be expressed in standard deviations from the control mean indicating degree of change (Appendix 2).

Discriminant function analysis gives a probability for group membership and a discriminant function score for each subject. The analysis can discriminate between patients and controls. We hypothesize that those patients whose score place them closer to the normal group are those which will be most amenable to treatment. These are the patients with the least dysfunction. Future studies will include further extension of the data base and investigations into the outcome of various treatment modalities.

Discrimination between the two patient groups was statistically significant, but the classification analysis was not clinically useful.

The classification may be useful in identifying constipated patients at risk for incontinence. Thirty-two percent of the constipated group were classified as incontinent. These patients were more like the incontinent patients than the other constipated patients, an indicator that they are at potential risk for future incontinence. Sixty-two percent of the incontinent patients were classified as constipated and may be the most amenable to treatment.

Two limitations of these findings are that the control group was significantly younger than the patient groups and that the study population was small. By using young nulliparous healthy females as a "gold standard" any change in function when compared to the patient groups is more obvious. The affect of age on defecography measurements remains unclear. Felt-Bersma et al. (1982) found no sex or age differences in patient groups, but axial angles and the chair were used as the reference points which is not optimal. The Goei et al. (1989) study had older controls matched for sex and age to the patient groups, but used axial measurements for angle and the pubo-coccyx for the junction levels which make comparison with this work difficult. Selvaggi et al. (1990), have controls older than ours, and found similar angle and descent measurements, but the study was small and a mix of four males and six females. This study shows that age and parity have significant influences on anorectal angles in patients and more work needs to be done to clarify the influence and interaction of age and parity on anorectal function. We attempted to address the sample size by restricting the number of variables used in the discriminant analysis and jackknifing the data for cross-validation (Norman et al., 1986; Tabachnick et al., 1989).

This study emphasizes that measurements of angle and anorectal junction levels as well as pelvic floor movement used in combination reveal clinically relevant information and prove the usefulness of defecography as a tool in the diagnosis of pelvic floor dysfunction. Each patient evaluated in the context of other patients can be assessed for management and future risk.

FIGURE 1 ANORECTAL JUNCTION LEVELS AT REST LIFT AND STRAIN REFERENCED FROM THE ISCHIAL TUBEROSITIES

```
                                                    +          ++
CONTROL                                S------------------R--------L

CONSTIPATION                       S---R--------L

INCONTINENCE                       S--------R----L

                         cm    +----+----+----+----+----+----+----+----+----+----+
                              -2         -1          IT         1          2

IT = ischial tuberosities
R  = resting levels
S  = strain levels
L  = lifting levels

control compared to patients +p=.0001
                             ++p=.00001
```

TABLE I ANORECTAL JUNCTION LEVELS

	REST	LIFT	STRAIN
CONTROLS	0.41 ±1.32*	1.43 ±1.17**	-1.57 ±1.56
CONSTIPATION	-1.33 ±1.49	-0.43 ±1.17	-1.70 ±1.70
INCONTINENCE	-0.92 ±1.02	-0.47 ±1.59	-1.93 ±1.04

Data are expressed in cm as mean and standard deviation.

TABLE II MOVEMENT OF THE PELVIC FLOOR

	LIFT	STRAIN	TOTAL
CONTROLS	1.0 ±0.7	2.0 ±1.5*	3.0 ±1.2*
CONSTIPATION	0.9 ±0.9	0.4 ±0.9**	1.2 ±1.1
INCONTINENCE	0.5 ±0.7	0.9 ±0.9	1.5 ±1.1

Data are expressed in cm as mean and standard deviation.

comparing normal and patient groups *P<.0001
comparing patient groups **P<.044

FIGURE 2 ANORECTAL ANGLES AT LIFT, REST AND STRAIN

```
             +++                          +       ++
CONTROLS     L-----------------------R------S

CONSTIPATION                                L-----------R--------S

INCONTINENCE                                    L-------R--------S

      +----+----+----+----+----+----+----+----+----+----+----+----+  degrees
          70        80        90        100       110       120
```

R = resting levels
S = strain levels
L = lifting levels

controls compared to patients *p.004
**p.001
***p.00001

TABLE III ANORECTAL ANGLES

	REST	LIFT	STRAIN
CONTROLS	94.6 ±16.4*	70.8 ±11.5***	100.0 ±15.3**
CONSTIPATION	112.0 ±22.9	99.6 ±25.0	121.3 ±26.3
INCONTINENCE	112.4 ±17.4	103.0 ±22.9	120.9 ±17.3

Data are expressed in degrees as mean and standard deviation.

TABLE IV RADIOGRAPHIC FEATURES

INTUSSUCEPTION

N	GRADE	0	1	2	3	4	5	6	7
21*	Controls	4	2	2	2	6	3	1	0
25	Constipation	13	2	4	1	1	2	2	0
21	Incontinent	7	4	4	4	1	1	0	0

RECTOCELE

N	Grade	<.5	.5-1	1-1.5	1.5-2	>2
21*	Controls	4	7	5	4	1
25	Constipation	7	6	3	7	2
21	Incontinent	3	4	3	8	3

ENTEROCELE

N		YES	NO
21*	Controls	2	20
25	Constipation	5	20
21	Incontinent	3	18

*1 film could not be evaluated.

TABLE V

CLASSIFICATION RESULTS CONTROLS AND INCONTINENT PATIENTS

Actual Group	Number of Cases	Predicted Group Membership: Control	Incontinent
Control	22	21 (95.5%)	1 (4.5%)
Incontinent	21	2 (9.5%)	19 (90.5%)

Percent of "grouped" cases correctly classified - 93%

Sensitivity = $\frac{19}{19+2} = .90$

Specificity = $\frac{21}{21+1} = .95$

TABLE VI

CLASSIFICATION RESULTS CONTROLS AND CONSTIPATED PATIENTS

Actual Group	Number of Cases	Predicted Group Membership: Control	Incontinent
Control	22	21 (95.5%)	1 (4.5%)
Constipation	25	3 (12.0%)	22 (88.0%)

Percent of "grouped" cases correctly classified - 91%

Sensitivity = $\frac{22}{22+3} = .88$

Specificity = $\frac{21}{21+1} = .95$

TABLE VII

CLASSIFICATION RESULTS CONSTIPATED AND INCONTINENT PATIENTS

Actual Group	Number of Cases	Predicted Group Membership	
		Incontinent	Constipation
Incontinent	21	8 (38.1%)	13 (61.9%)
Constipation	25	8 (32.0%)	17 (68.0%)

Percent of "grouped" cases correctly classified - 54%

Sensitivity = $\frac{8}{8+13} = .38$

Specificity = $\frac{17}{17+8} = .68$

CHAPTER SEVEN

ABSTRACT

The manometry and defecography assessments of 21 incontinent and 26 constipated female patients were evaluated to examine the relationship between the two techniques and to identify when manometry and defecography are useful in the management of patients with constipation and incontinence.

The were no significant correlations in the incontinent patient group for the defecography and manometry variables. There were significant correlations between resting pressure, angle and junction level ($p<0.03$) in the constipated patients. Squeeze pressure was significantly correlated with lift junction level ($p<0.004$), but not lift angle in the constipated patients. Parity was negatively correlated with squeeze pressure ($p<0.005$) in all patients, and lift junction level ($p<0.007$) in the constipated patients. The combined variables of manometry and defecography did not improve the discrimination between the two patient groups better than manometry variables alone.

Comparison of the variables of sphincter pressure, angle and junction level show that there can be impairment in more than one type of nerve pathway to the muscles of the anorectum. This study puts forth the hypothesis that some of the constipated patients are at risk for incontinence. Twelve percent of the constipated patients had classification probabilities which categorized them as incontinent. Childbirth and straining at stool are the factors which increase the risk of incontinence in constipated patients.

INTRODUCTION

The two most widely used assessments for anorectal dysfunction are manometry and the radiological assessments video proctography and defecography. Each type of assessment measures a different type of function. Manometry evaluates the strength of the internal and external anal sphincters, anal reflexes and sensory awareness of rectal distension. Defecography evaluates changes in rectal wall morphology and the movement of the pelvic floor muscles, including the puborectalis which is not evaluated with manometry (Coller, 1987). Because these muscles work together to maintain continence, the relationship between manometry and defecography variables may reveal more about anorectal dysfunction than either assessment alone.

Because of the small amount of literature dealing with manometry and defecography, the studies of video proctography and manometry are also discussed. Recently a number of studies have used video proctography and manometry assessments together in examining patients in order to clarify the pathophysiology of anorectal dysfunction. Most of the studies do not report combining the results of the two types of assessment in the analysis of the data. The studies are difficult to interpret, because of the different types of diagnostic categories in each of the studies and because most included both males and females in the study and control groups.

Perineal descent syndrome is the diagnosis in patients who have radiological examinations which show markedly lower anorectal junction levels at rest (Miller et al., 1989), and some studies have shown reduced squeeze pressures and impaired rectal sensitivity in these patients, but the findings are not consistent between studies. Patients with perineal descent syndrome have lower squeeze pressure (Read et al., 1983a), and more descent compared to controls, but no difference in angle (Touchais et al., 1988). Bannister et al. (1986) found significantly wider resting and strain angles and lower resting and squeeze pressures in young constipated women compared to age matched female controls. Roe et al. (1986), compared patients with constipation and normal or slow transit studies to controls and found impaired sensation to rectal stimulation and increased perineal descent in the patients with normal gastrointestinal transit, but not in the slow transit or controls. Bartolo et al. (1988b) examined constipated patients compared to controls. There were no significant differences for resting pressure or resting and lifting angles. The patients failed to elevate the junction level with squeezing in this study.

The findings for manometry and proctography in studies of incontinent patients are also inconsistent. Read and Abouzekry (1986a), found increased anorectal angles and impaired rectal sensation, but no difference in resting and squeeze pressures or anorectal junction levels in impacted elderly patients compared to elderly controls. Bartolo et al. (1983a), found incontinent patients with perineal descent had lower anorectal junction levels at rest and lower resting and squeeze pressures compared to the constipated patients with perineal descent and controls. Miller et al. (1989), compared patients with perineal descent and incontinence, constipation and rectal prolapse with controls. They found that the incontinent patients had significantly lower resting pressure, less rectal sensitivity, lower anorectal junction levels at strain and wider resting angles than other patients with perineal descent.

A few studies have examined the relationship of defecography and manometry variables. Felt-Bersma et al. (1990), in a study of 92 male and female patients with a variety of defecation disorders, found no relationship between resting and straining angles and resting and squeeze pressures. Rex and Lappas (1992), studied incontinent patients and examined the relationship between the manometry and defecography variables. Their study sample consisted of 47 female and 7 male patients with incontinence caused by a variety of etiologies. They found significant correlations between resting and squeeze pressures with resting anorectal junction levels, but not with angle. The relationship between any one particular measurement on assessment to dysfunction, or the comparison of the manometry and radiological assessments on the same patients have not clarified the cause of the patient's symptoms. The conflicting results of these investigations can be accounted for in part by the combination of male and female patients and controls in the same study. It is now clear that there are sex differences both in manometry and defecography results, (McHugh and Diamant, 1987; Loening-Baucke and Anuras, 1985; Laurberg and Swash, 1989). Some studies examined specific types of constipation, such as short transit, impaction or descending perineal syndrome and the results are confusing. There may be specific types of dysfunction in each of these disorders. There are also differences due to evaluation technique, especially for radiology assessments. Video proctography assessment of angles and anorectal junction levels is done with the patient in the left lateral position with a relatively small amount of barium. Defecography assessments of angles and junction levels are done with the patient in the sitting position and a large amount of barium paste. Jorge et al. (1994) show that there are significant differences in patients for resting and strain angle and all measures of anorectal junction level when patients are seated, as in defecography, compared to the left lateral position during video proctography.

The aim of this study was to gain insight into the contribution of the combination of these assessments in understanding the mechanisms leading to incontinence and constipation. The objectives of this study are to: examine the relationship between manometry and defecography assessments, to identify the important variables in discriminating between the two patient groups and to use the assessment variables to identify the abnormalities in function specific to constipation and incontinence.

METHODS

Forty-six female patients consecutively referred to the gastrointestinal clinics at McMaster University Medical Centre for assessment with both defecography and manometry were evaluated. These patients are a subset of a larger group reported on in a previous study of the manometry assessment. Twenty-one patients were incontinent and twenty-six were constipated with varying etiology. The mean age of the incontinent group was 54.8, ± 17.7 years, and the mean age of the constipated patients was 50.1, ± 15.8 years.

Defecography and Manometry Procedures

The defecography assessment was based on the technique described by Shorvon et al. (1989b). Pressures in the anal canal were recorded on a Grass polygraph by a station pull-through technique (Read et al., 1986b). Both procedures are described in previous chapters.

Statistical Analyses

Analysis of variance was used to examine the differences between the groups. Pearson's correlation was used to examine the relationships between the variables for each patient group. Discriminant function analysis (DFA) was used to determine which variables best separated the patient groups, for manometry, defecography and the combined assessments. Classification analysis was used to examine the usefulness of the discriminant function as a 'predictor' of the patient's symptom group. The data were analyzed using the SPSS computer programs (SPSS Inc. 1986).

RESULTS

The defecography results are for the same patients reported in the previous chapter. The patient groups differed only on descent or downward movement of the junction level with straining, the constipated having significantly less movement than the incontinent ($p<0.04$). The patient groups did not differ in grades of rectocoeles, enterocoeles or intussusception. The incontinent patients had lower resting, ($p<0.02$) and squeeze pressures ($p<0.05$) and lower balloon volumes to induce feelings of urgency ($p<0.01$) than the constipated patients. Table I summarizes the manometry and defecography results.

Correlation of Defecography and Manometry Variables

The correlation of inter-related variable's where one variable's measurement is part of the second variables measurement does not yield much useful information. The defecography variables are inter-related because each measurement contains elements of the resting measure. The resting, lift and strain junction levels were significantly correlated as were the resting lift and strain angles in both patient groups. Similarly the resting pressure and total squeeze pressure and the volumes to first perception urgency and discomfort were significantly correlated, because they contain elements of each other.

More importantly, for the constipated patients there were significant negative correlations for resting angle and junction level (r-.44, p<0.03), lift angle and junction level (r-.45, p<0.02) and strain angle and junction level (r-.52, p<0.01).

Relationship of Manometry and Defecography Variables

When the relationships of the manometry and defecography variables were examined, the constipated patients had a significant negative correlation for resting pressure and resting angle (r-.42, p<0.04) and a significant positive correlation for resting pressure and resting junction level (r.47, p<0.02). Total squeeze pressure was significantly correlated to lift junction level (r.55, p<0.004), but there was no correlation with lift angle. Larger lift movements were associated with greater balloon volumes to feelings of urgency (r.45, p<0.02) and discomfort (r.47, p<0.02). The higher the patient's parity rate the lower the lift junction level (r-.42, p<0.04) total squeeze pressure (r-.45, p<0.03) and resting pressure (r -4.0 p<0.05). There were no significant correlations for any of the manometry variables with the constipated patients' age.

The relationships between the junction levels with angles and with resting and squeeze pressures were not significant in the incontinent patient group. The total squeeze pressure was negatively correlated with the volume to first perception of the rectal balloon (r-.58, p<0.005) in the incontinent patients, but there was no correlation for the constipated patients. Parity was negatively correlated with squeeze pressure (r-.50, p<0.02) and positively to volume to first perception (r.49, p<0.05). Age was associated with lower lift junction levels (r-.51, p<0.02) in the incontinent patients.

Manometry Index and Defecography Variables

Patients were classified by the manometry index as having a resting pressure greater or less than 40 mm Hg and a squeeze pressure greater or less than 60 mm Hg. The defecography variables were examined by analysis of variance using the manometry index as the grouping variable to show the overall relationship of the manometry index and defecography variables. Oneway analysis of variance with range tests were used to examine the patients within each category. Eighty-three percent of the patients were in the low squeeze pressure categories. There were significant differences for strain junction level ($p<0.002$), and rectal sensitivity ($p<0.003$), and volumes to relax the sphincter ($p<0.003$) between the categories. (table II) The patients with low squeeze and low resting pressures had wider angles and lower anorectal junction levels than patients in the high resting pressure low squeeze pressure, but the differences were not significant. Table III shows the distribution of the patients within the index.

Discriminant Function Analysis

Discriminant analysis of the manometry assessment for this patient sample shows that volume to urgency, resting pressure and age are the variables in the function which separate the two patient groups (Chi-square 11.43 degrees of freedom 3, $p<0.01$). The manometry data correctly classified 71% of the incontinent and 76% of the constipated ($p<0.001$).

Discriminant analysis of the defecography variables show that descent movement was the only variable to discriminate between the two patient groups ($p<0.04$). The classification analysis which is based on each subject's discriminant score, was not better than chance.

Discriminant analysis of the combined manometry and defecography variables formed a function which was significant, (Chi-square 19.0 degrees of freedom 4, $p<0.003$). The variables in order of importance in correlation within the function were: volume to urgency, descent, resting pressure, volume to discomfort, age and strain junction level. Classification results were the same as manometry alone for the incontinent patients and improved for the constipated patients (table IV, figure 1).

The discriminant function analysis provides a discriminant score for each patient. When the discriminant scores were compared using the manometry index, there was a significant difference in the scores between the manometry index categories ($p<0.02$). (table V).

DISCUSSION

This is the first study to shows that parity is associated with lower squeeze pressures and lower lift anorectal junction levels in patients. This implies that there is damage to the nerve supply to both the external anal sphincter and to the levator ani in these patients. Bannister et al. (1986) found no difference between multiparous and nulliparous constipated patients for resting pressure and angle or for squeeze pressure. The strain anorectal junction level was significant lower in the multiparous patients, however they were also significantly older than the nulliparous patients. Snooks et al. (1984) shows that the innervation of the pelvic floor musculature may be damaged in childbirth. Tears to the perineum, vagina and rectum that are not properly repaired also result in weakened sphincters. Of all normal vaginal deliveries, five percent involve serious perineal tears. Incontinence is a well recognised complication of perineal tears and disruption of the repair of a tear or of an episiotomy (Khanduja et al., 1994). Snooks et al. (1986) show that in healthy multiparae there are changes in pudendal nerve function after delivery and in 60% of these women there is recovery in 2 months. Parity is not a variable which effects squeeze pressure in healthy controls (McHugh and Diamant, 1987).

This study shows that there is a relationship between defecography and manometry variables, between the resting anal pressures and the junction level and angle in the constipated patients. High resting pressures were associated with narrower resting angles and high resting junction levels. This indicates that manometry can assess the external anal sphincter muscle function, and the puborectalis and levator ani at rest. High squeeze pressures were related to higher lift junction levels, but not to lift angles. The constipated patients did however, significantly narrow the angle with lifting. The manometry assessment does not evaluate puborectalis contraction with squeezing, but does indicate levator ani function in constipated patients.

The relationship between the manometry and defecography variables is weak in the incontinent patients. The angles and junction levels are similar to the constipated patients, but the resting and squeeze pressures are significantly lower. The barium load used in defecography may be sufficient to mask differences in the patient groups for angle or junction levels found on video proctography, when the rectum is relatively empty. The differences between the findings of defecography and video proctography have also been described by Delemane et al. (1994). This may be a significant factor in the incontinent patients who have the most muscle impairment. The low resting pressure in the incontinent patients may reflect impairment to the external sphincter's resting tone, demonstrated by the lack of correlation between resting pressure, angle and junction level. Jones et al. (1987a), describes incontinent patients as having increased descent of the pelvic floor which has caused pudendal nerve damage by stretching the nerve. Studies show that some of the nerve supply to the pelvic floor muscles is from direct branches of the sacral nerves which run in plane between the intra pelvic fascia and the levator ani muscles (Matzel et al., 1990). Damage to either or both of these nerve supplies would result in different types of muscle dysfunction. Damage to the pudendal nerve through excessive straining at stool can result in low squeeze pressures, but lift could be still be achieved by the other levator ani muscles, as found in some of the constipated patients in this study. Damage to both nerve supplies would result in lower resting and squeeze pressures and little or no lift as found in some of the incontinent patients in this study. Bartolo et al. (1983a), and Johansson et al. (1992), suggest that patients with neuropathic damage to the external sphincter and puborectalis are likely to be incontinent.

This study shows that the greater the lift movement, the larger volumes the patients required for feelings of urgency and discomfort, which describes normal function. Most of the patients could not lift the junction level past the ischial tuberosities (which was the resting level for the controls). Low squeeze pressures were related to higher volumes to first perception. Why the rectum becomes more sensitive to larger distentions and less sensitive to smaller volumes is not evident is this study. Some of the receptors for rectal sensation are thought to be in the muscles of the pelvic floor (Whitehead and Schuster, 1987), and these nerves may also be damaged by stretching the pelvic floor muscles. Studies indicate that sensory awareness is lost due to neurological damage caused by abnormal pelvic floor descent (Touchais et al., 1988; Womack et al., 1986; Miller et al., 1989).

Read et al. (1986b) and Bannister et al. (1986) describe changes in sensory awareness in severely constipated patients, indicating that there may be two pathways. They found that the volume to first perception and discomfort similar to controls, but the patients had impairment of the sensations associated with urge to defecate. A patient's awareness to rectal filling may also be a learned response. Increases in rectal filling may be interpreted as urgency at low volumes because of a patient's heightened awareness due to past experience with faecal incontinence. The same amount of rectal filling might be ignored by a constipated patient who has experienced difficulty at defecation in the past.

This study shows the manometry assessment to be more sensitive and better able to discriminate between the constipated and incontinent patient groups, than the defecography assessment. The combination of manometry and defecography variables improves the ability of discriminant function analysis to classify the constipated patients. The defecography and manometry results show that there is a continuum of dysfunction and that some of the constipated patients in this study may be at risk for incontinence. Twelve percent of the constipated patients had classification probabilities greater than .5 for incontinent group membership. Twenty-nine percent of the incontinent groups were misclassified into the constipated group.

Eighty-three percent of the patients in this study were in the low squeeze pressure categories of the manometry index. Sixty-two percent of the incontinent patients were in the low resting pressure categories and patients in this category had significantly wider angles and lower anorectal junction levels. Sixty-four percent of the constipated patients were in the high resting pressure categories. The distribution of the discriminant scores in the manometry index exhibit a continuum of dysfunction described by the combination of the manometry and defecography assessments.

The limitation of this study is the small sample size. Any inferences drawn from such a small sample should be treated with caution. Although the manometry findings for this sub-sample of patients were similar to the larger sample of patients, the constipated patients were older than the constipated patients in the previous manometry study (reported in Chapter four). Further work needs to be done to examine generalizability of the results. If manometry assessment can be used to evaluate pelvic floor function in patients then defecography may be indicated only for patients with suspected structural abnormalities.

TABLE I. MANOMETRY AND DEFECOGRAPHY RESULTS

	CONSTIPATION	INCONTINENCE
n	25	21
MANOMETRY		
Pressure(mm Hg)		
Resting	54.2* ± 25.6	38.5 ± 17.4
Squeeze	44.6 ± 30.0	38.2 ± 33.5
Total squeeze	98.4* ± 39.5	76.1 ± 35.4
Volume (cc)		
Preception	31.4 ± 17.8	28.3 ± 18.7
Relaxation	27.6 ± 28.4	23.2 ± 12.4
Urgency	128.6* ± 80.2	79.8 ± 39.5
Maximum	170.4 ± 85.4	127.0 ± 63.5
DEFECOGRAPHY		
Angle (degrees)		
Resting	112.0 ± 22.9	112.4 ± 17.4
Lift	99.6 ± 24.9	103.0 ± 22.9
Strain	121.3 ± 26.3	120.9 ± 17.3
Junction level (cm)	- 1.3 ± 1.5	- 0.9 ± 1.3
Resting	- 0.5 ± 1.6	- 0.4 ± 1.2
Lift	- 1.7 ± 1.7	- 1.9 ± 1.1
Strain		
	0.9 ± 0.9	0.5 ± 0.7
Lift	0.4* ± 0.9	0.9 ± 0.9
Descent		
	50.1 ± 15.8	54.8 ± 17.7
Age	2.2 ± 1.5	2.3 ± 1.3
Parity		

Constipation compared to incontinence. * $p<0.05$

TABLE II. DESCRIPTION OF ALL PATIENTS BY INDEX CATEGORY.

SQUEEZE PRESSURE	RESTING PRESSURE: Low		RESTING PRESSURE: High	
Low	*N 18*		*n 20*	
	MANOMETRY		MANOMETRY	
	Pressure(mm Hg)		*Pressure(mm Hg)*	
	Resting	29.7 ± 10.1	Resting	60.7 ± 21.5
	Total squeeze	68.1 ± 16.8	Total squeeze	89.0 ± 29.8
	Squeeze	32.0 15.9		
	Volume (cc)		*Volume (cc)*	
	Perception	41.4 ± 17.6	Perception[3,4]	24.2 ± 15.5
	Relaxation	25.8 ± 12.6	Relaxation	16.0 ± 9.9
	Urgency	103.0 ± 57.1	Urgency	101.8 ± 71.1
	DEFECOGRAPHY		DEFECOGRAPHY	
	Angle (degrees)		*Angle (degrees)*	
	Resting	116.5 ± 21.7	Resting	109.9 ± 20.6
	Lift	105.3 ± 27.4	Lift	99.6 ± 21.8
	Strain	124.8 ± 13.6	Strain	118.4 ± 24.3
	Junction level (cm)		*Junction level (cm)*	
	Resting	-1.6 ± 1.6	Resting	-1.0 ± 1.7
	Lift	-1.0 ± 1.7	Lift	-0.3 ± 0.9
	Strain	-2.5 ± 1.4	Strain	-1.4 ± 1.1
	Lift	0.7 ± 0.8	Lift	0.7 ± 0.9
	Descent	0.8 ± 0.7	Descent	0.4 ± 0.7
	Age	54.4 ± 18.4	Age	50.0 ± 13.3
	Parity	2.3 ± 1.4	Parity	2.5 ± 1.7
High	*N 4*		*n 4*	
	MANOMETRY		MANOMETRY	
	Pressure (mm Hg)		*Pressure (mm Hg)*	
	Rest	30.0 ± 7.1	Resting	73.2 ± 18.3
	Total squeeze	42.7 ± 18.1	Total squeeze	167.5 ± 23.2
	Squeeze	100.0 13.5	*Volume (cc)*	
	Volume (cc)		Preception	22.5 ± 12.5
	Preception	15.0 ± 10.0	Relaxation	52.2 ± 32.6
	Relaxation	45.8 ± 53.5	Urgency	111.2 ± 79.6
	Urgency	138.8 ±111.8	Maximum	
	DEFECOGRAPHY		DEFECOGRAPHY	
	Angle (degrees)		*Angle (degrees)*	
	Resting	116.3 ± 0.9	Resting	100.2 ± 21.6
	Lift	103.4 ± 13.2	Lift	86.3 ± 25.0
	Strain	127.0 ± 19.6	Strain	112.3 ± 34.1
	Junction level (cm)		*Junction level (cm)*	
	Resting	-1.1 ± 1.7	Resting	0.1 ± 1.1
	Lift	-0.1 ± 1.6	Lift	0.8 ± 0.5
	Strain	-2.4 ± 1.1	Strain[1,2,3]	0.2 ± 1.3
	Lift	1.0 ± 0.8	Lift	0.7 ± 0.7
	Descent	1.4 ± 1.4	Descent	-0.1 ± 1.4
	Age	51.0 ± 25.7	Age	52.0 ± 19.5
	Parity	1.1 ± 1.2	Parity	1.6 ± 1.0

- Volume to perception $p<0.003$, F 5.45 degrees of freedom 3
- Strain junction level $p<0.002$, F 6.07 degrees of freedom 3
- Superscripts indicate which categories are significantly different, $p<0.05$. Legend of superscripts for categories: [1] Low rest low squeeze [2] High rest low squeeze [3] Low rest high squeeze [4] High rest high squeeze

TABLE III. DISTRIBUTION OF PATIENTS IN MANOMETRY INDEX.

A). CONSTIPATION PATIENTS

SQUEEZE PRESSURE	RESTING PRESSURE Low	RESTING PRESSURE High	Row Totals
Low	8	13	21
High	1	3	4
Column Totals	9	16	N = 25

B). INCONTINENT PATIENTS

SQUEEZE PRESSURE	RESTING PRESSURE Low	RESTING PRESSURE High	Row Totals
Low	10	7	17
High	3	1	4
Column Totals	13	8	N = 21

RESTING PRESSURE Low >40 mm Hg, High <40 mm Hg
SQUEEZE PRESSURE Low >60 mm Hg, High <60 mm Hg

TABLE IV. MANOMETRY AND DEFECOGRAPHY DISCRIMINANT FUNCTION CLASSIFICATION RESULTS

Actual Group	Number of Cases	Predicted Group Membership	
		Incontinent	Constipation
Incontinent	21	15 (71.4%)	6 (28.6%)
Constipation	25	3 (12.0%)	22 (88.0%)

Percent of "grouped" cases correctly classified - 80.43%

Sensitivity = $\frac{15}{15+6} = .71$

Specificity = $\frac{22}{22+3} = .88$

TABLE V. DISCRIMINANT SCORES AND MANOMETRY INDEX

SQUEEZE PRESSURE	RESTING PRESSURE Low	RESTING PRESSURE High
Low	-0.54 (± 1.2)	0.46 (± 1.0)
High	-0.63 (± 1.2)	0.82 (± 1.2)

RESTING PRESSURE Low >40 mm Hg
High <40 mm Hg

SQUEEZE PRESSURE Low >60 mm Hg
High <60 mm Hg

FIGURE 1 **HISTOGRAM OF DISCRIMINANT FUNCTION SCORES**

```
              All-groups stacked Histogram

              Canonical Discriminant Function
       8 +                                         +
         |                                         |
         |                                         |
         |                                         |
       6 +                2     2                  +
         |                2     2                  |
         |                2     2                  |
         |                2     2                  |
       4 +                1  2  2                  +
         |                1  2  2                  |
         |                12 2 22                  |
         |                12 2 22                  |
       2 +          1   1 11212212  2   2          +
         |          1   1 11212212  2   2          |
         |       1  11121 11111111 222222  22      |
         |       1  11121 11111111 222222  22      |
          X----+----+----+-*--+---*+----+----+----X
              -3   -2   -1    0    1    2    3
  Class            DISCRIMINANT SCORES
Centroids                  1      2


Legend     1 = INCONTINENCE
           2 = CONSTIPATION

Group Centroids
           INCONTINENCE    -.75289
           CONSTIPATION     .63243


p<0.005, Chi-square 15.45 degrees of freedom 4
```

CHAPTER EIGHT

THE RELATIONSHIP OF DEFECOGRAPHY AND MANOMETRY VARIABLES TO RECTAL WALL MORPHOLOGY

ABSTRACT

The manometry and defecography assessments of 21 incontinent and 25 constipated female patients were evaluated to examine the relationship of the assessments to rectal wall morphology.

There were no significant differences in the patient groups and the grades of rectocele, intussusception and enterocele. The patient groups were combined and the data analyzed by analysis of variance. There were no significant differences in the manometry or defecography variables for patients with different grades of rectocele. The patients with larger grades intussusception had significantly lower resting and lifting junction levels ($p<0.01$). The patients with enterocele were older ($p<.003$) and had significantly lower junction levels (all $p<0.01$), wider resting and lifting angles ($p<0.01$) and lower resting and squeeze pressures ($p<0.05$) than patients without enterocele.

A number of patients had more than one change in rectal wall morphology and the changes were grouped as: no changes, rectocele, rectocele and intussusception, and rectocele, intussusception and enterocele. Analysis of variance with the factors patient group and morphology group showed the incontinent patient group had significantly lower resting pressures ($p<0.03$). Morphology group was a significant factor for the defecography variables of resting ($p<0.02$) and lift ($p<0.001$) junction levels and lift angle ($p<0.02$), and for the manometry variables squeeze pressure ($p<0.03$), balloon volumes to perception ($p<0.004$) and urgency ($p<0.05$). Stepwise regression analysis showed lift junction level, squeeze

pressure and patient age were the variables which predicted rectal wall morphology grade ($p<0.0001$).

Patients with constipation and incontinence have similar changes in rectal wall morphology, including rectoceles, intussusceptions and enteroceles. Both defecography and manometry assessments show significant differences in patients with increasing degrees of rectal wall change, indicating weakened anorectal and pelvic floor musculature and less functional strength.

INTRODUCTION

Rectal wall changes are not always seen on external examination, routine radiology or colonoscopy because they do not occur at rest. The rectal wall changes usually develop during straining and recede during rest (Kuijpers and Strijk, 1984). Defecography is a particularly useful technique for detecting the presence of rectal wall changes. Because defecography is a dynamic study of defecation, one can visualize as well as collect qualitative and quantitative data on the development of transient changes in morphology of the rectal walls.

The most common change is rectocele, which is a bulge in the anterior of the rectal mucosa. Rectocele is measured from the expected line of the anterior wall of the rectum to the maximum depth of the bulge, (Shorvon et al., 1989a). When the walls of the rectocele fold in at the end of evacuation, barium can be trapped within. If the rectocele inverts into the rectum and folds over the anal canal at the end of evacuation, it becomes an anterior mucosal prolapse (Bartram et al., 1988). Rectocele is common in women and may be the result of the relatively weak recto-vaginal septum. Some women, when attempting defecation, apply intra-abdominal pressure to posterior wall of the vagina and use their fingers in the vagina to support the vagina and to press stool through the anus (Mahieu et al., 1984).

Intussusception is the slipping of one part of the rectum into the more distal part. It is described as a ring-like invagination of the entire rectal wall which usually starts in the middle of the rectum as an invagination of the prominent mucosal folds called the valves of

Houston. Intussusception is distinguished from the folds of the rectum by the relative increase in thickness of the mucosa fold, as seen on the defecography films (Fry and Kodner, 1985; Broden et al., 1988). The severity of intussusception was graded by Shorvon et al. (1989a) from one and two, (infolding of the rectal wall less than 3mm thick) to 7, (prolapse through the anal canal to protrude externally). Grade 7 is the same as procidentia or complete rectal prolapse when the full thickness of the rectal wall protrudes. Ekberg et al. (1985) describe intussusception as descending to the top of the anal canal which dilates allowing complete rectal prolapse to develop. Partial prolapse is the protrusion of only the mucosa. Skomorowska et al. (1987), Felt-Bersma et al. (1990) and Johansson et al. (1985), found that intussusception occurred at the end of straining and was often preceded by a rectocele. Roberts (1985) describes rectal prolapse as an intussusception which develops over ten to twenty years due to prolonged and excessive straining. It is found to occur eighty to ninety percent of the time in women after middle age, peaking around ages sixty to seventy. Sun et al. (1989b) found that patients with rectal prolapse were about twenty years older than patients with anterior mucosal prolapse and suggest that the disorders are different stages of the same condition.

Theories on the development of these changes include weak pelvic floor muscles (Goligher, 1975), a sliding herniation of the rectal wall and weak sphincter muscles (Bartolo et al., 1983b). Roberts proposes that anatomical defects such as weakened pelvic floor and anal sphincter muscles are secondary to the prolapse. This is supported by four pieces of evidence. Intussusception starts above the pelvic floor, patients can have prolapse and normal sphincter function, most defects in sphincter function are not changed by surgical repair (Keighley et al., 1980), and prolapse reoccurs in about 10 percent of the patients who have surgical repair (Williams et al., 1992; Christiansen, 1992).

In the patient with rectal prolapse a herniation of the small bowel can invaginate the anterior rectal wall and prolapse with the rectum and this is called an enterocele (Shorvon and Stevenson, 1989b; Ekberg et al., 1985). Mackle and Parks (1986) suggest that enterocele is a result of many years of chronic intussusception.

Most studies using defecography assessment mention rectal wall change in an qualitative way. The implications of the presence of rectal wall changes, such as rectocele and intussusception, to anal function in patients with defecation disorders are unclear. Defecography studies show healthy controls have a variety of rectal wall changes some severe, but report no symptoms (Shorvon et al., 1989a; Gibbons et al., 1986; Bartram et al., 1988). Ekberg et al. (1985), show that of eighty-three patients with dyschezia, twenty-eight had normal defecography and a variety of symptoms and sixteen patients with rectal wall changes had no symptoms. Mellgren et al. (1994) in a review of 2816 patients investigated with defecography found intussusception, prolapse and enterocele occurred with similar frequencies in patients with and without abnormal perineal descent. Rectocele was found more often in patients with abnormal descent. Seventy-seven percent of the patients had one or more pathological findings. Other studies have implied that rectal wall changes contribute to the patients' symptoms. Goei (1990) reports that twenty-eight percent patients he studied, with various disorders including constipation and incontinence, had rectocele and or intussusception. Incontinent and constipated patients have a similar incidence of rectocele as controls, but had significantly higher rates and larger intussusception (Bartolo et al., 1988b). Felt-Bersma et al. (1990) found sixty-seven percent of patients with incontinence also had rectal wall changes. Kuijpers et al. (1986b) studied ninteen patients with solitary rectal ulcer syndrome and a variety of other symptoms and thirteen were found to have rectal wall changes.

Intussusception had been implicated in both constipation and incontinence. Kuijpers et al. (1984), Roe et al. (1986), and Bartolo et al. (1988b) found an association between intussusception and obstructed defecation, in patients with constipation and abnormal perineal descent. Rectal wall prolapse occludes the anal passage preventing defecation and/or causing feelings of incomplete evacuation. Rex et al. (1992) found that of fifty incontinent patients, eleven had incomplete evacuation of the barium paste at defecography due to rectocele and intussusception.

A few studies of defecography assessment have looked at rectal wall morphology in a quantitative way. Johansson et al. (1990) reported a study of twenty patients with intussusception and prolapse who were evaluated with defecography and electromyographic recordings. Three patients with prolapse had striated muscle activity which disappeared completely during straining and did not recover until the prolapse was reduced. This was unlike the controls who had a pronounced contraction of the striated muscles after straining. They suggest that reason for incontinence with rectal prolapse is this absence of striated muscle activity. Ekberg et al. (1985) found that patients with internal procidentia had twice the descent movement of the pelvic floor on strain compared to controls. Turnbull et al. (1988) showed that angles, junction level descent on staining and anterior rectocele did not discriminate between constipated patients and controls. This study did show that barium was held in the folds of the rectal mucosa more often in the constipated patients than in the controls.

Several studies have found manometry results are different for patients with changes in rectal wall morphology compared to controls. Snooks et al. (1985b) found no manometric differences between incontinent patients and incontinent patients with rectal prolapse, both groups were significantly different from controls. Keighly et al. (1980) found decreased resting and squeeze pressures in incontinent patients with prolapse compared to controls. The patients with only prolapse were not significantly different from controls, although they were in the same age range as the incontinent patients with prolapse. In patients with anterior mucosal prolapse and rectal prolapse, Sun et al. (1989b) found resting and squeeze pressures and volumes to urgency to be significantly lower than controls. Siproudis et al. (1992) found that increased grades of intussusception were associated with decreased resting pressure in patients with defecation difficulties including incontinence. They also found that patients with larger rectocele required significantly larger volumes to urgency and discomfort.

Bartolo et al. (1988b) reported a quantitative study of manometry and defecography assessments of patients with obstructed defecation. In Bartolo's study patients were divided into groups with intussusception and prolapse and compared to controls. Patients with prolapse had higher squeeze pressures, increased strain angles and lower lift and strain junction levels compared to controls, but not to patients with intussusception. Patients with intussusception had lower strain and lift junction levels compared to controls.

The purpose of this study is to describe the relationships between the rectal wall changes, manometry and defecography assessments and patient characteristics.

METHODS

The methods for defecography and manometry and the subject sample were the same as previously reported. In this study there were forty-six patients with anorectal dysfunction: twenty-one incontinent and twenty-five constipated.

Pearson's correlation was used to examine the relationship of the grade of rectocele, intussusception and the presence of absence of enterocele and the manometry and defecography variables, patient age and parity. Oneway analysis of variance was used to examine the relationship of the rectal wall morphology with the manometry and defecography variables. Aposteriori range tests (Neuman Keuls) were used to contrast the group means and to show where the significant differences and similarities between the groups occurred. Two factor analysis of variance was used to examine the influence of patient group (incontinence and constipation) and rectal morphology grade on the manometry and defecography variables.

Stepwise multiple regression was used to find the variables which best form a model to predict rectal wall changes.

RESULTS

There were no significant differences in the patient groups in terms of the presence or degree of rectal wall changes. There were no significant differences in the patient groups for rectal emptying during defecography or for the symptoms of the feeling of urgency, incomplete bowel movement or pain. Only three of the patients had complete emptying during defecography.

Thirty-six of the patients had rectocele, twenty-six of the patients had intussusception and eight had enterocele. In the first analysis, the relationships between the grade of rectal wall change and the manometry and defecography variables were examined. Because of the small sample size, the grades of rectocele and intussusception described by Shorvon and Stevenson (1989b) were collapsed into three groups, 0 or no change was group one, grades 1 to 3 were group 2, and grades 4 to 7 were group 3. There were no significant differences in the rectocele grade groups for any of the manometry or defecography variables. In the intussusception grade groups there were significantly lower resting and lift anorectal junction levels with greater degrees of intussusception, ($p<0.01$). Age was also related to increased grades of intussusception, ($p<0.03$). There were no significant differences in anorectal angle or any of the manometry variables with intussusception. There were eight patients with enterocele, three were incontinent and five were constipated. The patients with enterocele were significantly older compared to the other patients, ($p<0.003$). They had significantly lower resting, strain and lifting anorectal junction levels, ($p<0.01$), resting and lifting angles ($p<0.01$), resting pressures ($p<0.05$), and squeeze pressures ($p<0.02$).

Most patients had rectal wall changes, and a number of them had more than one type. Intussusception was significantly correlated with enterocele (r .44, $p<0.01$), and rectocele (r .29, $p<0.05$). A new way of classifying rectal wall morphology was developed to examine the effects of the combination of change types. The changes in rectal wall morphology were classified as follows: 0 no change, 1 rectocele only, 2 intussusception and intussusception with rectocele and 3 enterocele and enterocele with intussusception and rectocele, (Table 1). The morphology grade was significantly correlated with anorectal junction levels and angles, resting and squeeze pressure and patient age, (Table II). There was a positive but not significant correlation between the morphology groups and parity.

Patients with no rectal wall changes had manometry values similar to reported normal values and significantly different from patients with higher grades of rectal morphology; for resting ($p<0.04$) and squeeze pressure ($p<0.02$), and balloon volumes to induce feelings of urgency ($p<0.02$) and discomfort ($p<0.03$). These patients differed from the patients with rectocele and intussusception in needing the greater balloon volumes to induce the feeling of something in the rectum. Five of the six patients in this group were constipated. Lack of rectal sensitivity may be the chief problem contributing to anorectal dysfunction in these patients (figure 1).

Patients with rectocele had significantly higher lift junction levels than patients with intussusception and intussusception and rectocele ($p<0.001$). On the remaining defecography variables there were no significant differences; however, the patients with intussusception consistently had values which reflected weaker muscles, than the patients with no change or rectocele only.

The analyses of the defecography variables showed patients with enterocele and intussusception had significantly wider lift angles than the other patients ($p<0.01$). Patients with enterocele and intussusception had lower resting junction levels than patients who had only rectocele ($p<0.01$). These patients were also significantly older than the patients with no changes or patients with rectocele (figure 2).

Analysis of variance with two factors (patient group and morphology grade) showed the factor morphology grade significant for the defecography variables of resting ($p<0.02$), and lift ($p<0.001$) junction levels and lift angle ($p<0.02$) and for the manometry variable of volume to perception ($p<0.01$). Higher morphology grades were also associated with older patients ($p<0.001$). Patient group was the significant factor for resting pressure ($p<0.03$). Incontinent patients had lower resting pressures. Stepwise regression analysis showed lift junction level ($p<0.001$), total squeeze pressure ($p<0.0002$), and patient age ($p<0.0001$), formed the equation which predicted the degree of rectal wall change, (adjusted R square .362, F 9.50 $p<0.0001$). Lift anorectal junction level accounted for 23 percent of the variance between the morphology grades. Total squeeze pressure explained and additional 10 percent, and age added 8 percent more to the explained variance. The rest of the variables, although they may be important in understanding the influence of rectal wall changes, did not explain significantly more of the variance.

CONCLUSIONS

This study that shows there are significant differences in both defecography and manometry assessments of patients with rectal wall changes. Patients with constipation and incontinence have similar changes in rectal wall morphology, including rectoceles, intussusceptions and enteroceles. Manometry assessment shows that patients who have rectal wall changes have reduced resting and squeeze pressures and patients with incontinence have the lowest pressures. The reduced rectal sensitivity to small volumes and increased sensitivity to feelings of urgency indicate that changes in rectal wall morphology are associated with changes in rectal sensitivity. Large grades of rectal wall changes are associated with lower resting and lift junction levels and wider lift angles, indicating weakened pelvic floor muscles at rest and muscles with less functional strength. Regression analysis shows that it is the functional strength of the muscles of the pelvic floor and the external anal sphincter as well as the patient's age which predict the degree of the rectal wall change.

Patients with no rectal wall change are the closest of all the groups to the values reported in the literature for healthy controls. These patients show impaired rectal sensitivity. They are young and five of the six were constipated. These patients may be good candidates for biofeedback training to increase their cognitive awareness for rectal sensations, such as Burser and Miner (1986) developed for incontinent patients.

Patients with rectocele, intussusception and enterocele consistently reflect greater degrees of muscle weakness as shown by both the manometry and defecography assessment variables. Patients with no rectal wall changes or rectocele only, have the least dysfunction and patients with enterocele the most. However, there is no reliable evidence that pre-operation manometry or defecography assessment can predict good outcomes for surgery. Low resting and squeeze pressures assessed by manometry prior to surgery are predictors of poor outcomes in some studies (Williams et al., 1991).

Surgical treatment for rectal wall changes should be reviewed with caution as suggested by Wald et al. (1990) as there is little evidence that there is any correlation between rectal wall changes and the symptoms of either constipation or incontinence. Surgery is successful in reducing symptoms in about half the incontinent patients with rectal prolapse Williams et al. (1991), but has had poor outcomes for constipated patients with rectal prolapse. Christiansen et al. (1992) found that intussusception is secondary to patient symptoms. They found that surgery had a limited effect on the symptoms of the constipated patients and may have aggravated a pre-existing emptying disorder. Johansson et al. (1985) also found patients with obstruction and intussusception had poor results with surgery and in a third of the patients the symptoms worsened. Patients with incontinence and intussusception also had evacuation difficulties after surgery and this may indicate that they also had a pre-existing emptying disorder. Fleshman et al. (1992a), Wexner et al. (1992) and Turnbull and Ritvo (1992), have developed successful biofeedback programs to help constipated patients to relax the pelvic floor muscles. Such biofeedback programs may also be beneficial for incontinent patients. The importance of changes in rectal wall morphology to the pathogenesis of anorectal dysfunction is not clear. Many patients with incontinence report a previous history of constipation and it seems likely that the combination of years of straining at stool and aging have weakened the pelvic floor musculature, and this in turn encourages rectoceles to develop into intussusception. Histological studies of the external anal sphincter muscles of aging humans show changes in the thickness of the connective tissue fibres associated with friable and loose collagen fibres, which contribute to weakened sphincter strength responses (Meunier, 1986).

The changes in rectal wall morphology may contribute to the patients' symptoms in a mechanical way. The intussusception may block the anal passage causing the constipated patient to strain harder when trying to defecate. The intussusception many also enclose stool in the folds of the rectal mucosa, which if the patient has weak anal sphincter, leak out later as soiling. When the pelvic floor muscles are extremely weak they can no longer support the small bowel and enteroceles develop.

Rectal wall changes are a reflection of weak and damaged anorectal musculature in this study. The combination of rectal wall changes with weak pelvic floor and sphincter muscles do not account for the patients' symptoms. Studies with greater sample sizes may be more sensitive in revealing the relationship between patient symptoms, history, age, pelvic floor and anorectal function and the size and type of change in rectal wall morphology.

TABLE I. INCONTINENT AND CONSTIPATED PATIENTS AND RECTAL WALL MORPHOLOGY GRADE

MOPHOLOGY GRADE	N	CONSTIPATION	INCONTINENCE
0 NO CHANGE	6	5	1
1 RECTOCELE	13	7	6
2 RECTOCELE AND INTUSSUSCEPTION	19	8	11
3 RECTOCELE, INTUSSUSCEPTION AND ENTEROCELE	8	5	3

TABLE II. CORRELATION OF DEFECOGRAPHY AND MANOMETRY VARIABLES AND RECTAL WALL MORPHOLOGY GRADE

DEFECOGRAPHY	PEARSONS' CORRELATION	SIGNIFICANCE
Junction levels		
Resting	.381	$p<0.01$
Lifting	-.470	$p<0.001$
Straining	-.415	$p<0.004$
Angles		
Resting	.384	$p<0.01$
Lifting	.413	$p<0.003$
Straining	.300	$p<0.05$
MANOMETRY		
Pressure		
Resting	-.405	$p<0.01$
Squeeze	-.270	ns
Total squeeze	-.458	$p<0.001$
Volumes		
Perception	-.050	ns
Relaxation	-.045	ns
Urgency	-.204	ns
Discomfort	-.241	ns
AGE	.380	$p<0.01$
PARITY	.100	ns

Two-tailed Pearson's correlation

FIGURE 1 RESTING AND SQUEEZE PRESSURES AND RECTAL WALL MORPHOLOGY GRADE

```
MORPHOLOGY GRADE

O                             R---------------------------------//-S

1                  R---------------------------------------S

2            R-----------------------------------S

3      R-//-----------------S

    //--+----+----+----+----+----+----+----+----+----+----+-----+--//---+
mm Hg  40        50        60        70        80         90        100    135
```

Legend
R resting pressure p<0.04
S squeeze pressure p<0.02

VOLUMES TO PERCEPTION, URGENCY AND DISCOMFORT AND RECTAL WALL MORPHOLOGY GRADE

```
O                  P----------------------------U----M

1              P----------------U------M

2                P------------U--------M

3                  P---------------U--------M

       +----+----+-//-+----+----+----+----+----+----+----+----+--//-+
  cc   10        30   50   75   100      150           200          265
```

Legend
P volume to first perception p<0.01
U volume to feeling of urgency p<0.02
M maximum volume p<0.03

FIGURE 2 ANORECTAL JUNCTION LEVELS AND RECTAL WALL MORPHOLOGY GRADE

```
MORPHOLOGY GRADE

0                                SR------L

1                               S--------R-------L

2                         S------R----L

3           S-------R--L

            3----+----2----+----1----+----IT---+----1----+----2----+
      cm
```

Legend
S straining junction level p<0.04
R resting junction level p<0.01
L lifting junction level P<0.001

ANORECTAL ANGLES AND RECTAL WALL MORPHOLOGY GRADE

```
0                        L-------------R-----S

1                                L---------R----------S

2                                    L------------R-------S

3                                                     L----R------S

              +----+----+----+----+----+----+----+----+----+----+----+
degreees      80        90        100       110       120       130
```

Legend
L lifting angle p<0.01
R resting angle ns
S straining angle ns

DISCUSSION

SENSITIVITY AND SPECIFICITY

Manometry and defecography were evaluated three ways: first by comparing each of patient groups to healthy volunteers using analysis of variance; second by using discriminant function analysis to calculate the sensitivity and specificity of manometry and assessments; and third by comparing the patient groups using the assessment variables as well as age and parity to examine factors influencing discrimination between the constipated and incontinent patients.

The manometry variables of resting and squeeze pressure had significantly lower values in both patient groups compared to healthy volunteers in the same age range. Discriminant function and classification analyses showed that the manometry variables of resting and total squeeze pressure could separate the incontinent patients from the healthy volunteers and gave the manometry assessment a sensitivity of 79% and a specificity of 87%. The probability of a negative test in a patient with incontinence was .21 (1-sensitivity). Twenty-one percent of the patients had resting and squeeze pressures similar to the healthy volunteers, and other factors must be contributing to the symptoms of these patients.

Discriminant function and classification analysis based on the resting and squeeze pressures of the constipated patients and healthy volunteers showed that the two groups could be discriminated, but the sensitivity was only thirty-two percent. The probability of a negative test in a constipated patient was sixty-eight percent. The majority of the constipated patients were similar to the healthy volunteers. The specificity was the same as for the incontinent patient analysis at eighty-seven percent. Thirteen percent of the healthy volunteers had manometry assessments similar to the patient groups. This evaluation gives manometry assessments a .13 probability of a healthy volunteer having a positive test (1-specificity).

Manometry assessments can discriminate between constipated and incontinent patients. The discriminant function and classification analysis used the variables resting pressure, total squeeze pressure, and volume to urgency to separate the two patient groups. The variables of age and parity improved the classification of the constipated patients. The analysis of the two patient groups had a sensitivity of eight-eight percent in classifying the incontinent patients, but only a sixty-eight percent accuracy for the constipated patients. In this analysis thirty-two percent of the constipated patients were classified as incontinent. Inclusion of the manometry variables for rectal distention, age and parity will improve the discrimination between the patients and healthy controls.

The patient groups were significantly different from the healthy volunteers for the defecography variables of resting and lift anorectal junction levels and resting and strain angles. Discriminant function and classification analysis separated the each patient group from the controls with a sensitivity of 90 percent for the incontinent patients, a sensitivity of 88 percent for the constipated and a specificity of 95%. Movement of the anorectal junction with straining was the only variable which was significantly different between the two patient groups. Although the discriminant function was significant in separating the two patient groups the analysis could not classify the patients into the correct groups.

The combination of manometry and defecography assessments for the patient groups improved the discriminant function classification analysis for the constipated patients from seventy six percent with manometry to eight-eight percent with the combination of manometry and defecography variables. The classification for the incontinent was the same in both analyses at seventy-one percent. The variables in order of importance were volume to urgency, descent of the pelvic floor from resting levels with straining, resting pressure, volume to discomfort, age and strain anorectal junction level.

SYMPTOMS AND FUNCTION

Eighty-five percent of the incontinent patients had squeeze pressures of less than 60 mm Hg and fifty percent had resting pressures of less than 40 mm Hg. The incontinent patients had wider angles and lower resting and lifting anorectal junction levels than healthy volunteers but not when compared to the constipated patients. In most of these patients incontinence is the result of impairment of the sphincters, which was caused by trauma during childbirth, chronic straining at stool or disease such as diabetes or stroke. There was no relationship between the severity of incontinence and any of the manometry or defecography variables.

The constipated patients had higher resting and squeeze pressures than the incontinent patients. Their manometry variables were significantly lower than the healthy volunteers. The combination of manometry and defecography showed significant correlations in the constipated patients between resting pressure, angle and junction level, and total squeeze pressure and lift junction level, but not with lift angle. Neither the manometry or defecography variables were related to symptom severity in the constipated patients. Assessment with manometry and defecography showed muscle impairment in the constipated patients, but did not clarify the cause of the symptoms. Changes in rectal wall morphology are not associated with the patients' symptoms, but with lower lift junction levels, lower total squeeze pressures, and age.

PARITY AND AGE

Parity is associated with lower total squeeze pressure and wider resting and lift anorectal angles of the constipated and incontinent patients in this study. Ageing was associated with low resting pressures and wide lift anorectal angles. The combination of aging and increased parity may increase the risk of future incontinence in some of the constipated patients.

CLINICAL USEFULNESS

The clinical usefulness of manometry can be enhanced by presenting the data in a graph which clearly demonstrates the changes in resting and squeeze pressure in the patient compared to controls. The use of the manometry index based on resting and squeeze pressures presents the manometry variables in a way that makes the specific areas of impairment obvious. The index has the advantage over reporting the variables individually in that places the patient in context with other patients and clarifies the type of dysfunction.

Patients can be identified as having weakness in the internal or external anal sphincter, both or normal function.

The defecography assessments can also be reported in a way that illustrates the changes in junction level and angle at rest and during lifting and straining. The comparison of the patients' assessment with that of controls shows that there are significant changes in function in the patient groups compared to controls, but the patient groups are similar.

PREDICTION OF PATIENT OUTCOME

These studies give evidence to support the hypothesis that manometry and defecography assessments can be used to predict patient outcomes. Information for making a prognosis and treatment plans is revealed when individual patients are evaluated in context with other patients and controls. Manometry and defecography variables were used in discriminant function and classification analysis to position patients and controls on the continuum and to make predictions on individual patient's prognosis. The continuum describes the degree of anorectal dysfunction for each patient. The continuum is made from the combination of individual assessment measures and gives each patient a score. The scores show that incontinent patients have the most dysfunction and the controls the least. The constipated patients' scores fall between those of the incontinent and controls. The continuum does not describe the patient's severity of symptoms for either constipation or incontinence, nor does it describe the symptoms caused by other factors including disease, trauma, infection and changes in stool consistency.

Of more use for patient evaluation was the discriminant function classification analysis, which yields probabilities for group membership for each patient. The results showed that about a third of the constipated patients were more like the incontinent group and may be at risk for future incontinence. The incontinent patients misclassified as constipated are closer to the healthy end of the continuum and may respond best to treatment.

In conclusion manometry assessment and patient history examined in context with other patients and controls by using an index of function is a clinically useful tool. A prognosis of risk of future incontinence or the likelihood of successful treatment can be derived from using the manometry variables in the index and in discriminant function analysis. Long term follow up of patients is necessary for confirmation of these hypotheses. Ageing is a factor in reduced resting pressures and increased parity in reduced squeeze pressures. Defecography is useful in evaluating rectal wall changes in patients with defecation disorders and in research toward a better understanding of defecation disorders.

APPENDIX 1

ANORECTAL MANOMETRY REPORT

DATE:
PATIENT:
HOSPITAL ID:
REFERRING PHYSICIAN:
MANOMETRY DATE:
CLINICAL INDICATION:

PRESSURE RECORDING:

```
CONTROLS:                                R-------------------------S

PATIENT:    R---------------S
        30----40----50----60----70----80----90---100----110--//---150
pressure mm Hg
```

R resting pressure: 36 mm Hg
S squeeze pressure: 65 mm Hg

RECTAL SENSITIVITY

```
CONTROLS:     P---------------------------------------U-----//-------M

PATIENT:        P--------------U----M
             20---40----60----80----100---120---140---160----180-//------300
volume in cc
```

P = volume to first perception: 20 cc
U = volume to feeling of urgency: 75 cc
M = volume to discomfort: 95 cc

COMMENTS:

APPENDIX 2

DEFECOGRAPHY REPORT

DATE:
PATIENT:
HOSPITAL ID:
REFERRING PHYSICIAN:
DEFECOGRAPHY DATE:
CLINICAL INDICATION:

ANORECTAL JUNCTION LEVELS:

```
CONTROL:       S------------------R--------L

PATIENT:           S---R--------L
cm   +----+----+----+----+----+----+----+----+----+----+
          -2        -1        IT        1         2
                            ischial tuberosities
```

R = rest level: -0.7 cm
S = strain level: -1.1 cm
L = lift level: 0.2 cm

ANORECTAL ANGLES:

```
CONTROLS:  L-------------------------R------S

PATIENT:                                         L-----------R--------S
        +----+----+----+----+----+----+----+----+----+----+----+----+  degrees
             70           80          90         100         110        120
```

R = resting angle: 104
S = strain angle: 113
L = lift angle: 92

COMMENTS:

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