STUDIES IN ANORECTAL DISORDERS

FAECAL INCONTINENCE
AND
INTRACTABLE CONSTIPATION

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I

This thesis is dedicated

to my husband

Nicholas

Statement

I declare that all the work contained in this thesis has been performed by myself unless otherwise stated herein.

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OδΗΓΟΣ ΚΑΙ ΒΟΗΘΟΣ ΜΟΙ ΓΕΝΟΙΤΟ Ο ΘΕΟΣ

(So help me God)

Acknowledgements

Abbreviations

AC	anal canal functional length
AI	anismus index
ARA	anorectal angle
CAP	rectal maximum tolerable capacity
cm	centimetres
COM	rectal compliance
CP	EAS cough reflex pressure increment
DRATE	defaecation rate
DTIME	defaecation time
EAS	external anal sphincter
EMG	electromyography
EVAC %	percentage of the evacuated activity
H_2O	water
HPZ	high pressure zone
Hz	Hertz
IAS	internal anal sphincter
IRP	intrarectal pressure
LA	levator ani muscle
MRP	maximum anal canal resting pressure
ml	millilitres
mm	millimetres
ms	milliseconds
MUP	motor unit potential
MUPD	motor unit potential duration

OD	obstructive defaecation
p	probability
PAR	pudendo-anal reflex
PF	pelvic floor
PR	puborectalis
r	correlation coefficient
s	seconds
S2,S3,S4	sacral spinal segments 2, 3, and 4
SEM	standard error of the mean
SEN	rectal sensory threshold (in millilitres)
SQP	EAS maximum voluntary 'squeeze' pressure increment
V	volts
μV	microvolts

Publications Arising From This Thesis

PAPERS

Binnie NR, Kawimbe BM, Papachrysostomou M, Smith AN. Use of the pudendo-anal reflex in the treatment of neurogenic faecal incontinence. Gut 1990; 31: 1051-1055

Binnie NR, Kawimbe BM, Papachrysostomou M, Clare N, Smith AN. The importance of the orientation of the electrode plates in recording the external anal sphincter EMG by non-invasive anal plug electrodes. Int. J. Colorect. Dis. 1991; 6: 5-8

Kawimbe BM, Papachrysostomou M, Binnie NR, Clare N, Smith AN. Outlet obstruction constipation (anismus) managed by biofeedback. Gut 1991; 32: 1175-1179

Papachrysostomou M, Pye SD, Wild SR, Smith AN. Anal endosonography - which endoprobe? Br. J. Radiol. 1991 (in press)

Papachrysostomou M, Griffin TMJ, Ferrington C, Merrick MV, Smith AN. method of computerised isotope dynamic proctography. Eur. J. Nucl. Med. 1991 (in press)

PRESENTATIONS

Papachrysostomou M, Kawimbe B, Binnie NR, Smith AN. Electromyography Biofeedback in the treatment of obstructive defaecation (anismus). The British Pelvic Floor Society, May 1989, Edinburgh, Scotland

Papachrysostomou M, Pye SD, Wild SR, Smith AN. The significance of the thickness of the anal sphincters in faecal incontinence. The Caledonian Society of Gastroenterology, February 1991, Edinburgh, Scotland

Papachrysostomou M, Griffin TMJ, Merrick MV, Smith AN. Dynamic isotope proctography in constipated subjects. The British Society of Gastroenterology; March 1991, Manchester, England.

Papachrysostomou M, Smith AN, Griffin TMJ, Merrick MV. Dynamic isotope proctography (DIP) in patients with obstructive defaecation (OD). The Surgical Research Society, July 1991, Lancaster, England.

ABSTRACT

The thesis discusses disorders of anorectal and pelvic floor function, i.e. faecal incontinence and intractable constipation. Relevant anatomy, physiology and methodology are first described. Newer forms of apparatus were applied such as a surface anal plug electrode for non-invasive integrated electromyography, a pudendo-anal reflex electrical stimulator for activating the external anal sphincter and a form of EMG biofeedback for relaxation of the pelvic floor musculature. An essential part of the study is anorectal manometry. Various systems for the measurement of pressure are contrasted using both analogue and digital recorders. The digital system was the more sensitive, but the analogue system using a microballoon was free of orientational changes.

Over 200 patients with idiopathic faecal incontinence were examined by manometric and somatosensory testing, the majority of whom had pudendal neuropathy. Four subgroups were characterised, two with impairment of either the external or internal anal sphincters, another with both sphincters affected and a fourth with no apparent sphincter deficit but presenting an abnormal rectal compliance. The effect of stimulating the sacral outflow from the spinal cord, via the pudendal nerve to the sphincter mechanism, was therefore assessed and revealed significant improvement in tests of anorectal function. Radiological video-proctography provided an additional means of determining the contribution of stimulation of the S2, 3, 4 nerve roots to the control of continence, via observation of the anorectal angle and pelvic floor changes. The significance of the morphology of the anal sphincters in the control of continence was further assessed by anal endosonography. A preliminary study showed that increase in endoprobe size

altered the appearance of the internal anal sphincter. Variations for age and gender were established in both external and internal anal sphincters in asymptomatic controls. A reciprocal relationship was observed between the two sphincters in health, and the sum of their thicknesses was proportional to their tonic pressure, important in the control of continence. These associations were disturbed in faecal incontinence.

For the study of intractable constipation a computerised method of isotope proctography was devised and validated against radiological video-proctography. This allowed measurements of the anorectal angle, the pelvic floor movements and the adequacy of rectal evacuation in constipated subjects. The problem of obstructive defaecation was analysed by a dynamic study that combined proctography, intrarectal manometry and external anal sphincter electromyography. The efficacy of biofeedback treatment was evaluated by these parameters and showed reduction in the abnormally increased external sphincter voltage and increase in the anorectal angle thus facilitating defaecation.

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«... Be very careful, O physician, that in your study you show diligence and weigh matters according to these precepts, which means that you should investigate them thoroughly...»

Hippocrates, 5th C. BC

CHAPTER 1

INTRODUCTION

The disorders of defaecation are now being well recognised and attract much attention and special interest from both the gastroenterologist and the surgeon. Amongst these, functional disorders are associated with considerable emotional overlay, loss of self-respect and social deprivation.

In turn this has led, especially during the past decade to an increasing awareness of the problems of incontinence, motor disorders of the large bowel and abnormalities of rectal evacuation. This is not altogether a 'new' problem since Hippocrates in 400 BC described constipation and dysuria as persisting symptoms in chronic paraplegia (Hughes, 1988). However, in a western society in which the demographic structure is changing, there is an increasing number of elderly people, more commonly suffering from defaecatory problems. In addition a greater clinical awareness of these problems has stimulated an interest in physiological monitoring and more refined evaluation, and has required the availability of anorectal laboratory tests allowing a more thorough scientific assessment of these disorders. Furthermore, the development of radiological techniques has given a better understanding of the pathophysiology of certain aspects of these defaecatory disorders.

Increased co-operation between the various disciplines also brings patients into contact with other specialists. Patients under the care of gastroenterologists, coloproctologists, geriatricians, neurologists, urologists, gynaecologists may require joint management of faecal and urinary incontinence, constipation and other seemingly intractable bowel and pelvic floor disorders.

The normal defaecatory process requires mechanisms of continence and evacuation. This is in turn dependent upon normal anorectal anatomy

and innervation for the integration and regulation of the complex functions of the pelvic floor. Anorectal trauma and pelvic nerve damage result in dysfunction of the distal colon, pelvic floor and external anal sphincter. Manometric, electrophysiological and radiological techniques are the means most commonly used to assess these problems.

Studies have now been reported using an instrumental means of correcting disorders such as faecal incontinence and constipation. The measurement of the external anal sphincter has been facilitated by the use of an anal plug surface electrode (Binnie et al, 1991), employed to detect any inappropriate increase in EMG voltage on attempted straining in constipated patients with features of obstructive defaecation. In these patients with intractable constipation due to non-relaxing pelvic floor muscles on attempted defaecation, a biofeedback approach has been adopted (Kawimbe et al, 1991). A new investigative method for patients with intractable constipation has been developed in the form of a dynamic computerised isotope proctography (Papachrysostomou et al, 1991), and has served as a means of evaluating objectively any improvement achieved by the biofeedback treatment as well as illuminating facets of the defaecatory mechanism (Hallan et al, 1988; Orrom et al, 1991).

For neurogenic faecal incontinence attributable to pudendal neuropathy an externally applied electrical stimulator has been devised and applied to this problem by Binnie et al (1990). The appearance of the anal sphincters have been studied by anal ultrasonography, measuring the thickness of the anal muscles in health and faecal incontinence (Papachrysostomou et al, 1991) as well as detecting any apparent defects in them. Radiological videoproctography has been used to investigate and assess patients with faecal incontinence in whom electrical stimulation has

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been applied. In the light of this, aspects of the continence mechanism have been investigated to facilitate a more special approach to the attempted correction of this problem.

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A fundamental requirement for understanding anorectal function, is an accurate knowledge of the anatomy of the anorectum and its related structures. This region is undoubtedly one of the most difficult parts of the human body to dissect and understand (Kerremans, 1969) and conflicting statements about its structure still persist (Duthie, 1981; Shafik, 1975; Oh and Kark, 1972).

1.1 ANATOMY

The gastrointestinal tract may be described in terms of the foregut, midgut and hindgut. The hindgut extends distally from the middle of the transverse colon. The rectum commences at the level of the third sacral vertebral body and extends to the junction with the anal canal, the anorectal junction, at the level of the muscular diaphragm of the pelvic floor (Ellis, 1977).

1.1.1 Pelvic Floor

The major component of the pelvic floor is the pelvic diaphragm composed of a pair of symmetrical predominantly striated muscles, the

levator ani. This muscle can be divided conventionally, into four parts. The puborectalis and pubococcygeous components are both attached to the pubic bone. The puborectalis runs around the ano-rectal flexure (anorectal junction) as a muscular loop (Figure 1.1). The pubococcygeous arises from the pubic bone in continuity with the puborectalis but extends laterally and is attached onto the ventral sacrococcygeal ligament unlike puborectalis which has no significant attachment to the vertebral column. The medial part of the pubococcygeous is further subdivided into the levator prostatae, pubo-urethralis and pubovaginalis, merging with the musculature of prostate, perineal body and vagina. Some of the pubococcygeous fibres enter the anal canal wall medial to the puborectalis, thus reinforcing the longitudinal smooth muscle (Wood, 1985).

The third part of the levator ani is the iliococcygeous which originates from the medial surface of the ischial spine and the arcus tendineus that overlies the ileum. It inserts onto the lateral surface of the terminal pieces of coccyx, the tip of the coccyx and the anococcygeal raphe overlapping on the perineal surface of pubococcygeous. The fourth component is the ischiococcygeous that arises from the tip and posterior surface of the ischial spine and is inserted into the lateral surface of the caudal part of the sacrum and the upper coccygeal vertebrae. This is often rudimentary and is represented in the human by a few muscle fibres on the surface of the sacrospinous ligament (Wendell-Smith, 1967). Anterior and posterior to the anal canal lie the perineal body and postanal plate respectively, which are fibromuscular structures fused to the levator ani muscles.

Wilson (1973) and Lawson (1974) have come to a different interpretation of levator ani's form, which subdivides the muscle into a posterior group of 'somatic', 'diaphragmatic' or 'obturator' muscles, and an
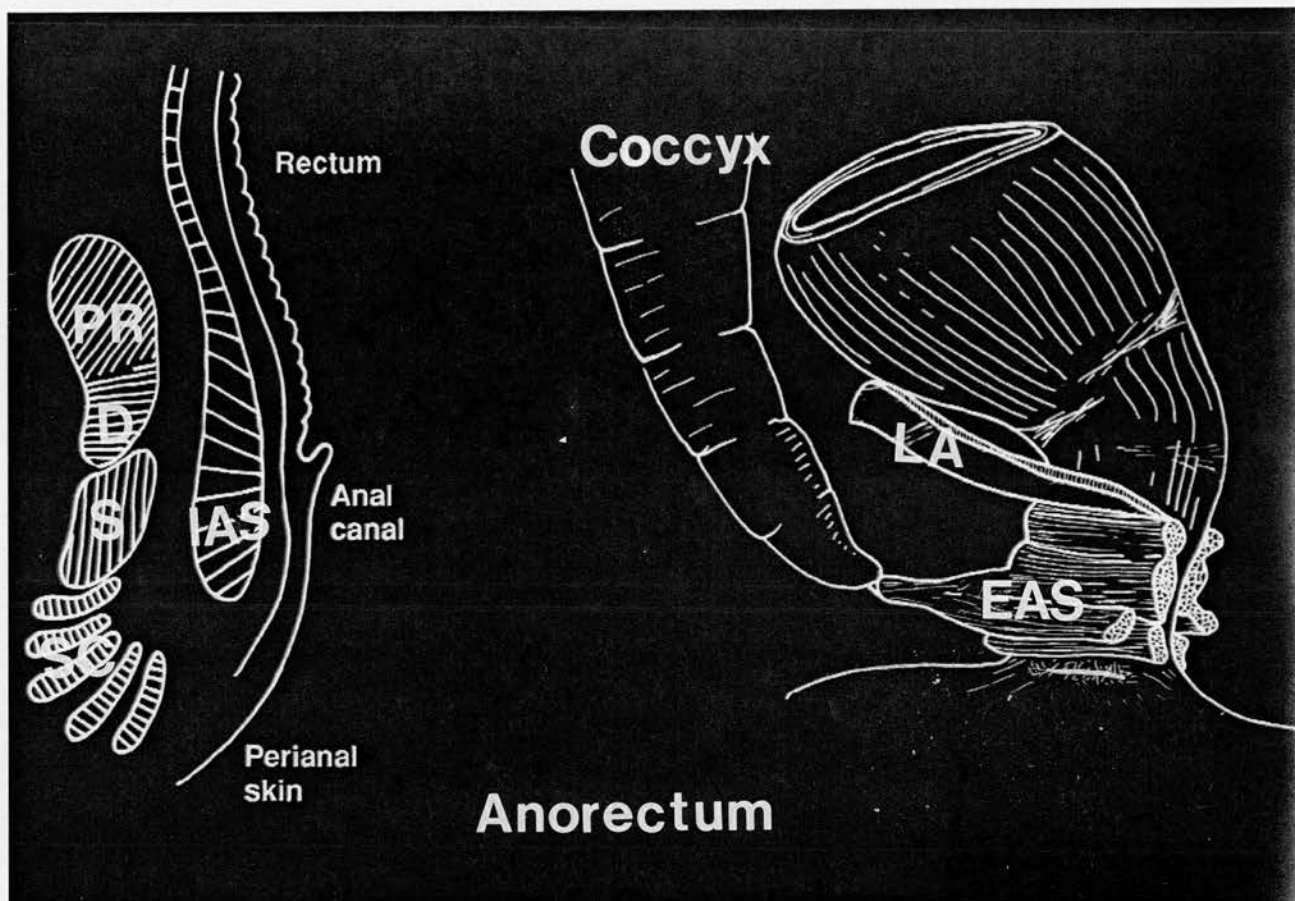
Figure 1.1   Diagrams of the Anorectum.
Left: A coronal section of the anal sphincters. The internal anal
sphincter (IAS) lies within the external anal sphincter (EAS) and
extends from the puborectalis ring to the anal verge. This
consists of a thickening of the circular muscle of rectal coat.
The EAS can be described as consisting of three parts - the deep
(D), the superficial (S) and the subcutaneous (SC). The D portion
is fused with the puborectalis part (PR) of the levator ani, and
is mainly an annular muscle. The S portion is elliptical in form
and lies below the D part and has a major attachment posteriorly
on the dorsal surface of the coccyx. The SC portion is below and
outside the end of the IAS and is an annular muscle.
Right: An illustration of external anal sphincter musculature and
levator ani (LA). The three portions are depicted - the deep, the
superficial and subcutaneous. This division of the EAS into three
parts is a classical description of it, however, it is considered
impossible to distinguish between these described portions of the
EAS. The S portion is posteriorly attached to the coccyx.
(Redrawn from Oh and Kark, and Reeve.)

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anterior group of 'visceral' fibres that is linked to the deep part of the striated external anal sphincter. Whether the external anal sphincter and the puborectalis part of the levator ani form a homogeneous unit, or form a heterogeneous muscle complex this depends on the onto- and phylogenesis of these muscles.

The levator ani seems to have a common developmental origin with the external anal sphincter and appears in the embryo at eight weeks (Nobles, 1984). However, the distribution of muscle in cases of anal agenesis would suggest that the levator ani and the external sphincter arise separately (Stephens and Durham-Smith, 1971). Wendell-Smith (1967) studied the phylogeny of the sphincter and showed that two groups of muscles exist related to the cloaca, ontogenetically and phylogenetically distinct from each other. The first group, 'sphincter' muscles, was present in most animals investigated. The second group, 'pelvicaudal' muscles, connected the rudimentary pelvis to the caudal end of the vertebral column.

In higher mammals, the sphincter musculature is divided into a ventral or urogenital, and a dorsal or anal, group of muscles; the latter make up the external anal sphincter. Furthermore, a group of striated muscle fibres encircle the rectum and attach to the symphysis pubis, parallel and closely applied to the pelvicaudal muscles. These fibres are well developed in man and are known as the puborectalis. In the female fibres run in the figure of eight pattern around the rectum and vagina to reach pubis (Elftman, 1932). On the basis of the above evidence, it is believed that the puborectalis is part of the sphincter cloacae complex (Wendell-Smith, 1967) and is separated from the pelvicaudal group of muscles together with the rest of the sphincter musculature (Lawson, 1974).

1.1.2 Anorectum

The anal canal was regarded, prior to Symington's account in 1889 as the distal, terminal, portion of the rectum, the so called 'pars analis recti'. There are two anal canals : a longer 'clinical' or 'functional' (approximately 4 cm long), and a shorter 'anatomical' or 'embryological' (about 2 cm long). The 'anatomical' one is said to extend from the anal valves to the anal margin, whereas the 'functional' is described proximally at the level of the anorectal ring as it corresponds to the distal end of the rectal ampulla (Milligan and Morgan, 1934). The anal canal that will be referred to in the chapters of this thesis will concern the 'functional' canal as this is believed to play an important physiological role in the mechanisms of continence and defaecation.

The junction between the rectum and anal canal occurs at an angle of about 80-100 degrees. This angle is maintained by the tonic contraction of the puborectalis loop (Bennett and Duthie, 1964). The anal canal is a narrow muscular channel, forms an anteroposterior slit with its lateral walls in close contact which passes downwards and posteriorly through the pelvic floor. It is surrounded by two muscular sleeves, the internal anal sphincter, composed of visceral smooth muscle, and the external anal sphincter, consisting of striated muscle. The tonic activity of the above mentioned muscles ensures a usually closed canal (Ellis, 1977).

1.1.3 The Construction Of The Anorectal Wall

Starting from the luminal surface the following layers make up the wall :

The innermost layer is the mucosa, which consists of the epithelium,

the lamina propria and the muscularis mucosae. The epithelium is glandular (except in the most distal 1-2 cm of the anal canal is squamous) and is formed into glands, the crypts of Lieberkuhn. The principal cell of the epithelium is the columnar absorptive cell. There are abundant goblet cells and sparse enteroendocrine of Type D, D1, EC, L and PP cells. The lamina propria fills the space between the epithelium and the muscularis mucosae and is made up of a stroma of connective tissue fibres, mainly collagen. The muscularis mucosae consists of a thin layer of muscle cells surrounded by a network of collagen and elastic fibres and separates the lamina propria from the submucosa (Gabella, 1988).

The submucosa is filled with a loose stroma of collagen and elastic fibres and contains branches of arterioles, capillaries, venules and plexus of nerves. The muscularis propria lies in two layers the inner or circular muscle layer and the longitudinal muscle covering the circular one. The intermuscular space contains neural elements of the myenteric plexus and vascular plexuses of arterioles, capillaries and venules. The serosa, a continuous sheet of squamous epithelial cells invests the outer surface of the colon (Christensen, 1988).

Smooth Musculature

The distribution of smooth muscle in the rectum is typical for the gut. It has a modest muscularis mucosae, an inner circular and an outer longitudinal muscular layers. The thickness of the circular muscle increases to form the internal anal sphincter (IAS), of about 3-4 cm long, that extends distally to form the inner layer of the muscular wall of the anal canal. The IAS is powerful circular muscle, of 0.15 to 0.5 cm thick, the lower border of which usually reaches the anal margin (Figure 1.1). The sphincter has a

homogeneous structure and is made up of dense bundles of smooth muscle cells. Within a bundle of smooth muscle, there are thin sheets of collagen fibres that do not separate the muscle cells enough to interfere with cell to cell contact. Connective tissue, collagen fibrils with fibroblasts, fill the spaces between bundles, binding them together (D' Mello and Bennett, 1981).

The longitudinal muscle becomes diffuse around the rectum, concentrated in broad bands which are connected with the perineal body and the coccyx. It splits at the anorectal junction and descends between the internal and external anal sphincters. Some fibres lie on the inner aspect of the internal sphincter; these are called the muscularis mucosae ani (Hughes, 1957). The more substantial part of it lies between the internal and external sphincters. Inserted just below the anal valves, is the mucosal suspensory ligament (Parks, 1956).

Striated Musculature

The external anal sphincter (EAS) is derived from the posterior part of the cloacal sphincter and is a complex muscle that can be divided into three layers : the deep, superficial and subcutaneous (Figure 1.1). The deep part decussates anteriorly, attached to the pubis in close relation to the puborectalis. The superficial part has an elliptical shape and is attached posteriorly to the coccyx. The subcutaneous part is regarded by many as a ring of muscle without any distinct ventral or dorsal attachments. There is still debate about the form of the EAS structural arrangement. Some investigators abandoned the trilaminar structure of this muscle in favour of a bi-compartment consisting of a superficial and deep layers stressing about the variability and sex differences in the form of the EAS. Shafik (1975) regarded the EAS as a series of three loops (top, middle and base loop), whereas

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Ayoub (1979) rejected any subdivision of the EAS into component parts, commenting on the great degree of variation between specimens. Two fibre Types were identified in the EAS : a tonic type and a kinetic type. (Parks et al, 1977). The external anal sphincter and puborectalis muscles contain predominantly Type I than Type II fibres, which are larger in diameter, as would be expected in muscles in a state of tonic contraction, unlike other striated skeletal muscles in the body (Wunderlich and Swash, 1983). Oh and Kark (1972) stressed that there are sex differences in the structure of the EAS. Anteriorly, in the male, the conjoined longitudinal fibres envelop the deep EAS but the laminar pattern is well maintained; in the female, the EAS is totally encapsulated by conjoined longitudinal fibres. Hence the length of the EAS is shorter in the female than in the male.

1.1.4 Innervation Of Pelvic Floor And Anorectum

Wendell-Smith (1967) showed that the pudendal nerve supplied the 'sphincter cloacae derivatives' on their perineal aspect, whereas sacral plexus branches supplied the pelvicaudal muscles on their pelvic surface. However, recent in vivo studies, via electrophysiological investigations of the puborectalis, showed EMG activity in the ipsilateral puborectalis after stimulation of the sacral nerves above the pelvic floor (Percy et al, 1981).

Sensory Innervation

Sensory innervation to the rectum is via autonomic nerve fibres. Abundant non-myelinated nerve fibres and one ending of an intra-epithelial receptor have been identified, in the rectal mucosa (Duthie and Gairns, 1960). Sensation of rectal distention is transmitted through the pelvic

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splachnic nerves to S2 and S3. Little doubt exists that there are several types of mucosal receptors which enable individuals to distinguish between fluid, solid and gaseous distention. In addition, stretch receptors are present within the muscle layers (Christensen, 1981). Others however are outside the muscle layers in the mesentery, and can respond to forces transmitted through mesenteric connectors during contraction and distension. Clifton (1976) demonstrated the existence of some receptors in the mucosa of the anal canal and rectum, responding to high levels of pressure applied locally to their punctate endings; these are regarded as nociceptors. Nociceptive information travels in both the parasympathetic and sympathetic (inferior and superior hypogastric plexuses).

The cutaneous sensation experienced in the perianal region and the anal canal wall below the dentate line, is conveyed by the afferent fibres in the inferior rectal nerve, since this can be abolished by an inferior rectal nerve block. Anal and guarding reflexes can be obtained by perineal scratch and anal penetration, respectively, and are responsible for sudden contractions of the EAS. These are spinal reflexes since they are preserved in the paraplegic patients (cortical control is not involved). A poorly defined dull sensation, experienced in the mucosa above the dentate line in response to touching or injection of haemorrhoids, is possibly mediated via the parasympathetic nerves. Afferents in the pudendal nerve travel in Lissauer's tract from S3 to L1, and enter the dorsal columns. Duthie and Gairns (1960) were able to show by qualitative testing that the anal canal is sensitive to pain, heat and cold, touch and movement.

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Motor Innervation

◆ Intrinsic Innervation

The intrinsic nerve supply to the colon is via the myenteric plexus and the submucosal plexuses. The myenteric (Auerbach's) plexus mainly controls colonic movements while the submucous (Meissner's) plexus mainly controls the colonic absorption and secretion. The distribution density of the ganglion cells appears uniform along the colon. However, in the rectum, the ganglia are smaller and fewer and the nerve bundles are thinner than in the proximal colon. The intrinsic nerves of the colon have been shown via immunofluorescence to contain various regulatory peptides such as substance-P, VIP, neurotensin, CCK, and somatostatin. The roles of these peptides in this location is not yet understood. Transmural electrical stimulation illustrates that the excitatory response involves both cholinergic and non-cholinergic transmitters while the inhibitory response is non-adrenergic and non-cholinergic (Taylor and Bywater, 1988).

◆ Extrinsic Innervation

The rectum and IAS are innervated by the autonomic nervous system, sympathetic and parasympathetic.

1. Sympathetic innervation

The cell bodies of the sympathetic preganglionic neurones emerge in the ventral roots of the thoracic and upper two lumbar spinal nerves as white rami communicantes. Their axons run in the lumbar splachnic nerves, and synapse with postganglionic noradrenergic neurones in the inferior mesenteric ganglion those axons reach the rectal ampulla and the internal anal sphincter via the hypogastric nerves. Postganglionic fibres in the

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grey rami communicantes from level T4 to L2 supply the viscera and vessels in the abdomen (Baron et al, 1985). Stimulation of the distal end of the hypogastric nerves, lumbar colonic nerves, or second, third, and fourth lumbar spinal nerves induces internal anal sphincter contraction. The excitatory effect of the sympathetic neurones is caused by release, at postganglionic nerve endings, of noradrenaline acting directly on smooth muscle cells through noradrenergic alpha-receptors (Bouvier and Gonella, 1981).

2. Parasympathetic innervation

The pelvic splanchnic nerves (S2-S4) provide the para-sympathetic supply to the rectum and the internal anal sphincter. Their axons leave the spinal cord by sacral nerve roots, run in the pelvic nerves, and synapse with postganglionic intramural neurones. Electrical stimulation of the pelvic nerves relaxes the internal anal sphincter in humans. The inhibitory effect of the parasympathetic nervous system is due to the activation of cholinergic preganglionic neurones connected to non-adrenergic non-cholinergic intramural inhibitory neurones (Shepherd and Wright, 1968).

The pelvic nerves supply the large intestine through the pelvic plexus. Nerve trunks from the sacral levels of the spinal cord form the pelvic plexus which lies about the organs above the pelvic floor. Colonic branches pass from the pelvic plexus to the upper rectum where they penetrate the longitudinal muscle layer to continue within the myenteric plexus. The pelvic plexus also receives fibres from the inferior mesenteric ganglion, so may be a minor pathway for the distribution of sympathetic fibres as well.

♦ Motorneurons

In the spinal cord, extending from the caudal S1 to the S3 segments, are the cell bodies of motorneurones innervating the urethral and

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anal sphincters, and pelvic floor muscles. This region has been termed Onuf's nucleus (Schroder, 1981). The EAS is supplied by the inferior rectal branch of the pudendal nerve, and the perineal branch of the fourth sacral nerve. Levator ani muscles are supplied, on their pelvic surface, by twigs from the fourth sacral nerves, and on their perineal aspect by branches from the lumbosacral plexus (Percy et al, 1981; Snooks and Swash, 1986). Studies in the rat have shown that sex steroids can bind Onuf's nucleus and there are more somatic neurones innervating the male pelvic organs. This may suggest that male subjects naturally have stronger pelvic muscles than female subjects (Sun and Read, 1989).

1.2 PHYSIOLOGY

In establishing the role of various functional parameters in abnormal states, it is important to study the normal physiological functions of the large bowel, and how the structure of the anorectum itself allows these functions to be performed. Undoubtedly, the physiology of the colon and anorectum are complex and not, as yet, fully understood. This is largely due to the lack of a suitable animal model of the human colon and the variability of the 'normal' colonic function in humans.

1.2.1 Physiology Of Defaecation

The factors that are thought necessary for defaecation are listed in Table 1.1. Defaecation is a complex act under the influence of the central

nervous system (Wood, 1981).

Table 1.1 Important Factors in Defaecation

Colorectal activity
Anorectal sensation
Abdominal force
Anal sphincters and pelvic floor musculature

Rectal distention and excitation of the anorectal mechanoreceptors stimulate the initiation of defaecation (Duthie, 1975). This act has two main components; a rise in intra-abdominal pressure and a contraction of the rectal wall associated with relaxation of the pelvic floor muscles and thus with straightening of the anorectal angle. There are three phases of response to distention of the rectum the sampling reflex, the accomodation reflex and the defaecation response (Duthie, 1982).

Colorectal Activity

It was originally believed that the receptors responsible for the detection of rectal distention were present within the rectal wall. However, similar sensations were demonstrated in the 'neo-rectum' in patients after total resection of the rectum (Lane and Parks 1977). Therefore, the receptors should lie outside the rectal wall. It has been suggested that muscle spindles within the pelvic floor muscles may be responsible for this function. When the rectum is empty, its spontaneous activity is minimal.

Rectal contractions are initiated with a frequency of 5-10/minute after some rectal distention. With some material entering the rectum thereafter,

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resulting in rectal distention, this is associated with a rise in the intrarectal pressure. During this period, there is a transient increase of the EAS activity and the IAS is slightly relaxed. The intrarectal pressure returns to its normal resting level after the rectum accomodates to the volume present. This is the sampling reflex and may occur in the absence of any rectal sensation (Duthie, 1975). The rectal contents increase in volume being appreciated by the subject as an urge to defaecate. The sphincteric responses are the same as in sampling reflex, e.g. increase activity in the EAS and relaxation of the IAS. However, the urge to defaecate passes off with rectal relaxation over a period of about 45 seconds. This is the accomodation reflex (Duthie, 1975).

The defaecation response occurs when the rectal contents reach the maximum tolerable rectal volume. The accomodation reflex ceases and an inhibition of the EAS follows the inhibited IAS. This drop in the anal canal pressures, in the presence of higher intrarectal pressures, allows defaecation to proceed. However, if defaecation is to be deferred a voluntary contraction of the pelvic floor and EAS muscles reinforces the sphincteric mechanisms and returns rectal contents from the upper anal canal to the rectal ampulla (Phillips and Edwards, 1965).

Anorectal Sensation

The process of defaecation is normally initiated by excitation of mechano-receptors in the anorectal region. These receptors are excited by rectal distention and contraction. The sensation aroused has been attributed to the firing of stretch receptors in the wall of the rectal ampulla (Duthie and Gairns, 1960). Patients, however, who had undergone coloanal anastomosis had a nearly normal sensation (Lane and Parks, 1977), suggesting the existence of receptors in the pelvic floor.

When the bowel content passes via the anal canal the subject is aware of its passage. The sensory nerve endings extend up to 1-1.5 cm above the anal valves (Duthie and Gairns, 1960). It is assumed that participation of this zone of sensation allows discrimination of the nature of the contents of the rectum (Duthie and Bennett, 1963).

Abdominal force

When the decision is made to defaecate, the subject takes up the sitting or squatting position. This allows straightening of the anorectal angle and therefore facilitates rectal evacuation (Barkel et al, 1988). The next stage is the performance of a Valsalva manoeuvre, closing the glottis and contracting the abdominal muscles. The rise in the intrarectal pressure results from transmission of increased intra-abdominal pressure caused by voluntary contraction of the abdominal musculature against a closed glottis. The rise in intra-abdominal pressure and the inhibition of the pelvic floor muscles result in pelvic floor descent (Kerremans, 1969). A transient increase in sphincter activity, that is observed with a rise in intra-abdominal pressure, is followed 1-2 seconds later with the pelvic floor inhibition (Womack 1989).

Anal Sphincters and Pelvic Floor musculature

The smooth muscle of the internal anal sphincter exhibits continuous activity. This electrical activity is observed as a regular cyclical wave pattern with an amplitude of 50 to 400 microvolts and a frequency of 10 to 40 cycles per minute (Kerremans, 1969). The inhibitory internal anal relaxation increases in depth and duration as the distending volume increases. This reflex is strongly bound to intrinsic innervation since it occurs normally in patients with high transection of the spinal cord (Frenckner, 1975). Recent

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studies, carried out in patients undergoing rectal excision, showed that the recto-anal reflex is present after bilateral hypogastric nerve blockade (Lubowski et al, 1988). This confirms that the pathways for this reflex are entirely within the wall of the rectum and anal canal.

During defaecation, the sphincters relax to permit the passage of the faecal bolus (Kerremans, 1969). Two mechanisms may be involved in this relaxation: cerebral inhibition of the sphincter contraction and mechanical stimulation within the anal canal (Duthie, 1975). Contraction of the levator ani is thought by some to be necessary to lift the posterior pelvic wall and together with relaxation of the puborectalis, open up the anorectal angle so that the faecal bolus has a direct passage to the exterior (Finlay and Brown, 1988). On evacuation the intrarectal pressure rises and the pelvic floor descends. The anorectal angle becomes more obtuse as the distal rectum and anal canal open out as voiding starts (Goei et al, 1989). Only when this angle is opened by relaxation of the puborectalis muscle can rectal contents pass through the anal canal (Preston and Lennard-Jones, 1985). At the end of defaecation, once the rectum and anal canal are empty, a contraction of the sphincteric and pelvic floor muscles returns the pelvic floor to the rest position. Thus, the external anal sphincter and pelvic floor muscles regain their resting activity reconstituting the resting anorectal angle and the anal canal is closed; this is the closing reflex (Kerremans, 1969; Womack et al, 1985). In a minority of normal subjects straining is accompanied by increased sphincter activity which persists throughout voiding (Womack et al, 1987).

1.2.2 Physiology Of Continence

Maintenance of faecal continence is a complex phenomenon which is mediated by local reflexes and is subject to voluntary control (Wood, 1981).

Certain factors such as anatomical integrity of the sphincteric and pelvic floor muscle complex, coordination of the anorectal and pelvic floor musculature and the consistency of rectal content are important (Table 1.2).

Table 1.2 Important Factors In Preservation Of Continence

Coordination of the sphincteric and pelvic floor musculature
Anorectal Sensation
Colorectal activity
Stool consistency

Anal Sphincters and Pelvic Floor Musculature

Preservation of faecal continence requires integration of the IAS and EAS sphincter function, maintenance of the anorectal angle and an adequate sensory function. The IAS contributes as much as 85% of the resting anal canal pressure (Bennett and Duthie, 1964). The remaining 15% is due to activity of the EAS, which unlike the majority of the human striated muscles is in a state of continuous tonic contraction. This background activity supplements the tonic contraction of the IAS in maintaining a region of high pressure at the sphincter zone in the anal canal. However, it has been shown that the division of the IAS alone causes only a minor functional abnormality and likewise division of the EAS causes minimal derangement of function (Bennett and Duthie, 1964; Milligan and Morgan, 1934).

The other contributory factor in maintaining faecal continence is the puborectalis muscle, which is a striated muscle also in a state of continuous, tonic contraction. The puborectalis activity sustains the anorectal angle so that the flap valve mechanism is operative. This is based on a pressure differential between the intra-abdominal pressure and that of the anal canal.

A rise in intra-abdominal pressure compresses the anterior rectal wall to flap down onto the upper part of the sphincters of the anal canal thereby creating a 'flap' valve mechanism, which prevents leakage of rectal contents (Parks et al, 1962). Phillips and Edwards (1965), by manometric and radiological observation, suggested that a rise in intra-abdominal pressure is transmitted to the anal sphincter at the level of the levator ani, lateral to the side of the anal canal. This pressure com presses the anal canal, occluding its lumen in a similar way, acting as a non-return 'flutter' valve. Both these theories depend on the existence of a pressure gradient between the abdomen and the anal canal, with the highest pressure in the abdomen. Proctometrogram studies, however, showed that increased intra-abdominal pressure causes contraction of the external anal sphincter that increases the pressure within the anal canal (Varma and Smith, 1986).

Anorectal Sensation

Anorectal sensation is another contributor to the mechanism of faecal continence. The receptors responsible for the sensory function were thought to be located in the rectum and sigmoid colon (Schuster et al, 1963). However, sensation was preserved in the 'neo-rectum' in patients after total resection of the rectum (Lane and Parks 1977). It has been suggested that muscle spindles within the pelvic floor muscles may be responsible for this function and not receptors within the rectal wall.

Discrimination between the rectal contents is facilitated by their contact with the sensitive mucosa of the anal canal, due to the relaxation of the IAS (Recto-sphincteric reflex) with reduction of anal canal (proximal) pressure in response to rectal filling. However, Read and Read (1982) showed that anal continence was preserved in normal subjects having

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anaesthetised the anal canal, although the amplitude and duration of voluntary contractions of the anal sphincters were reduced. Studies in normal humans have suggested that the reflex sensory pathways are mediated by the spinal cord.

Colorectal Activity

Increased colonic activity would not only send more bowel contents into the rectum but reduce the faecal consistency, threatening the preservation of continence. The reservoir function of the rectum plays an important role in the distal colon mechanism of maintaining continence (Lundgren et al, 1988). Mechanically, the adaptive compliance of the rectum, and the capacity and distensibility of the rectal ampulla are as well important in maintaining continence. Patients with diarrhoea, malabsorption and after ileal resection may have secondary incontinence. Such patients may have a high concentration of unbound bile acid (Merrick et al, 1985) and therefore bile acid binding agents may be useful in the treatment of incontinence in this instance. Physiologically, high frequency electrical activity and high amplitude contractile activity are found more in the rectum than in the sigmoid (Gordon, 1987). This reverse gradient may provide a pressure barrier for the distal movement of contents. The pressure differences between the anal canal and the rectum provide a distal pressure barrier in the rectal ampulla.

Stool Volume And Consistency

Stool weight and volume vary from individual to individual, depending on time, geographic region and diet. Bulking agents and fibre increase the amount of faeces and decrease transit time (Eastwood et al, 1984). The stool

consistency, however, may be the most important physical characteristic that influences faecal continence (Read et al, 1979). The ability to maintain continence control may depend on whether the rectal contents are solid, liquid or gas. Patients may be continent for solid stool but not for liquid or gas, or may experience incontinence only with flatus (Read et al, 1984). Some of these patients may merely regain continence control by changing stool consistency from liquid to solid.

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Morphophysiological investigations provide an accurate assessment of the anorectal function, such as anorectal manometry, electromyography, defaecography, proctoscintigraphy and anal ultrasonography. These are described in the following chapter. The methodology available for anorectal studies and the use of apparatus employed in the management of patients with functional anorectal disorders provides an additional tool aiming at a better understanding of the above mentioned physiological mechanisms and their changes in the state of disease.

♦ ♦ ♦

CHAPTER 2

METHODOLOGY
AND
APPARATUS

The assessment of anorectal function depends upon the ability to carry out accurate investigations and provides useful information about the pathophysiology and more recently the morphology of colorectal disorders. The techniques currently employed are anorectal manometry and electrophysiology, radiological videoproctography and scintigraphic proctography and ultrasonography. With advances in investigative technology and the development of new computerised methods of recording various aspects of colonic function, many of these techniques have become more widely available enabling the physician and general surgeon to reach important and crucial decision about management of such cases with a better understanding of the aetiology and pathophysiology of these disorders.

2.1 METHODOLOGY

The following chapter describes tests, some of which are routinely performed in the anorectal physiology laboratory, and some that are more sophisticated, less well established and as such are under clinical scrutiny while at present mainly used in research.

2.1.1 Anorectal Manometry

Anal manometry aims to provide accurate objective measurements of the estimation of the pressures generated by the anal sphincters. It is widely used to assess internal and external sphincter function (Roberts et al, 1990; Johnson et al, 1990; Williamson et al, 1990). Intraluminal anal canal pressures can be measured by water- or air- filled microballoons (Keighley et

al, 1989; Miller et al, 1989), open-ended water perfused catheters (Phillips, 1965) and microtransducers (Varma and Smith, 1984; Miller et al, 1988). Some of these methods of manometry are critically assessed in a subsequent chapter.

Anal Sphincter Pressure Profile

The standard method used is that described by Varma and Smith in 1984, in which the intraluminal anal canal pressure is registered by using a microballoon water-filled system. The subject is placed in the left lateral position and the microballoon is inserted into the rectum 6 cm from the anal verge. The balloon is then withdrawn in 1 cm station pull-through technique, recording the intrarectal and intra-anal canal pressure for approximately 30 seconds each station. The recordings at the 1 cm intervals reveal the high pressure zone (HPZ) or the functional anal canal length (AC). The maximum resting pressure (MRP) in the anal canal is usually elicited at the lower 1-2 cm from the anal verge. This is the point where the subcutaneous part of the external anal sphincter surrounds the internal one in its thickest portion and is chosen as the best point to elicit the maximum voluntary contraction of the anal sphincter or 'squeeze' pressure (SQP) and the external sphincter response to coughing (CP).

The Recto-Sphincteric Reflex

This reflex is tested by placing the microballoon intra-anally at the MRP point recording the resting pressure in the anal canal while inflating a rectal balloon with 20, 30, 50 ml of air. The reflex is present if a drop in pressure recorded intra-anally is elicited as a result of internal sphincter inhibition to rectal distention.

The Proctometrogram

The method used involves distending a highly compliant rectal balloon with saline at a rate of 67.77 ml/min, while recording the intrarectal pressure using a microballoon pressure transducer (Varma and Smith 1986). The subject is placed again in the left lateral position with two balloons - one intrarectally approximately 7 cm from the anal verge and a second intra-anally 1 cm from the anal verge approximately. The pressures are recorded continuously on a polygraph chart recorder. The time marker on the tracing indicates the volume being instilled while noting the rectal sensory threshold, 'cold' sensation, and the maximal tolerable rectal capacity, as perceived by the subject. The simultaneously recorded intrarectal pressures allowed the rectal compliance to be derived as the maximal rectal volume divided by the maximal rectal pressure.

Intrarectal Radiotelemetry

In a series of isotope proctograms intrarectal pressures were recorded with the subject seated upright. A 'radiopill' pressure measurement capsule was placed intrarectally (Type 7014, Remote Control Systems Ltd.). A signal receiver belt was wrapped around the patient's waist, allowing the pressure recording signal to be transmitted to a computerised system for subsequent analysis (Telemetry Receiver Type 7060, Remote Control Systems Ltd.). This provided valuable information of the intrarectal pressure during the various expulsive manoeuvres and evacuation (Thorburn et al, 1989).

2.1.2 Electrophysiology

Pudendo-Anal Reflex

The pudendo-anal reflex arc comprises the afferent dorso-genital nerve, release through the spinal cord segments S2, S3, S4 and the efferent nerves to the pelvic floor and external anal sphincter. The integrity and latency of the reflex arc can be assessed using the method developed by Varma et al, (1986). The subject lies in the left lateral position on an insulated examination couch. Using the Medelec (MS92a) apparatus a ground electrode is wrapped around the subject's right thigh and an anal plug electrode coated with electrode gel is placed in the anal canal. The dorso-genital nerve is stimulated at the base of the penis in male subjects or the clitoris in female subjects using saline soaked felt electrodes. At least one hundred impulses are applied and the response signals recorded via the anal plug surface electrode are digitised and averaged. The latency from stimulus artefact to the external sphincter response is measured in milliseconds and referred to as pudendo-anal reflex latency (PARL). This has been held to be a reliable index of pudendal neuropathy and as such used to assess patients with faecal incontinence (Varma et al, 1986).

Electromyography

External anal sphincter motor unit potential duration (MUPD) were recorded (Bartolo et al, 1983). The subject is placed on the left lateral position and a ground electrode placed around the right thigh before a concentric needle electrode is inserted into the external anal sphincter. The EMG monitor was set up with a display time base 10 ms/cm, a gain of 100 μV

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and filter settings of 20 Hz - 10 kHz. The trigger and delay facility of the Medelec (MS92a) EMG apparatus enabled individual MUPs to be identified and their stability assessed. At least 100 consecutive action potentials were recorded on two channels so to allow superimposing of the two confirming the recording of the same motor unit. The action potential duration was then measured from the first deflection to its return to the baseline. The mean duration of twenty action potentials was taken as the mean MUPD of the external sphincter and was used as an index of neuropathy. The number of phases in each action potential were assessed, referring to a polyphasic unit the one containing more than four phases or crossings of the baseline.

For integrated electromyograms, an integrator (4880 Isolated EMG, MX2P-637, Lectromed Ltd.) has been used along with an anal plug surface EMG electrode. The subject was placed in the left lateral position, a ground electrode wrapped around the right thigh, with the anal plug electrode inserted intra-anally. Both were connected to the integrator (Lectromed Ltd.). The EMG of the external sphincter was recorded at rest, on 'squeezing' when the subject was asked to contract maximally the muscle, and on straining when the subject was asked to try to expel the anal plug electrode. The tracings were assessed and any inappropriate increase of the EMG activity on straining noted. A ratio was derived, namely the Anismus index (AI), by dividing the increment of EMG activity on straining by the increment of EMG activity during voluntary contraction of the anal sphincter (Kawimbe et al, 1988).

Integrated EMGs were also recorded, with the subject in an upright seated position, using teflon coated wire electrodes inserted in the external sphincter using a needle (19G, Microlance^{TM}) prior to proctographic tests. This allowed simultaneous recording of the activity of the external sphincter

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during the various expulsive manoeuvres and evacuation. Evidence of the muscle activity was therefore obtained during the process of defaecation and any associated inappropriate increase in the EMG noted in cases with obstructive defaecatory features.

2.1.3 Gastrointestinal Transit Time

The method used for Oro-anal transit time involved a single ingestion of fifty, 2 mm cube, radio-opaque pellets with a standard meal (Hinton et al, 1969). The subject was asked to attend the hospital, after a bowel evacuation, for a plain abdominal X-Ray that defined the number of radio-opaque pellets still in the bowel. In instances where more than 20% of these pellets were residually present the X-Ray was repeated after another bowel evacuation. The method thus, establishes particularly the severity of constipation present.

2.1.4 Anorectal Imaging

Anal Endosonography

Anal ultrasonography allows the visualization of both the internal and external anal sphincters (Law and Bartram, 1989). The ultrasound endoprobe that was used was a 1 cm in diameter tip probe that allowed rectal and anal canal scanning with the subject in the left lateral position (Papachrysostomou et al, 1991). It has provided measurements of the external and internal anal sphincter thicknesses in patients with faecal incontinence and allowed comparison with normal subjects. This method will be described in detail in chapter 6.

Isotope Proctography

Proctographic recordings of the anorectal images were performed using radio-labelled (99m Tc MDP-III) potato mash inserted rectally to provoke the urge to defaecate. Alterations of the anorectal angle and pelvic floor movements were detected in association with the evacuation and defaecatory time (Papachrysostomou et al, 1991). This method particularly lent itself to the distinguishing of various types of constipation and associated functional anorectal disorders as it was safe to study even the most protracted defaecation. The method as applied to the investigation of constipated subjects and those with obstructive defaecation will be described in detail in chapter 7.

Radiological Videoproctography

Radiological videoproctography has been used mainly to investigate subjects with suspected anatomical and/or pathological defects such as rectal intussusception, rectal prolapse, rectocoele (Bartolo et al, 1985). Although invaluable in detecting such defects, it is less suitable in investigating functional disorders of constipation because of the abnormal characteristics of the medium used (barium) and the radiation involved. However, this method has been developed for investigating patients with faecal incontinence prior to and after treatment and will be described in detail in chapter 5.

2.2 APPARATUS

Newer forms of apparatus were introduced during the studies presented in this thesis and are evaluated in subsequent chapters. These are as follows :

1. Anal plug surface EMG electrode
2. Pudendo-anal reflex electrical stimulator
3. EMG Biofeedback in obstructive defaecation

2.2.1 Anal Plug EMG Electrode

2.2.1.1 Introduction

The standard anal plug electrode has two circular electrode plates circumferential to the anal plug which thus lie parallel to the external anal sphincter muscle fibres. Due to the increased longitudinal conductivity of muscle, it is accepted that bipolar surface electrodes for recording striated muscle EMG are usually placed in the direction of the muscle fibres (Lindstrom and Petersen, 1983). Each electrode is connected to either side of a balanced amplifier while a third electrode connects the patient to ground (Lenman et al, 1983). Based on this theoretical implication, an anal plug electrode was constructed with two electrode plates placed along the long axis of the anal plug, the electrodes being equally separated on the circumference. A series of anorectal electrophysiological investigations was done to compare the anal plug electrode with invasive fine wire stainless steel

electrodes, which included recording integrated EMG activity of the external anal sphincter at rest, during voluntary squeeze and during straining.

2.2.1.2 Materials And Methods

Eight consecutive subjects attending the anorectal laboratory participated in a comparison of the anal plug electrode with the fine-wire stainless steel one. All patients gave informed consent for the procedures involved.

The electrode referred to as the anal plug electrode has two 0.25X2 cm stainless steel electrode plates placed in parallel on the longitudinal axis of the neck of the plastic anal plug, separated equally on the circumference, in the direction of the external anal sphincter muscle fibres (Figure 2.1). The plastic plug is machined to the appropriate shape with an overall length of 7 cm, a bulbous distal end 1.5 cm diameter and the neck of the plug being 2 cm in length and 0.5 cm in diameter (Binnie et al, 1991). The fine wire stainless steel electrodes (Womack et al, 1985) were placed in a hypodermic needle with ends protruding. The wires were insulated with teflon coating and approximately 0.25 cm of the tips were bared and hooked over to allow the position to be maintained in the muscle on withdrawal of the muscle.

The subjects were placed in the left lateral position and the fine wire stainless steel electrodes introduced into the external anal sphincter in the mid-line posteriorly with a hypodermic needle to a depth of 1.5 cm. The needle was then withdrawn leaving the hooked electrodes in place in the external anal sphincter muscle. The wires were connected to an isolated EMG integrator (Ormed 4880, MX216) and the recorder calibrated to read the required EMG range (0-500 μV). After insertional EMG activity ceased,
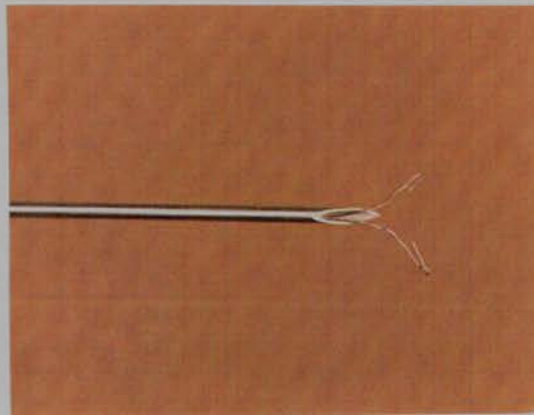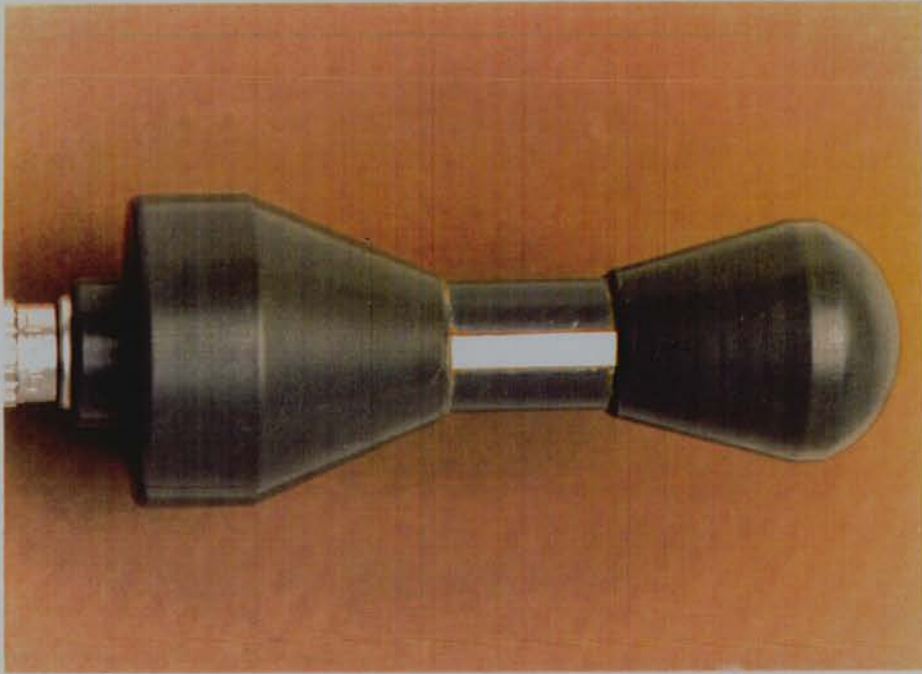
Figure 2.1 The anal plug EMG electrode used in recording the EMG
of the external anal sphincter. The plug is constructed from solid
PVC and machined to the dumbbell shape, measuring 1.5 cm at the
bulbous distal end, 0.5 cm in the middle and of overall length
7 cm. The longitudinal stainless steel electrode plates measure
0.25X2 cm and are distributed equidistantly in the long axis.
    The lower illustration depicts the teflon coated stainless steel
wire electrodes which are inserted into the external sphincter
through a hypodermic needle. The protruding bared ends of the
wires are recurved to hook into the tissues so that they are
retained in them when the needle is withdrawn. The wire electrodes
were particularly useful for the external anal sphincter EMG
measurement during proctographic examinations.

the resting EMG activity in the external anal sphincter was recorded. The subject was then asked to contract the external anal sphincter and the squeeze EMG voltage was recorded. The subject was finally asked to strain as if at stool and the strain EMG was recorded. This procedure was repeated twice to confirm the recordings. The wire electrodes were now withdrawn and the anal plug electrode to be compared was inserted into the anal canal for the same investigations to be repeated.

Statistical analysis of the results used the p values and the Pearson correlation coefficient.

2.2.1.3 Results

There was a significant correlation between the rectified EMG voltage recorded with the longitudinal anal plug electrode and the fine wire electrode of the external anal sphincter resting EMG ($r = 0.99$, $p < 0.001$), the squeeze EMG ($r = 0.99$, $p < 0.001$), and the strain EMG ($r = 0.91$, $p < 0.01$). The direct correlation persisted between the two techniques in both the normal situation with reduction of EMG activity on straining, and in the abnormal state of anismus when there was an inappropriate contraction of the external anal sphincter on straining at stool.

2.2.1.4 Discussion

When healthy skeletal muscle is completely relaxed it has no detectable EMG activity (Lenman et al, 1983). The pelvic floor, external anal sphincter and external urethral sphincter are unusual in that they have continuous tonic EMG activity at rest (Parks et al, 1962), provided that the reflex arc is intact (Guntenberg et al, 1976). The detection of changes in EMG activity in the pelvic floor can be recorded with a concentric needle

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electrode (Bartolo et al, 1983). The longitudinal electrodes detected these responses better than the circular ones and may be used to measure the reduction in EMG activity during 'normal' defaecation straining and to detect any failure of this in obstructive defaecation or anismus (Preston et al, 1985). The use of artefact-free fine wire electrodes is to be regarded as the 'gold standard' for diagnosing inappropriate contraction of the external anal sphincter during dynamic proctographic studies (Womack et al, 1985).

It is made possible to record the external sphincter EMG of a subject during attempted defaecation, by using the fine wire electrodes, whereas this is not the case when using the anal plug electrode because of its size and position in the anal canal. The presence of an anal plug within the anal canal might also induce non-physiological responses in the external anal sphincter. However, the significant direct correlation with the invasive fine wire electrode at rest ($p<0.001$), during 'squeeze' ($p<0.001$) and straining ($p<0.01$) shows that this is not so. The inappropriate increases in the rectified EMG during straining in obstructive defaecation or anismus were detected as readily with the longitudinal anal plug electrode as they were with the fine wire electrodes.

2.2.2 The Pudendo-Anal Reflex Electrical Stimulator

2.2.2.1 Introduction

On theoretical grounds, it should be possible to use an electrical stimulator to treat neurogenic faecal incontinence caused by pudendal neuropathy on the basis of repeated stimulation of the pudendo-anal reflex arc. The pudendo-anal reflex latency is a useful measurement in

the EMG investigation of neurogenic faecal incontinence (Varma et al, 1986). A prolonged latency from the stimulus artefact indicates the degree of neuropathy (Varma et al, 1986). A portable stimulator producing repetitive stimulation to the external sphincter via the pudendo-anal reflex arc has been used as a means of attempting to restore continence.

2.2.2.2 Materials And Methods

Eight women with a mean age of 47.5 years (range 32-65) took part in the study, for which ethical permission had been obtained from Lothian Health Board. Parity ranged from 1-5, with a mean of 3.1. None of the young women in this series had experienced childbirth in the last 5 years. All presented with faecal incontinence, were incapacitated socially and had to wear incontinence pads. During the study each patient acted as her own control. All had an intact pudendo-anal reflex arc with a mean latency of 55.9 ms and a range of 47.2 - 69.4 ms.

The portable electrical stimulator, which had a rechargeable nickel cadmium battery power source, provided a train of square wave stimuli to the dorso-genital nerve with fixed frequency of 1 Hz and a duration of 0.1 ms (Figure 2.2). Saline-soaked felt electrodes were used to apply the skin stimulus in the mid-line at the base of the clitoris identical to the one used for eliciting the pudendo-anal reflex latency. A submaximal tolerable stimulation voltage that was two to three times the sensory threshold was used.

Standard anorectal manometry was performed using the 1 cm station pull-through technique, recording the functional anal canal length, the maximum resting pressure, the maximum voluntary and cough reflex squeeze pressure at the point of the maximum resting pressure. An anal plug electrode was used with an electromyographic integrator to obtain amplitude

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Figure 2.2 The pudendo-anal reflex electrical stimulator. The black knob allowed adjustment of the voltage used according to patients sensory threshold. The sub-maximal tolerable stimulation voltage was usually 2 to 3 times the sensory threshold level. Two small arrows show the position of the saline soaked skin felt electrodes which were applied to either the clitoris or the base of the penis for the repetitive stimulation of the dorso-genital nerve. The device is portable, measures 15X9 cm and has been used on a domiciliary basis. It operates on a fixed frequency of 1 Hz and a pulse duration of 0.1 ms with a rechargeable nickel cadmium battery power source. The duration of stimulation has been 5 minutes 3 times a day. The reflex response does not attenuate with up to 5 minutes continuous stimulation at 1 Hz.

measurements of the external sphincter resting EMG and the EMG recorded during dorso-genital nerve stimulation. The mean motor unit potential duration (MUPD) of the external anal sphincter was calculated from the mean of 20 MUPDs taken at four sites around the anal sphincter circumference. These were obtained with a concentric needle electrode. The number of phases in each motor unit potential were counted and the fraction or overall percentage of polyphasic units was calculated for each subject. Each part of a motor unit which lay between two crossings of the base line, including the part of the potential between the onset and the first crossing, was termed a phase. A polyphasic unit has greater than four phases. Sphincter mapping was performed to show that the external anal sphincter ring was intact in all cases. All measurements were performed at the initial presentation and were repeated while applying repetitive continuous stimulation to the dorso-genital nerve to record immediate effect of activating the stimulator in the external sphincter EMG activity and anal canal resting pressure.

Statistical analysis of the results used the Student's t test for paired comparison of the manometric data and the Wilcoxon test for paired comparison of the electrophysiological data.

2.2.2.3 Results

The results of the neurophysiological tests performed before and after treatment by the stimulator are presented in Table 2.1. The immediate effect of activating the stimulator (expressed in : mean ± SEM) was to cause a significant rise ($p<0.01$) in the external anal sphincter EMG activity from 11.6 ± 1.7 to $44.9 \pm 1.9 \mu V$, with a corresponding significant rise ($p<0.01$) in the anal canal pressure from 49.1 ± 4 to 89 ± 10.4 cm H_2O.

Table 2.1   Neurophysiological tests performed before and after   treatment   by the electrical stimulator

	Pre-Stimulation	Post-Stimulation	p Value
PARL	55.9 (6.9) ms	65.9 (6.8) ms	p>0.05
A.PAR	37.5 (10.5) μV	49.5 (9.2) μV	p<0.01
MUPD	12.7 (3.3) ms	12.8 (3.4) ms	p>0.05
R.EMG	11.6 (4.9) μV	26.9 (7.3) μV	p<0.01

PARL=pudendo-anal reflex latency; A.PAR=pudendo-anal response amplitude; MUPD= motor unit potential duration; R.EMG=resting integrated electromyogram of the external sphincter. Statistical analysis by the Wilcoxon test for paired data. The results are expressed in: mean(SEM).

2.2.2.4 Discussion

The method of stimulating the pelvic floor has been successfully used for bladder control in paraplegia (Alexander and Rowan, 1970; Brindley et al, 1982; 1986) The stimulation of the pelvic floor and external anal sphincter makes use of the pudendo-anal reflex and has followed from the observation that the external sphincter contracts during recording of the reflex. The reflex shows no signs of habituation over several minutes of stimulation (Pedersen et al, 1982). The improvement in sphincter function is first reflected in the enhanced resting electromyogram, which should raise the spontaneous activity to that of a normal external anal sphincter and therefore increase the anal resting pressure.

The evidence suggests that the pudendo-anal reflex can be harnessed by repetitive electrical stimulation to aid the restoration of the control of defaecation. The action is more likely to be due to stimulation of the external sphincter rather than the internal one, as there was a direct increase in the

EMG activity recorded from this muscle. The associated increase in the resting anal canal pressure is more likely to result from the contribution of the external sphincter to the tonicity of the anal canal. This type of stimulation differs from Faradism, which has been abandoned because it is shortlived and its effects were achieved through the stimulation of local nerve endings only (Caldwell, 1963). The action on the external sphincter and on the pelvic floor in promoting clinical effects such as the control of continence in patients with faecal incontinence will be discussed in Chapter 4.

2.2.3 EMG Biofeedback In Obstructive Defaecation

2.2.3.1 Introduction

Inappropriate contraction of the pelvic floor musculature when straining at stool can produce a form of constipation which is caused by the ensuing anorectal outlet obstruction. This implies that there has been a failure of the relaxation of the pelvic floor muscle which occurs in normal defaecation. Thus a 'spasm' of the pelvic floor is created which causes the severe constipation in this state which is known as anismus (Preston and Lennard-Jones, 1985). The inappropriate external sphincter contraction can be detected by modern non-invasive EMG techniques (Binnie et al, 1991). Biofeedback training to suppress the activity of the non-relaxing pelvic floor can promote defaecation by restoring the capability of inhibiting the anomalous contraction of the pelvic floor.

2.2.3.2 Materials And Methods

Fifteen subjects, 12 women and three men, aged 22-76 years

presented with intractable constipation and excessive straining at stool due to difficulty in evacuating the rectum. All subjects had some perineal discomfort at defaecation.

Standard manometric methods were used to measure anal canal pressures and the recto-sphincteric reflex was performed in each subject to exclude any possible cause of constipation due to aganglionosis. A proctometrogram has been used to elicit the rectal sensory threshold, the rectal capacity and compliance. The rectal balloon expulsion test (with the balloon rectally and filled with fluid to the level of sensory awareness the subject was asked to expell this voluntarily) was performed in all the subjects. The pudendo-anal reflex latency and the motor unit potential duration were measured using a standard concentric needle electrode technique. The anal plug surface electrode connected to an isolated electromyographic integrator was placed at the anal canal.

The resting EMG was recorded from the external anal sphincter before the squeeze recording and the strain recording after bearing down as if at stool. An anismus index (Kawimbe et al, 1988) was calculated:

$$AI = \frac{\text{strain EMG voltage - rest EMG voltage}}{\text{squeeze EMG voltage - rest EMG voltage}} \times 100$$

Radiological videoproctograms were performed using a mixture of barium with potato mash in six of the subjects. The anorectal angle was measured at rest, on squeezing to contract the sphincters and on straining to simulate evacuation.

A self applied EMG device (Myotron 120, Physiological Feedback Systems, Dorst, the Netherlands) connected to an anal plug

surface electrode that is placed intra-anally, allows the subject to see (on a visual display) the number proportionate to the EMG voltage, or hear (via a built in loud speaker) the frequency of the sound varying proportionately with the EMG level (Figure 2.3). The EMG response of the external anal sphincter muscle achieved during straining, and the feedback of biological information is therefore the basis of the training technique. At straining attempts and by altering the method of straining as required to become purposeful, the subject tried to relax the pelvic floor and to reduce the straining recording down to below the resting recording and thus correct the anismus dysfunction by restoring the normal defaecation inhibition of the pelvic floor.

The duration of the domiciliary treatment was in multiple of two weeks depending on the subjects and their symptoms; biofeedback training with the device had been applied for at least two sessions a day. The subjects also kept a diary record of the number of stools passed per week, the time spent straining at the loo, the degree of difficulty in passing stools and noted any perineal pain or discomfort. The last two symptoms were scored as indices on an analogue scale of 0=none, 1=mild, 2=moderate and 3=severe.

The statistical analysis used the Wilcoxon test for paired data.

2.2.3.3 Results

In this group of patients there were no significant differences in the standard anorectal manometric investigations before and after biofeedback. The anismus index before and after biofeedback fell significantly (from 69.9 ± 7.8 to 14 ± 3.9 % ; $p<0.01$) and the subjective improvement as recorded on the analogue scale value for pain at

Figure 2.3   The EMG biofeedback device (Myotron 120) was used in
patients with evidence of obstructive defaecation.   The top panel
displays   the EMG voltage   of the external sphincter   as   recorded
from the anal plug electrode shown on the right. This provided the
patient with information about the tone of the anal sphincter. The
anal plug EMG electrode used with the device   had   longitudinally
arranged electrode plates   mounted on it.   The different   channels
selected on a push button basis allowed the patient to measure and
store the EMG voltage of the external anal sphincter at rest and
differentiate the   resting   tone   from the   increased   tone of the
sphincter on voluntary contraction or inappropriate straining. The
volume knob   along with   the threshold one   produced   an   audible
signal   when   the tone level   was increasing   inappropriately   on
straining.   This served as a guide for the patient in attempting
to modulate such responses.

defaecation, the time spent at straining were all significantly decreased (p<0.01), though the overall time spent at defaecation was increased. The increase in the frequency of defaecation was significant after biofeedback (p<0.01). Before the biofeedback training only two subjects were able to expel the rectal balloon, during the balloon expulsion test, whereas after biofeedback training 13 out of 15 could do so (Table 2.2). In the six subjects examined by radiology the anorectal angle became more obtuse on straining after the biofeedback treatment.

Table 2.2   The anismus index and records from diaries of 15 subjects before and after Biofeedback and at a later follow up (ranged from 2 months to 1 year).

	Pre-Biofeedback	Post-Biofeedback	Follow up
AI	69.9 (7.8)	14.0 (3.9)	14.6 (3.7)
PP Def.	2.3 (0.2)	0.5 (0.2)	0.4 (0.2)
Diff. Def.	2.8 (0.1)	1.1 (0.2)	0.6 (0.1)
BM / wk	5.2 (0.8)	8.8 (1.0)	7.4 (0.7)
BET	2	13	11
T.Def.	12.7 (1.2)	5.6 (0.8)	4.5 (0.5)

AI=anismus index; PP Def.=perineal pain at defaecation; Diff.Def.= difficulty at defaecation; BM / wk=bowel motions per week; BET=balloon expulsion test, expressing the number of patients successfully performed prior and after biofeedback; T. Def.=time spent during defaecation. The results are expressed in : mean (SEM)

Before biofeedback five of the subjects were unable to expel the barium potato mixture while only three did not do so after biofeedback, being examined by the same method. The three subjects denied any similar problems at home, and claimed that the failure to expell the barium potato mixture was due to lack of privacy.

2.2.3.4 Discussion

Anorectal outlet obstruction due to anismus follows the loss of the normal inhibition of the pelvic floor that occurs while straining to defaecate. The subjects studied sufferred from intractable constipation, in addition to their abnormal EMG responses detected via integrated electromyography. A sample of these patients studied radiologically, showed typical radiological signs of this condition, such as failure to achieve a more obtuse angle on straining to prepare for the evacuation of the 'faecal' bolus. The failure of the pelvic floor and external anal sphincter to relax is compounded by their inappropriate contraction (Womack et al, 1987). The condition is confirmed objectively by the rise in the intra-anal canal pressures and the increase in the EMG activity of these muscles on straining. As anismus subjects are unaware of the incoordination of the pelvic floor, biofeedback offers a simple and minimally invasive technique for relearning how to suppress the non-relaxing pelvic floor (Almy and Corson, 1979). The Myotron 120 device is ideally suited for retraining anismus subjects (Bleijenberg and Kuijpers, 1987). It is small, compact, easily operated and relatively inexpensive. The clinical aim is trouble free defaecation, which is not always accompanied by complete resolution of the anismus abnormality.

In this series a minor degree of electromyographic 'anismus' remained and was acceptable as asymptomatic. When tested after a biofeedback training period the fall in the anismus index was accompanied by less time spent in straining, more bowel movements per week, and less perineal pain and discomfort. The subjects more readily expelled a balloon bolus from the rectum and generally spent more time over defaecation, feeling that there was clinical improvement in their defaecation capability.

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2.3 SUBJECTS

All the normal subjects who participated in the studies of this Thesis were volunteers. They were recruited from members of the medical and nursing staff at the University and Western General Hospital of Edinburgh. They were questioned carefully about any gastrointestinal symptoms, bowel habit, past medical history and current medication. The age range and sex in the control group in each study will be defined in the related chapter.

The patients recruited in the studies of this Thesis were referred by consultant physicians and surgeons in the Lothian and Borders area for investigation of anorectal disorders. This implies that the patients were suffering from symptoms that were not tractable to treatment by simple measures. The age, sex together with important features in their medical histories and examinations will be given in detail in the appropriate chapter.

2.4 STATISTICAL ANALYSIS

The Statistical Analysis (Swinscow, 1989; Brown and Swanson Beck, 1990; Campbell and Machin, 1991) of the data obtained in each study of the Thesis, used the Minitab Statistical Software and Handbook (Ryan et al, 1985). The Statistical method used in the analysis of the results will be described in detail separately in individual chapters.

♦ ♦ ♦

CHAPTER 3

ANORECTAL PROFILOMETRY
WITH
MICROTRANSDUCERS

3.1 SUMMARY

Anorectal manometry was performed in 23 normal controls and 12 patients with anorectal disorders using several different systems of recording. The systems were evaluated in the following three experiments:

1. A 5 mm microtransducer was compared with a conventional 4 mm diameter waterfilled microballoon connected to an external transducer.

2. A 2 mm microtransducer was compared with a conventional 4 mm diameter waterfilled microballoon connected to an external transducer.

3. A third comparison was made between an analogue and digital recorders.

In vitro, pressure chamber tests during the application of pressures of 50, 100, 150 and 200 cm H_2O indicated good agreement (2.0, 1.9, 0.9 %) between the two catheters and the microballoon, with both digital and analogue recorders. In vivo, the parameters recorded for comparison were the maximum resting, 'squeeze' and cough anal canal pressures and the functional anal canal length. The 2 mm microtransducer recorded significantly lower pressures compared with the 5 mm microtransducer ($p < 0.001$) and the 4 mm microballoon ($p < 0.0003$). This is considered to be due to its smaller size which minimises the local effect on the anal sphincters. The 5 mm microtransducer catheter did not show consistency in pressure recordings during orientation within the anal canal. Despite the drawbacks associated with fluid-filled systems, they remain the simplest, most reliable method of performing anorectal manometry. The comparison made between analogue and digital systems using the same 5 mm microtransducer showed no significance difference.

3.2   INTRODUCTION

Manometry is fundamental to physiological assessment of the anorectum but a multiplicity of systems are currently in use. The two most common methods of measuring anorectal pressure utilize either open-tipped tubes (Bennett and Duthie, 1964; Phillips and Edwards, 1965; Duthie and Watts, 1965; Hancock, 1976) or closed balloon systems (Kerremans, 1969; Hancock, 1976; Henry and Parks, 1980; Neill et al, 1981; Miller et al, 1988; Orrom et al, 1990), connected via fine tubes to strain-gauge transducers outwith the anal canal. The output from the transducer is then amplified and recorded on a chart recorder.

Microtransducers, now available, can be fitted into fine catheters, thus eliminating the need for water-filled tubing and all the associated problems (Miller et al, 1988; Johnson et al, 1990; Lindquist, 1990). Anal canal pressure is conducted via a plastic membrane to an ultra-thin metal diaphragm, which in turn is connected to a strain gauge. The whole assembly is supported by a cradle surrounded by a steel cylinder and mounted in a silastic catheter, which may be as narrow as 2 mm in diameter (Figure 3.1).

The availability of reliable miniature transducers mounted on fine catheters (Varma and Smith, 1984; Orrom et al, 1990) has enabled the overcoming of many of the disadvantages (like the presence of air bubbles in any part of the system, artefacts produced by movement of the tubing and the zeroing at the anal verge), associated with water-filled systems. However, the pressure sensitive membrane of these microtransducer-tipped catheters is not circumferential and radial variation in anal canal pressure measurements has been shown (Miller et al, 1988).

Figure 3.1 The three probes used for anorectal manometry are
illustrated.
Top : the 4 mm diameter microballoon mounted on a 6FG ureteric
catheter connected to an external transducer. The pressure
measurements with this assembly were recorded with the use of an
analogue system (4-channel galvanometric pen plotter). The system
was water-filled and checked free of air bubbles.
Middle : the 3-sensor catheter - mounted 5 mm diameter micro-
transducer operating via a sensing diaphragm placed on one side of
the catheter. The pressure measurements were recorded digitally on
this assembly.
Bottom : the 2 mm diameter microtransducer connected to an
amplifier recording pressure measurements via an analogue chart
plotter. Again the sensing diaphragm is placed on one side of the
tip of the catheter.

Although the conventional fluid-filled systems have provided the coloproctologist with much of the information on which the basic present concepts of anorectal physiology are based, they are often the cause of conflicting results because of the disadvantages they possess (Dickinson, 1978; Eckardt and Elmer, 1991). A further logical development is to perform the original manometric recording on a computer system rather than on an analogue plotter. Gaeltec Research Ltd (Skye, Scotland) developed a prototype computerised waveform analysis system in the early 1980s. The Gaeltec company produced a multisensor catheter-tip pressure transducer on a silicone rubber catheter, interfaced to a standard computer. It soon became apparent that the analysis of digitised data could be much more efficient and less subject to observer error than manual analysis of analogue tracings (Wilson et al, 1991).

The aim of this study was to compare the performance of a digital recorder with a conventional analogue recorder in anorectal manometric investigation and evaluate the use of 5 mm, 2 mm catheter microtransducers and the conventional water-filled 4 mm in microballoon.

3.3 MATERIALS AND METHODS

3.3.1 Subjects

Twenty-three healthy volunteers (male : female = 12 : 11), median age 21 years (95% CI : 21, 22 years), participated in the study. No subject had a history of gastrointestinal disease or previous anorectal surgery. 12 patients (male : female = 1 : 11), median age 52 years (95% CI : 31, 67 years), who attended the anorectal laboratory with various problems were recruited to

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the study. No bowel preparation was used but the subjects were given the opportunity to empty their bowel prior to the study. The protocol was approved by the Lothian Health Board and the subjects gave written informed consent.

3.3.2 Methods

An initial bench comparison was made of the recorders. The three transducers were placed, one by one, in a sealed pressure chamber connected to a sphygmomanometer. Known pressures were applied at 50, 100, 150, and 200 cm H_2O from the sphygmomanometer and were recorded separately in each of the two recorders. This procedure was repeated at least 5 times.

The two recorders used were as follows:

◆ Digital

The solid state recorder used was a Tandon PCA20 AT computer (GR800, Aspen Medical, Dingwall, Scotland). It has a data compression system that allows a constant sampling rate of 32/sec but only those data points showing a change in pressure are stored in the memory to avoid overload. A visual trace of manometric events is produced in the anal canal profilometry channel. After recording, sections of the trace are selected by the operator for expansion. The peak or average pressure in the recording channel over a chosen segment of display is computed.

◆ Analogue

The chart plotter used was a 4-channel galvanometric pen plotter (M19-90, Devices Instruments Ltd).

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♦ Digital and Analogue Simultaneous Recording

An 8-channel analogue output module (Blue Chip Technology, Clwyd, Wales) was inserted into the computer mother board to allow digital to analogue conversion of the output signal. A cable link was established to allow instantaneous transmission of pressure data from the computer to the Devices recorder.

The three probes used (see Figure 3.1) were :

The 5 mm microtransducer

A 3 sensor catheter-mounted pressure transducer (16REC3, Gaeltec Research Ltd) was used with an outer diameter of 5 mm. The pressure sensor is placed directly at the pressure source which should achieve more accurate and dependable pressure measurement (Varma and Smith, 1984) is robust and insensitive to normal handling. This microtransducer was introduced 7 cm in the rectum. Withdrawal was then performed in 1 cm steps, rotating to allow pressure recordings to be obtained facing different directions in the anal canal. The pressure at each station being recorded for approximately 1 minute. Maximum voluntary contraction pressure (squeeze pressure : SQP) and pressure recorded on coughing (CP) were measured by placing the microtransducer at the site of the recorded maximum resting pressure (MRP). The functional sphincter length (AC) was measured as the length of the high-pressure zone in the anal canal (zone of pressure above the resting rectal pressure). The data were stored for analysis on a computer floppy disc, and paper print-outs obtained for archiving.

4 mm microballoon

A 4 mm diameter soft rubber microballoon (HSC4, Precision Dippings Ltd) mounted on a 6FG ureteric catheter and connected to an external transducer (4-442, Bell & Howell Ltd) was used. The entire system was water-filled and free of leakage and air bubbles. The transducer was calibrated to a full-scale deflection of 200 cm H_2O pressure which was recorded on a multichannel chart recorder. The microballoon was zeroed at the anal verge prior to each study. Then it was inserted into the rectum to 7 cm from the anal verge. Pressure recordings were obtained, as described earlier, withdrawing the microballoon via a 1 cm station, pull-through profilometry. The MRP, SQP, CP and AC were therefore elicited.

2 mm microtransducer

A catheter-mounted microtransducer of 2 mm outer diameter (16CT, Gaeltec Ltd) connected via an amplifier (S10/S11, Gaeltec Ltd) to a second channel on the chart recorder (see notes above) was introduced 7 cm into the rectum after calibration from 0 to 200 cm H_2O. Station pull-through withdrawal of the catheter at 1 cm steps was also performed, at each station rotating the tip-end of the catheter to allow pressure measurement facing different directions in the anal canal. The MRP, SQP, CP and AC were recorded as described earlier in methodology.

3.3.3 Data Analysis

Analogue and digital recordings were obtained at the same session from the 23 asymptomatic volunteers and 12 patients recruited for the study. The digitised computer measurements were analysed independently from the

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analogue chart recorder ones which were subjected to manual analysis. Any systematic bias between the three transducers were measured calculating the 95% confidence intervals of the differences (Gardner and Altman, 1986). The variation between the readings was assessed using limits of agreement (Altman and Bland, 1986). These limits represent the range within which 95% of the difference between each two transducers would be expected to fall, determining whether the different transducers could be used interchangeably. The sign test for paired comparison was used for the results of radial variation with the microtransducer.

3.4 RESULTS

The bench comparison of the 5 mm microtransducer (digital recording), the 2 mm microtransducer (analogue recording) and the 4 mm water-filled microballoon (analogue recording) showed that all three were in good agreement. The mean 'root-mean-square' difference between the pressure in the air chamber and the transducer systems was as follows:

2.0% for the 5 mm microtransducer using a digital recorder,

1.9% for the 2 mm microtransducer using an analogue recorder,

0.9% for the microballoon using again the analogue recorder.

An additional comparison was made using the 2 mm microtransducer on both the analogue and digital recorders. The mean difference between the measurements obtained using the microtransducer and the applied pressure of the chamber was -3.3% for the digital recorder and -3.1% for the analogue recorder. This shows that there was no systematic difference between the results obtained from the two recorders.

3.4.1 Analogue Recordings

Comparison Between The 5 mm Microtransducer

And The 4 mm Microballoon

The results of the clinical investigation are listed in Table 3.1. Statistically there was no significant difference in the measurement of the MRP the CP and SQP during the pressure recordings ($p > 0.05$). The functional length of the AC did not significantly differ in either method ($p > 0.05$). The limits of agreement in pressure measurement revealed some variation between the two methods (Figure 3.2).

Comparison Between The 2 mm Microtransducer And

The 4 mm Microballoon

The results of the clinical investigation are given in Table 3.2. The measurements obtained using both methods, were different for the MRP ($p < 0.0003$), the SQP ($p < 0.01$) and the CP ($p < 0.05$) but not for the AC functional length ($p > 0.5$). The microballoon was recording significantly higher readings than the 2 mm diameter Gaeltec catheter, for the anal canal pressures, MRP, SQP, and CP. The limits of agreement showed a great variation between the pressure readings obtained by the two probes, suggesting non-interchangeability between the two systems (Figure 3.3).

Analysis Of Pressure Recordings Obtained During Orientation

Of The 2 mm Microtransducer

In this study, during 1 cm station pull-through withdrawals the tip of the microtransducer catheter was rotated at approximately 90°. No significant difference was observed in any of the stations ($p > 0.05$).

150 —

100 —

$P_B - P_{5M}$ 50 —

(cm H2O)   0 ‑

-50 —

-100 —

-150 —

20   40   60   80   100   120   140

$(P_B + P_{5M})/2$ (cm H2O)
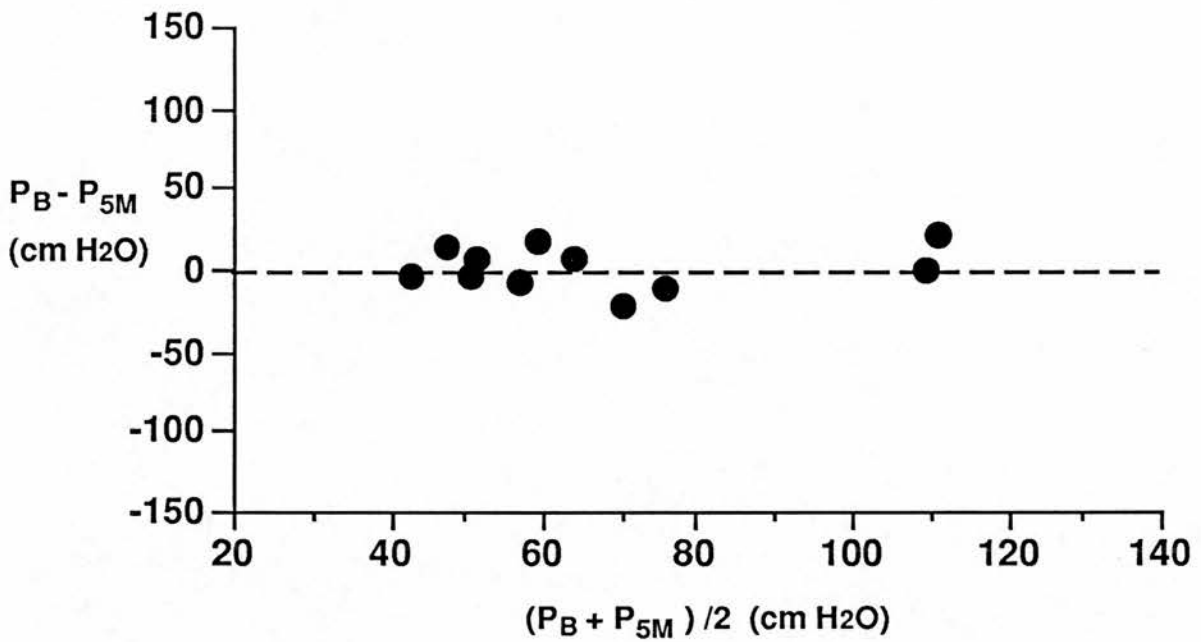
Figure   3.2   The comparison between   the   anal
canal pressure measurements obtained with the   use
of the 5 mm diameter Microtransducer (P_{5M}) and the
4   mm   diameter Microballoon   (P_B).   The   pressure
measurements   illustrated   are anal canal   pressure
recordings   at   rest derived with the use   of   the
analogue system.

Table 3.1 Anal canal pressure measurements (cm H_2O) obtained with the use of 5 mm microtransducer and 4 mm microballoon, at rest and on maximal contraction of the anal sphincter on coughing and voluntary 'squeezing'.

	5 mm Microtransducer	4 mm Microballoon
* MRP	57 (54, 70)	60 (49, 80)
CP	68 (39, 94)	52 (33, 90)
SQP	54 (21, 93)	68 (29, 82)

♦

Table 3.2 Anal canal pressure measurements (cm H_2O) obtained with the use of 2 mm microtransducer and 4 mm microballoon, at rest and on maximal contraction of the anal sphincter on coughing and voluntary 'squeezing'.

	2 mm Microtransducer	4 mm Microballoon
* MRP	80 (79, 81)	120 (105, 126)
CP	70 (60, 80)	90 (70, 131)
SQP	100 (80, 160)	150 (115, 171)

♦

Table 3.3 Anal canal pressure measurements (cm H_2O) obtained with the use of microtransducers of 5 and 2 mm diameters, at rest and on maximal contraction of the anal sphincter on coughing and voluntary 'squeezing'.

	5 mm Microtransducer	2 mm Microtransducer
* MRP	99 (92, 109)	80 (79, 81)
CP	87 (77, 102)	70 (60, 80)
SQP	116 (99, 225)	100 (80, 160)

*
MRP=maximum anal canal resting pressure; CP=anal canal cough pressure; SQP=anal canal squeeze pressure. The results are expressed as: median (95% confidence intervals).

3.4.2 Digital Manometry

Analysis Of Pressure Recordings Obtained During Orientation
Of The 5 mm Microtransducer

In this study, during 1 cm station pull-through withdrawals the tip of the microtransducer catheter was rotated at approximately 90°. This rotation demonstrated a significant change ($p < 0.002$) in the pressure recording at 3 cm from the anal verge. However, no significant changes were observed at the rest of the 'stations' ($p > 0.5$).

3.4.3 Digital and Analogue Manometry

Comparison Between Digital And Analogue Recorders

Pressure recordings were obtained and compared during simultaneous digital and analogue profilometry using the 5 mm diameter microtransducer. The pressure recordings did not show significant differences in the MRP, the CP, the SQP (Figure 3.4) and the AC ($p > 0.05$).

Comparison Between The Digitised 5 mm Microtransducer
And The Analogue 2 mm Microtransducer

The results of the clinical investigation are presented in Table 3.3. Once more the MRP ($p < 0.001$), CP ($p < 0.01$) and SQP ($p < 0.02$) were significantly greater when measured with the 5 mm microtransducer, while the AC functional length did not show any difference ($p > 0.5$). The limits of agreement revealed great variation unacceptable to the clinical practice.
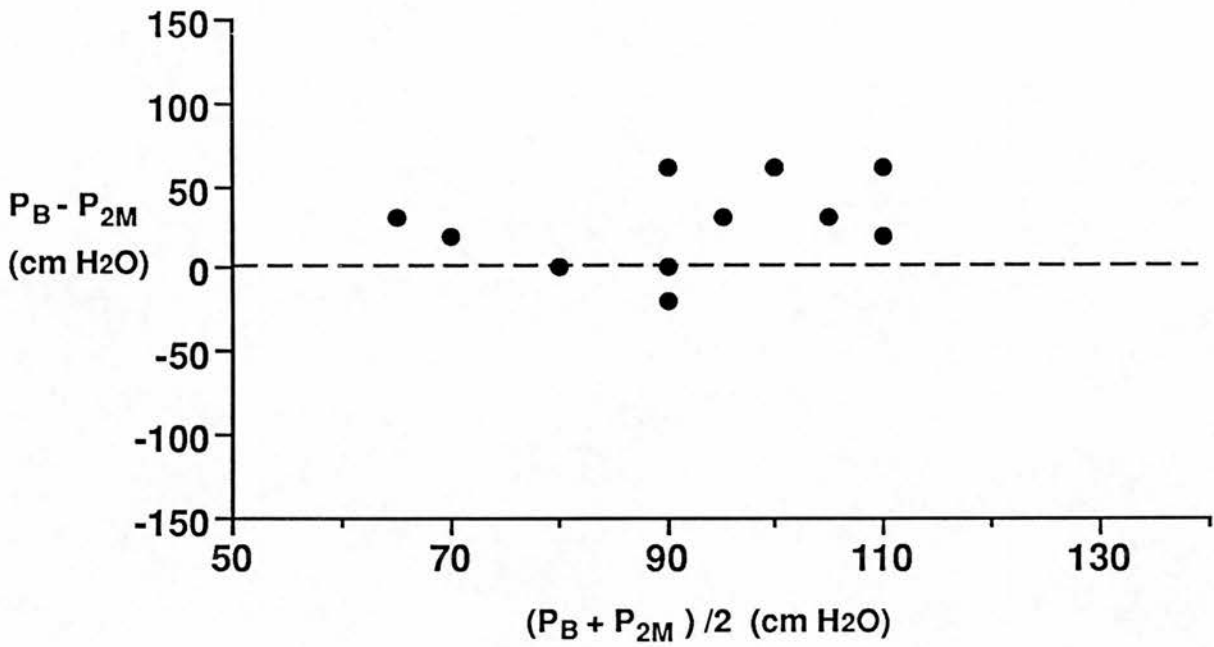
Figure 3.3 The comparison between the anal canal pressure measurements obtained with the use of the 2 mm diameter Microtransducer (P_{2M}) and the 4 mm Microballoon (P_B). The pressure measurements illustrated are anal canal pressure recordings at rest derived with the use of the analogue system.
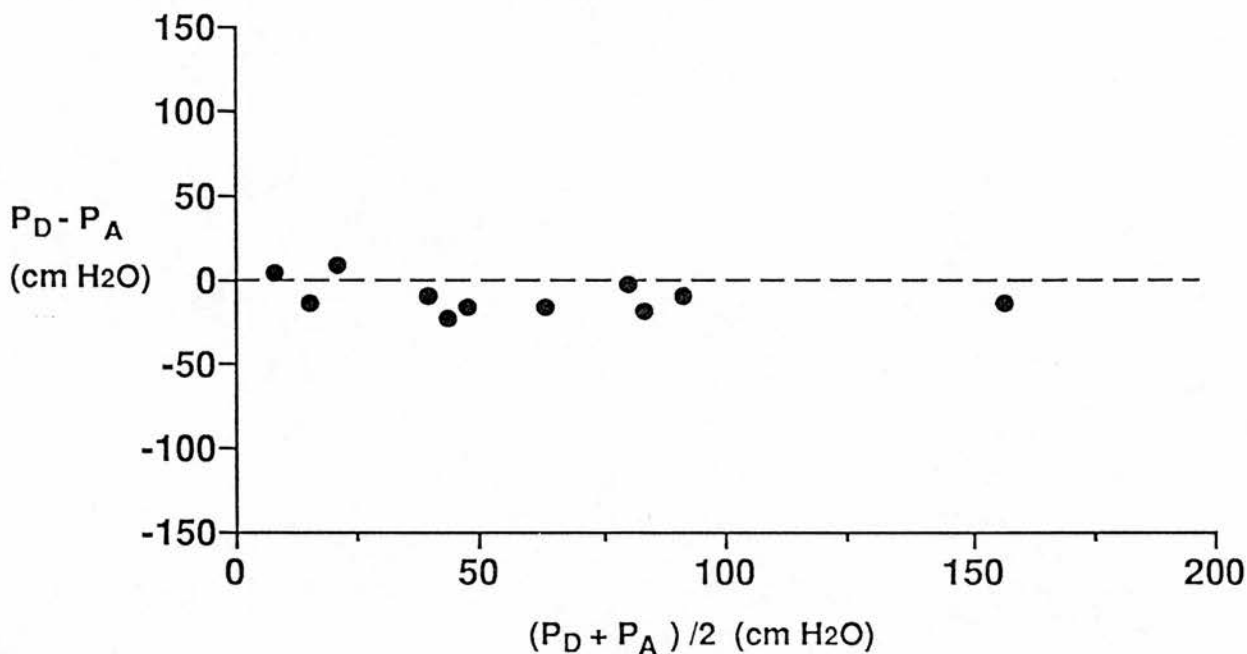
Figure 3.4 The comparison between the pressure measurements recorded via the digital (P_D) and analogue (P_A) systems, simultaneously, using the 5 mm diameter Microtransducer. The pressure measurements illustrated are anal canal pressure recordings on maximal contraction of the external anal sphincter during voluntary 'squeeze'.

3.5 DISCUSSION

In an attempt to test which manometric system of measurement is the 'gold standard' for routine use in the anorectal laboratory several investigations were performed. During these studies the conventional microballoon was tested against a microtransducer of 2 mm diameter on an analogue chart recorder and against a 5 mm diameter catheter on a digital recorder. Comparisons were carried out between the 5 mm catheter connected to a digital recorder with the 2 mm microtransducer connected to an analogue chart recorder.

Microballoon assemblies tend to be larger in diameter (4 mm, as compared to 2 mm of the microtransducer) and as the sphincter responds to distention by contracting they tend to record higher pressures (Hancock, 1976). The microballoon system must be free of air bubbles, is very prone to artefacts due to movement of the connecting tubing and has to be zeroed at the anal verge prior to each study. These reasons limit the usage of the microballoon system in ambulatory anorectal manometric tests and during dynamic proctography.

Microtransducer catheters have provided an alternative to using an external transducer (Varma and Smith, 1984). They have the advantage of being simpler in use and, being of narrow diameter (2 mm), they minimize disturbance to the sphincters. During the study, the 5 mm microtransducer catheter showed significant radial variation due to the directional nature of the sensing membrane; however this variation was not a significant result at all stations. The limitations demonstrated by the 2 mm microtransducer

catheter is its use in patients with faecal incontinence and disturbed anal sphincters, therefore with very low anal canal pressures. Since the 'disturbance' to the sphincters is minimal due to its narrow diameter, it may not provoke the slight contraction due to distension that a microballoon and a catheter of greater diameter do. Thus, the pressure measurement may be reported not detectable. Furthermore, the microtransducer catheters are much more expensive than those employing an external transducer and cannot be made disposable if need be!

The introduction of the micro-computer recording of anorectal profilometry has transformed the methodology of the anorectal manometry. It became apparent that the analysis of digitised data was more efficient and less subject to observer error (Wilson et al, 1991). However, no significant measurement difference was observed of the anal canal resting pressure or during the voluntary and reflex (in response to cough) contraction of the anal sphincters. The catheter used in this study connected to the digital recorder approximated in diameter the microballoon. Moreover the comparison of the recorder systems, digital and analogue, did not again show any significant measurement difference.

Given the advent of computerised diagnosis of anorectal motility, the GR800 system represents a logical advance in manometric technology (Wilson et al, 1991). However, the system was expensive (approximate cost of microtransducer with a digital recorder assembly: £20000.00), without providing spare equipment. Failure of the delicate transducer assembly, implies a temporary replacement by the conventional microballoon system. In the study, however, the two systems were not interchangeable. In fact the Gaeltec transducers were not very robust in practice. Thus, in order to avoid

making comparisons of pressure measurements acquired by different systems, that could presumably produce conflicting results, the studies in the chapters to follow were conducted using the conventional microballoon system. The microballoons themselves can be made disposable, are readily available, less costly (only £1.00 for each microballoon!) and proved reliable.

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CHAPTER 4

FAECAL INCONTINENCE

4.1 SUMMARY

Two-hundred and seventy-seven patients with faecal incontinence were investigated. Manometric assessment revealed that 30.7% had weakness of both anal sphincters, 53.8% had a predominant weakness of the external and 7.6% had a predominant weakness of the internal anal sphincters. 7.9% had no detectable weakness in either sphincter. Analysis of the results showed that all the patients had a reduced rectal compliance with higher intrarectal pressures. The minority who showed a weak internal sphincter also showed impaired sensory awareness. The residual group with no detectable sphincter problem had a reduced rectal compliance alone. The implication is that the derangement of the continence mechanism in neurogenic faecal incontinence is multifactorial.

A number of patients, all with weak sphincters, randomly selected had treatment by a pudendo-anal reflex electrical stimulator. The results were compared in each subject before and after the use of the stimulator. The intra-anal pressures showed an increase of the cough ($p<0.0001$), 'squeeze' ($p<0.03$) and maximum resting ($p<0.004$) anal canal pressures. The functional length of the anal canal was also enhanced ($p<0.004$). The stimulation of the pudendo-anal reflex is a means whereby the restoration of continence can be achieved.

4.2   INTRODUCTION

Faecal incontinence (FI) occurs in patients with various neurological disorders, particularly with spinal cord and lumbosacral root lesions, after trauma to the muscles of the pelvic floor (Parks and McPartlin, 1971), in association with rectal prolapse (Porter, 1962), and as an idiopathic disorder (Parks, 1975). 'Anorectal incontinence', a term used to denote faecal incontinence not caused by neurological disorders, occurs in about two-thirds of patients with rectal prolapse referred for operation. But a third of these remain incontinent after rectopexy, and these patients are then similar to those with 'idiopathic anorectal incontinence'. The latter disorder occurs almost exclusively in women (Snooks et al, 1984; 1985). These patients usually complain of a disturbance of anorectal sensation so that they are unable to differentiate flatus from faeces, though formal sensory examination of the skin of the anal margin reveals no abnormality, and the tendon reflexes in the legs are preserved. The rectal sphincter is commonly patulous, there is little if any voluntary sphincter contraction, and the anal reflex is usually absent. The normal anorectal angle is lost (Beersiek et al, 1979) and the pelvic floor is usually dropped in relation to surrounding structures. In many of these patients there may also be minor degrees of rectal prolapse.

Faecal incontinence is often associated with a long history of excessive straining during defaecation (Parks, 1975; Snooks et al, 1985), causing traction on the pudendal nerve, leading to rectal prolapse. Perianal trauma, obstetric damage and anal operations may be regarded as playing important aetiological roles in the development of anorectal incontinence (Christiansen and Pedersen, 1987). During the past few years a group of female patients

has been identified with 'idiopathic faecal incontinence', in whom there is evidence of denervation affecting the external anal sphincter and thus the pelvic floor. This neurogenic faecal incontinence is now an increasing problem in an ageing population. The pudendo-anal reflex latency (Varma et al, 1986) is a useful measurement in the electromyographic investigation of neurogenic faecal incontinence. A prolonged latency from the stimulous artefact to the sphincter response indicates, inter alia, the degree of neuropathy.

Not all patients are suitable for a post-anal repair, which is the mainstay of surgical treatment (Browning and Parks, 1983; Yoshioka et al, 1988; Orrom et al, 1991). Various electrical stimulators have been designed in the past with the aim of returning function to the pelvic floor muscles (Hopkinson, 1972). These make use of surface anal plug electrode or are implanted with a radiofrequency link outside the body (Hopkinson and Lightwood, 1966). A portable stimulator (Binnie et al, 1990) has been used, providing repetitive stimulation of the pudendo-anal reflex (PAR) which elicits contraction of both the external anal sphincter (EAS) and the pelvic floor, in an attempt to restore continence by provoking contraction of these muscles selectively through a reflex, provided there is no interruption in either the afferent, or efferent limbs of the reflex and conduction of the impulses through the S2, S3 and S4 segments of the spinal cord. This is made possible since the PAR is not a reflex which is easily fatigued.

This chapter explores the motor and sensory responses of the anorectum in patients with faecal incontinence, in an attempt to evaluate the importance and relevance of these responses in the continence mechanisms. Part of this study, therefore involves the investigation and detection of objective as well as subjective changes in patients who have been offered

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treatment for faecal incontinence, utilizing repetitive stimulation of the PAR.

4.3 MATERIAL AND METHODS

4.3.1 Subjects

In the past four years, a total of 324 patients, were referred to the anorectal laboratory at the Western General Hospital in Edinburgh, complaining of faecal incontinence. There were 243 (75%) female (age range 26 - 90 years) and 81 (25%) male patients (age range 14 - 86 years). All patients were incontinent of faeces at least once a month and had complained of incontinence for at least one month. Forty-seven of the above patients (14.5%) were excluded from the study because of having either spinal injuries or lesions, neuropathies as in multiple sclerosis and diabetes mellitus which would be expected to affect their anorectal function, or history of direct trauma to the perianal area.

Twenty-four patients (male : female = 3 : 21; 12.5% : 87.5%), median age 66 years (95% CI: 51, 70 years) with neurogenic faecal incontinence and who also had low sphincter pressures, were selected at random for treatment by an electrical stimulator acting via the pudendo-anal reflex.

Twenty-three volunteers (male : female = 12 : 11; 52% : 48%), with a median age of 21 years (95% CI : 21, 22 years) participated in this study and served as a control group. The normal controls were compared to the incontinent groups of patients. The control group was specially selected and questioned carefully about any gastrointestinal symptoms, bowel habit, problems with defaecation, past medical history and medication. The females were nulliparous so to avoid any misleading results due to damage to the anal

sphincters during childbirth (Snooks et al, 1986). This was a younger group thus to escape illusive results due to ageing process and anal sphincters changes (Bannister et al, 1987; Laurberg and Swash, 1989).

4.3.2 Methods

Anorectal Manometry

A standard water-filled microballoon system with external transducer measured the anal canal pressure by a 1 cm station pull through technique (see Chapter 2). The functional anal canal length was reflected in the anal sphincter high pressure zone, with the maximum resting pressure (MRP) recorded. The reflex contraction pressure of the EAS during coughing (CP) was recorded at the point of MRP, as was the maximum voluntary 'squeeze' (SQP) pressure of the same sphincter. The rectosphinctering reflex was also performed in all patients. The internal anal sphincter (IAS) relaxation is elicited on rectal distention by recording the inhibitory fall of the anal canal resting pressure on rapidly distending a rectal balloon with air at 20, 30 and 50 ml.

Rectal capacity and compiance were recorded in all the patients studied, via proctometrography. Using a rectal balloon, a slow infusion of normal saline through a pump at a speed of 67.77 ml per minute, connected to an external transducer allowed simultaneous recording of the intrarectal pressures during infusion (see Chapter 2). Records were acquired at the rectal sensory threshold volume, with the corresponding pressure measurement, and at the maximum tolerable rectal volume and the pressure at the maximum tolerable rectal capacity, with the patient lying on his/her left lateral position. In the case of uncontrolled, involuntary rectal balloon

expulsion, a note of the maximally recorded volume and the intrarectal pressure recorded at that level were noted. The rectal compliance was calculated as the maximum tolerable volume divided by the corresponding rectal pressure. In parallel to that intra-anal canal pressures were recorded simultaneously via another channel connected to a different external transducer, with the microballoon situated at the level of the maximum resting pressure in the anal canal.

Electrophysiology

An anal plug electrode was used with an electromyographic integrator (Binnie et al, 1991) to obtain amplitude measurements of the EAS resting and 'squeezing' electromyogram. The pudendo-anal reflex latency (PARL) and the response amplitude were recorded after applying over 100 consecutive synchronised impulses to the dorso-genital nerve using the Medelec MS 92a^{TM} apparatus (Varma et al, 1986).

Electrical Stimulator

The portable stimulator which was used had a rechargeable nickel cadmium battery power source (see Chapter 2), providing a train of square wave stimuli to the dorso-genital nerve with fixed frequency of 1 Hz and a duration of 0.1 ms (Figure 2.2 in Chapter 2). Saline soaked felt electrodes were used to apply the skin stimulus in the mid-line at the base of the glans penis in males and the clitoris in females identical to that used for the PARL test. A sub-maximal tolerable stimulation voltage was used, depending on the individual's tolerability, that was approximately three times the sensory threshold. Domiciliary self-administered treatment lasted for five minutes on three occasions per day for a minimum eight week course.

4.3.3 Statistical Analysis

In the statistical analysis of the results the median values and their 95% confidence intervals (CI) were used and for paired comparison the non-parametric sign test. The non-parametric Mann-Whitney test for unpaired samples was used for comparison of incontinent groups of patients with the normal control group.

4.4 RESULTS

All the patients (277) included in this study had anorectal tests which revealed abnormalities, either manometric and / or electrophysiological. Four groups were derived after analysing the data according to their sphincter pressures : A. Weakness of both anal sphincters (30.7%), B. Weakness of the EAS alone (53.8%), C. Weakness of the IAS (7.6%), D. No detectable manometric weakness in either sphincters (7.9%).

4.4.1 Group 'A'- Weakness Of Both Anal Sphincters

Eighty-five patients tested (male : female = 7 : 78; 8% : 92%), median age 66 years (95% CI: 63, 70 years) had weak anal sphincters as evidenced from the intraluminal anal canal pressures : MRP, CP and SQP.

Subjective Assessment

These patients reported having had faecal incontinence for 24 months (95% CI: 12, 36 months). The frequency of defaecation was 14

occasions per week (95% CI: 7, 15). Fifty-five of these patients (65%) complained of chronic constipation, whereas 10 patients (12%) had diarrhoea. Among the 78 female patients, 13 were nulliparous (17%), 43 admited traumatic deliveries (55%), with 24 of them having had forceps deliveries (31%).

Objective Assessment

The MRP was 40 cm H_2O (control group = 120 cm H_2O; $p<0.00001$), the CP was 60 cm H_2O (control group = 90 cm H_2O; $p<0.00001$) and the SQP was 40 cm H_2O (control group = 150 cm H_2O; $p<0.00001$). The proctometrogram showed the rectal sensory threshold as 100 ml (control group = 80 ml; $p>0.05$), the maximum tolerable rectal capacity as 245 ml (control group = 420 ml; $p<0.00001$) and the rectal compliance as being 3.4 ml/cm H_2O (control group = 7.4; $p<0.00001$). The electrophysiological test showed the PARL as 47.6 ms (control group = 39.4 ms; $p<0.0002$). See Table 4.1.

4.4.2 Group 'B'- Weakness Of The EAS

One hundred and forty-nine patients (male : female = 34 : 115; 23% : 77%), median age 56 years (95% CI : 51, 59 years), complaining of faecal incontinence, revealed competent IAS and weak EAS on manometric testing.

Subjective Assessment

These patients reported having faecal incontinence for 24 months (95% CI: 12, 30 months). The frequency of defaecation was 14 occasions per week (95% CI: 10, 18). Seventy-nine patients complained of

Table 4.1   Anal canal pressures recorded at rest, during maximum contraction on coughing and maximal conscious squeeze of the anal sphincter. Rectal volumes elicited at sensory threshold level and maximum tolerable rectal capacity. Rectal compliance and pudendo-anal reflex latency are also recorded.

	GROUP A		NORMAL CONTROLS	
	Median	95% CI	Median	95% CI
MRP cm H_2O	40	[40, 50]	120	[105, 126]
CP cm H_2O	60	(48, 60)	90	(70, 131)
SQP cm H_2O	40	(40, 50)	150	(115, 171)
SENSATION ml	100	(80, 105)	80	(70, 122)
CAPACITY ml	245	(220, 280)	420	(355, 490)
COMPL. ml/cmH_2O	3.4 (3, 4)		7.4 (5, 8)	
PARL ms	48	(43, 52)	39	(38, 40)

MRP=maximum resting anal canal pressure; CP=anal canal pressure on coughing; SQP=anal canal pressure on maximum voluntary contraction of the anal sphincter; SENSATION=rectal volume at the sensory threshold level; CAPACITY=maximum tolerable rectal volume; COMPL.= rectal compliance (rectal capacity/maximum rectal pressure); PARL= pudendo-anal reflex latency.

chronic constipation (53%), whereas 39 patients had diarrhoea (26%). Among the 115 female patients 69 had traumatic deliveries (60%), among whom 36 had forceps delivery (31%). Only 20 were nulliparous (17%).

Objective Assessment

The MRP was 100 cm H_2O (control group : 120 cm H_2O; $p > 0.05$), while the CP was 70 cm H_2O (control group : 90 cm H_2O; $p < 0.001$) and the SQP was 60 cm H_2O (control group : 150 cm H_2O; $p < 0.00001$). The proctometrogram showed the rectal sensory threshold as being 100 ml (control group : 80 ml; $p > 0.05$), the maximum tolerable rectal capacity as 280 ml (control group : 420 ml; $p < 0.00001$) and the rectal compliance as 3.6 ml/cm H_2O (control group : 7.4; $p < 0.00001$). The electrophysiological test showed the PARL as 46.6 ms (control group : 39.4; $p < 0.002$) in this group of patients. See Table 4.2.

4.4.3 Group 'C'- Weakness Of The IAS

Twenty-one were the patients (male : female = 8 : 13; 38% : 62%) in this group, median age 68 years (95% CI : 63, 77 years), who presented with faecal incontinence, and had weakness of their IAS whereas the EAS was detected competent via the manometric studies.

Subjective Assessment

These patients had been complaining of faecal incontinence for 18 months (95% CI: 7, 48 months). The frequency of defaecation was reported as 10 occasions per week (95% CI: 7, 18). Twelve of these patients (57%) complained of chronic constipation, whereas four had diarrhoea

TABLE 4.2   Anal canal pressures recorded at rest, during maximum contraction on coughing and maximum conscious squeeze of the anal sphincter. Rectal volumes elicited at sensory threshold level and maximum tolerable rectal capacity. Rectal compliance and pudendo-anal reflex latency are also recorded.

	GROUP B		NORMAL CONTROLS	
	Median	95% CI	Median	95% CI
MRP cm H_2O	100	(100, 110)	120	(105, 126)
CP cm H_2O	70	(60, 80)	90	(70, 131)
SQP cm H_2O	60	(50, 70)	150	(115, 171)
SENSATION ml	100	(90, 105)	80	(70, 122)
CAPACITY ml	280	(245, 294)	420	(355, 490)
COMPL. ml/cmH_2O	3.6	(3, 4)	7.4	(5, 8)
PARL ms	47	(45, 50)	39	(38, 40)

MRP=maximum resting anal canal pressure; CP=anal canal pressure on coughing; SQP=anal canal pressure on maximum voluntary contraction of the anal sphincter; SENSATION=rectal volume at the sensory threshold level; CAPACITY=maximum tolerable rectal volume; COMPL.= rectal compliance (rectal capacity/maximum rectal pressure); PARL= pudendo-anal reflex latency.

(19%). Among the 13 female patients 5 had traumatic deliveries (38%), 2 had forceps deliveries (15%) and 4 were nulliparous (31%).

Objective Assessment

Anorectal manometry showed the MRP as 50 cm H_2O (control group : 120 cm H_2O; $p<0.00001$), the CP as 120 cm H_2O (control group : 90 cm H_2O; $p>0.05$) and similarly the SQP as 140 cm H_2O (control group : 150 cm H_2O; $p>0.05$). The proctometrogram showed the rectal sensory threshold as 110 ml (control group : 80 ml; $p<0.03$), the maximum tolerable rectal capacity as 350 ml (control group : 420 ml; $p<0.02$) and the rectal compliance as 5 ml/cm H_2O (control group : 7.4; $p<0.007$). The electrophysiological tests showed the PARL as 48.4 ms (control group : 39.4; $p<0.003$). See Table 4.3.

4.4.4 Group 'D'- 'Normal' Anal Sphincters

In this last group that consisted of 22 patients (male : female = 18 : 4; 82% : 18%), median age 56 years (95% CI; 40, 65 years), complaining of faecal incontinence appeared to have competent anal sphincters on manometric testing.

Subjective Assessment

These patients complained of faecal incontinence for 36 months (95% CI; 12, 60 months). The frequency of defaecation was reported as 7 occasions per week (95% CI; 7, 14). Thirteen patients in this group complained of chronic constipation (59%), whereas three had diarrhoea

Table 4.3 Anal canal pressures recorded at rest, during maximum contraction on coughing and maximum conscious squeeze of the anal sphincter. Rectal volumes elicited at sensory threshold level and maximum tolerable rectal capacity. Rectal compliance and pudendo-anal reflex latency are also recorded.

	GROUP C		NORMAL CONTROLS	
	MEDIAN	95% CI	MEDIAN	95% CI
MRP cm H_2O	50	(43, 70)	120	(105, 126)
CP cm H_2O	120	(100, 127)	90	(70, 131)
SQP cm H_2O	140	(127, 153)	150	(115, 171)
SENSATION ml	110	(100, 140)	80	(70, 122)
CAPACITY ml	350	(280, 373)	420	(355, 490)
COMPL. ml/cmH_2O	5.0	(3, 6)	7.4	(5, 8)
PARL ms	49	(43, 54)	40	(38, 40)

MRP=maximum resting anal canal pressure; CP=anal canal pressure on coughing; SQP=anal canal pressure on maximum voluntary contraction of the anal sphincter; SENSATION=rectal volume at the sensory threshold level; CAPACITY=maximum tolerable rectal volume; COMPL.= rectal compliance (rectal capacity/maximum rectal pressure); PARL= pudendo-anal reflex latency.

(14%). One female was nulliparous and the rest three had traumatic deliveries, one with forceps assistance.

Objective Assessment

The manometry tests showed the MRP as 140 cm H_2O (control group : 120 cm H_2O; $p>0.05$), the CP as 130 cm H_2O and similarly the SQP as 150 cm H_2O and (control group : 150 and 90 cm H_2O respectively; $p>0.05$). The proctometrogram showed the rectal sensory threshold as 113 ml (control group : 80 ml; $p>0.05$), the maximum tolerable rectal capacity as 350 ml (control group : 420 ml; $p>0.05$), whereas the rectal compliance as being 4 ml/cm H_2O (control group : 7.4; $p<0.02$). The electrophysiological tests showed the PARL as 38.4 ms (control group : 39.4; $p>0.05$). See Table 4.4.

4.4.5 The Stimulator Trial

Twenty-four patients (male : female = 3 : 21; 12.5% : 87.5%), aged 66 years (95% CI: 51, 70 years), who had attended the anorectal physiology laboratory complaining of faecal incontinence in the last 2 years, showed weakness of their anal sphincters via manometry (MRP : 60; CP : 50; SQP : 40, measured in cm H_2O), and had detectable pudendal neuropathy elicited via the PARL (PARL : 52 ms).

In this series, the patients had anorectal studies, as described previously, and videoproctography (see Chapter 5) before and after the domiciliary treatment by the pudendo-anal electrical stimulator.

Table 4.4 Anal canal pressures recorded at rest, during maximum contraction on coughing and maximum conscious squeeze of the anal sphincter. Rectal volumes elicited at sensory threshold level and maximum tolerable rectal capacity. Rectal compliance and pudendo-anal reflex latency are also recorded.

	GROUP D		NORMAL CONTROLS	
	MEDIAN	95% CI	MEDIAN	95% CI
MRP cm H_2O	140	(120, 160)	120	(105, 126)
CP cm H_2O	130	(120, 150)	90	(70, 131)
SQP cm H_2O	150	(120, 160)	150	(115, 171)
SENSATION ml	113	(70, 170)	80	(70, 122)
CAPACITY ml	350	(210, 381)	420	(355, 490)
COMPL. ml/cmH_2O	4.0	(3, 6)	7.4	(5, 8)
PARL ms	38.4	(35, 51)	39.4	(38, 40)

MRP=maximum resting anal canal pressure; CP=anal canal pressure on coughing; SQP=anal canal pressure on maximum voluntary contraction of the anal sphincter; SENSATION=rectal volume at the sensory threshold level; CAPACITY=maximum tolerable rectal volume; COMPL.= rectal compliance (rectal capacity/maximum rectal pressure); PARL= pudendo-anal reflex latency.

Objective Assessment Of The Stimulator Results

Contrasting the pre-stimulator results to the post-stimulator ones, the functional anal canal length representing the high pressure barrier zone in it was significantly enhanced ($p<0.004$) after the use of the stimulator than before. There was a significant increase in the CP ($p<0.0001$), the SQP ($p<0.03$) and the MRP ($p<0.004$) after the stimulator treatment (Figures 4.1, 4.2, and 4.3, respectively). The rectal sensory threshold, the maximum tolerable rectal capacity and compliance as measured by the proctometrography did not change significantly ($p>0.05$). The PARL which was delayed in these subjects showed no significant ($p>0.05$) enhanced conduction. The results from the study before and after the treatment with electrical stimulator are given in Table 4.5.

4.5   DISCUSSION

Faecal incontinence is a benign disorder whose effects can be devastating. It is a distressing condition both physically and emotionally (Brocklehurst, 1975). Afflicted individuals frequently become socially and professionally isolated, are reluctant to seek help because of embarassment. Although the condition is widely accepted as a problem in the elderly, in whom the incidence approaches 60%, it is now apparent that much younger age groups are frequently affected (Barret et al, 1989).

Continence to rectal mucus and faeces is maintained, under resting conditions, by the tonic contraction of the IAS, and to a lesser extend by the tonic activity of the EAS, both of which form the intra-anal canal pressure reaching a maximum resting pressure that in its turn secures continence.

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Table 4.5 Anal canal pressures recorded at rest, during maximum contraction on coughing and maximum conscious squeeze of the anal sphincter. Rectal volumes elicited at sensory threshold level and maximum tolerable rectal capacity. Rectal compliance and pudendo-anal reflex latency are also recorded.

	PRE-STIMULATOR		POST-STIMULATOR	
	MEDIAN	95% CI	MEDIAN	95% CI
MRP cm H_2O	60	(50, 60)	70	(60, 84)
CP cm H_2O	50	(38, 62)	60	(60, 80)
SQP cm H_2O	40	(30, 60)	60	(40, 80)
SENSATION ml	113	(87, 127)	100	(83, 110)
CAPACITY ml	263	(230, 311)	280	(245, 326)
COMPL. ml/cmH_2O	4.0	(3, 5)	4.0	(3, 5)
PARL ms	52	(46, 57)	48	(41, 54)

MRP=maximum resting anal canal pressure; CP=anal canal pressure on coughing; SQP=anal canal pressure on maximum voluntary contraction of the anal sphincter; SENSATION=rectal volume at the sensory threshold level; CAPACITY=maximum tolerable rectal volume; COMPL.= rectal compliance (rectal capacity/maximum rectal pressure); PARL= pudendo-anal reflex latency.

n = 24
p < 0.0001

120 —

80 —

cm H_2O

40 —

0 —

CP
BEFORE

SCP
AFTER STIMULATOR

Anal canal cough pressure
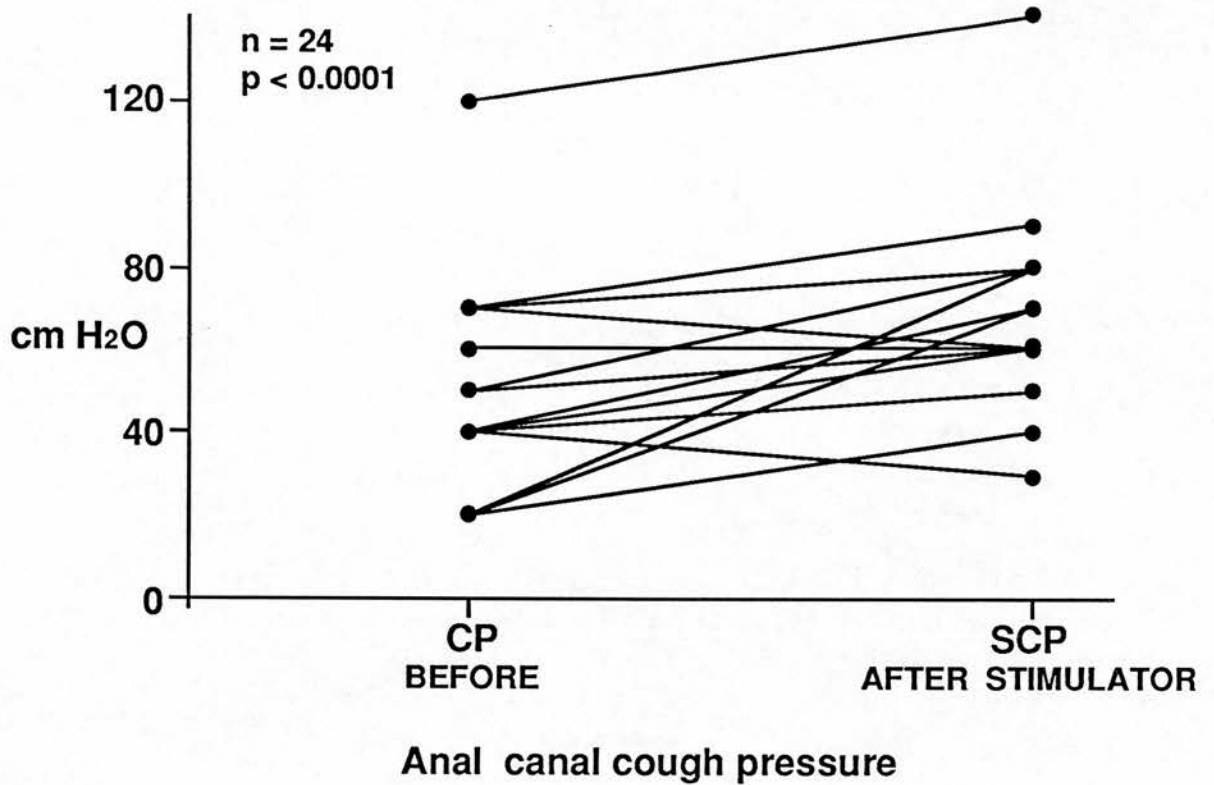
Figure 4.1   Maximum   pressure recorded in the anal
canal during reflex response to a cough before and
after the course of dorso-genital nerve stimulation,
showing the p value (statistical analysis used the sign
test for paired comparison).

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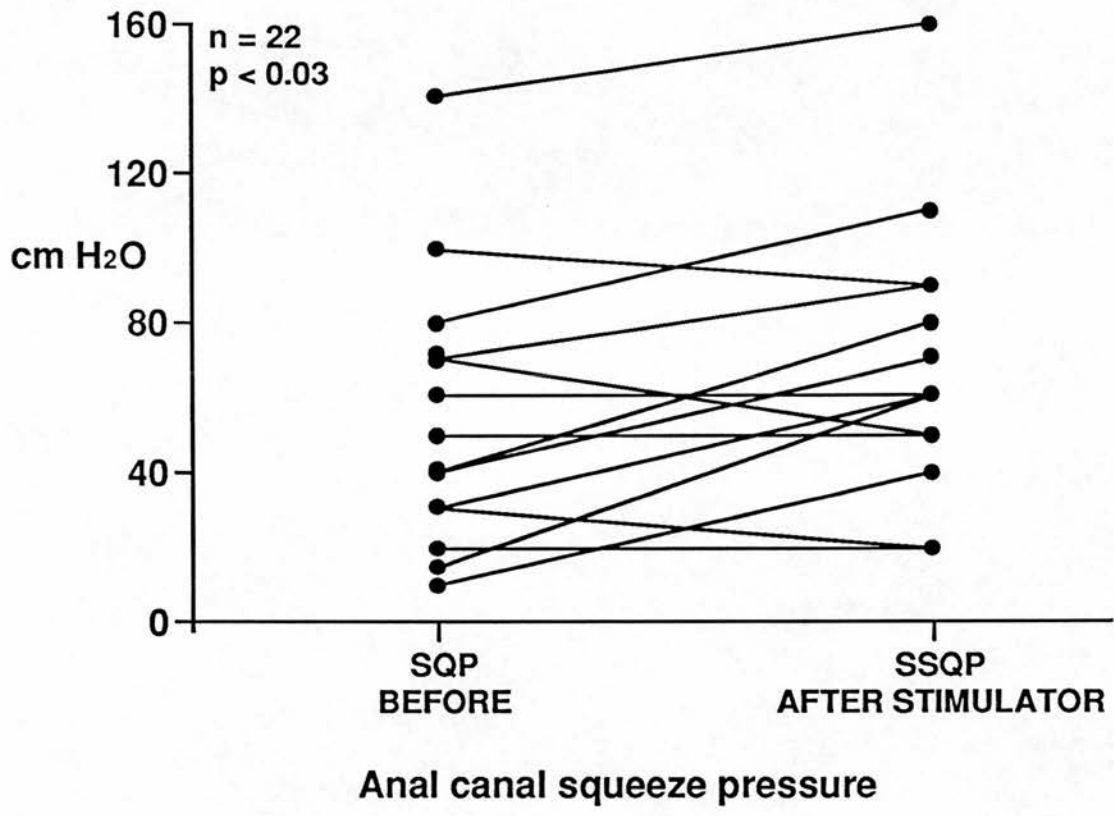
Figure 4.2   Maximum   pressure recorded in the anal
canal during maximal voluntary squeeze contraction of
the anal sphincter before and after the course of
dorso-genital nerve stimulation, showing the p value
(statistical analysis used the sign test for paired
comparison).

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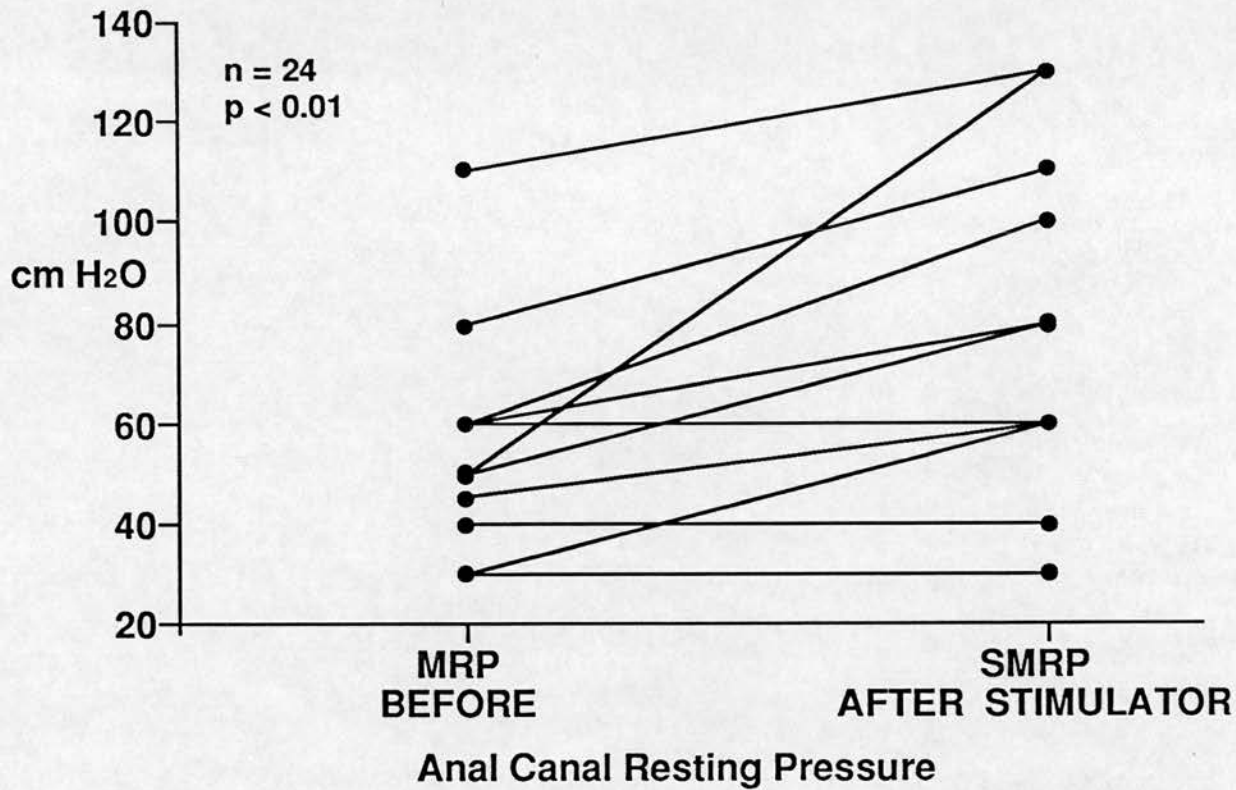
Figure 4.3   The maximum resting pressure recorded in
the anal canal before and after the course of dorso-
genital nerve stimulation, showing the p value
(statistical analysis used the sign test for paired
comparison).

During gradually increasing distention of the rectum, that is accompanied by the increase in the intrarectal pressure, a point is reached when the intrarectal pressures overcome the intra-anal canal pressure and either defaecation is initiated, or voluntary contraction of the EAS reinforces an even higher intra-anal canal pressure thus inhibiting defaecation. In the presence of rapid rectal distention and increase in intra-abdominal pressure, during spastic rectal contractions, the MRP in the anal canal may be lower than the intrarectal pressure in spite of the compensatory contraction of the EAS, leading to incontinence (Read, 1987).

The innervation of all the pelvic floor muscles originates in the S2, S3 and S4 spinal segments (Schroder, 1980; 1981). The EAS receives fibres via the pudendal nerves (Snooks and Swash, 1985). Local anaesthetic block of the pudendal nerve abolishes the activity in the EAS, but reduces the intraluminal anal canal pressure by only 15% (Duthie and Watts, 1965). The involuntarily controlled smooth muscle of the IAS contributes upto 80% of the intraluminal anal resting tone (Bennett and Duthie, 1964). The factors that influence the high resting tone of the anal sphincters in the maintenance of continence are not as yet fully understood, however in recent reports, the EAS response has been proved to be important in the control of continence (Felt-Bersma et al, 1989). The control of continence is a spinal reflex (Parks et al, 1962) and its activity is related to sensory awareness and stimuli (Sun et al, 1990) as well as to muscle response to stretch by intra-abdominal pressure (Read et al, 1983; Swash, 1985). It therefore becomes possible that any impairement in either of these factors disrupting the intactness of this reflex leads to incontinence.

Anorectal studies consisting of manometry with sensory responses and electrophysiology revealed abnormalities in all our patients tested for FI.

The majority of patients (84.5%) had weakness of the EAS, 54% were faecally incontinent due to EAS weakness alone. FI was associated with weakness of the IAS in 38.3% of patients, with 7.6% presented due to IAS weakness alone. An interesting fact is that 7.9% of patients in this study were faecally incontinent not because of failure of competency of anal sphincters. This once more confirms the idea of the multifactorial aetiology of FI (Williams, 1988).

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In analysing the groups A, B, C and D it became apparent that in all of them there was a reduction in compliance, irrespective of sphincter function, thus suggesting overlap with a relatively high intrarectal pressure which is consistent with the irritable bowel syndrome (Varma and Smith, 1984). This is an additional reason for these patients being clinically predisposed to FI whatever other abnormality, if any, coexisted.

In group 'A', the effectiveness of both sphincters was severely impaired but the sensory threshold was not significantly different from that of the control group. However, weak anal sphincters were not the only abnormalities elicited. The rectal overall capacity and compliance were significantly reduced. Evidence of pudendal neuropathy was also present via a significantly increased PARL. The fact that this group consisted of females (majority of 92%), confirms that females are bound to suffer from FI more than men are.

In group 'B', the EAS was indicated incompetent via manometric tests, whereas the IAS pressure was not significantly different from that in the control group. As for the previous group, the female preponderance was obvious (majority of 77%). Although, rectal sensory threshold did not differ

from the control group, the rectal capacity and compliance were again markedly reduced. Therefore, one would expect the IAS inhibitory response of relaxation to the distention of the rectum (as of the type which follows 'sampling') to be the main aetiological factor in this group's incontinence. This is because it would require a minimal rectal volume stimulus ('spastic rectum') to initiate the IAS response and thus overcome the only 'force' maintaining high intraluminal anal canal pressure, resulting in incontinence. Not surprisingly, this group showed a prolonged PAR, accompanying the weakness of the EAS.

Group 'C' comprises a rather small group of patients compared to the above mentioned ones, these were patients who were troubled with faecal incontinence on the basis of normal EAS pressure responses and a reduced intra-anal canal resting pressure, thus revealing weakness of the IAS. However, the rectal sensory threshold was significantly impaired in this group (Miller et al, 1988). Thus the 'powerful' EAS could have been late in responding (with a contraction) to a faecal stimulus, resulting in incontinence. This underlines the importance of the EAS in the maintainance of continence especially in the presence of other abnormalities such as sensory defects, which eliminate the voluntary response of the EAS to contraction which additionally serves to promote continence. Furthermore, the rectal capacity and compliance were significantly reduced and once more pudendal neuropathy was elicited via a prolonged PARL.

In the last 'D' group, the anal sphincters had high intraluminal pressures, thus revealing competent sphincters and virtually eliminating the possibility of incontinence due to failure of sphincter control. There was neither a rectal sensory deficit in this group, nor a reduced rectal capacity was observed. The PARL did not significantly differ from the one in the control

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group. In this unusual group the only abnormality detected was a significantly decreased rectal compliance. The reduced compliance observed, in the presence of a normal rectal capacity, possibly implies a higher intrarectal (intra-abdominal) pressure and is thus similar to that described in the Irritable Bowel Syndrome (Varma and Smith, 1984). This is an area which needs more investigation, both clinically and physiologically, requiring ambulatory intrarectal and intra-anal recordings to illuminate further details of the mechanism of incontinence (Miller et al, 1988; Kumar et al, 1989). It could be the case that higher intrarectal than intra-anal pressure may lead to incontinence. Alternatively, high intrarectal pressure might overcome the anal canal barrier pressure during phases of spontaneous relaxation (Sun et al, 1989; 1990), such as occur in the sampling reflex (Miller et al, 1988).

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The pelvic floor and EAS at rest are in a state of continuous tonic contraction, dependent on a spinal reflex completed through the conus medullaris by afferent and efferent pathways in the sacral S2, S3 and S4 segments of the spinal cord. The integrity of the arc can be tested by the pudendo-anal reflex (Varma et al, 1986; Snooks and Swash, 1987). Its elicitation is performed by detecting a measurable reflex contraction of the pelvic floor and external sphincter but in patients with faecal incontinence (neurogenic FI) there is an increased latency from stimulation to response. The delay in conduction has been used as a sensitive indicator of neurogenic damage (Varma et al, 1986). Traction injury to the pudendal and pelvic nerves is associated with dysfunction of the pelvic floor and EAS therefore leading to faecal incontinence (Neill et al, 1981). Injury to these nerves also

occurs during excessive straining in the perineal descent of chronic constipation and a more acute event of a similar type occurs during labour (Snooks et al, 1984; Swash et al, 1985; Jacobs et al, 1990). When there is partial denervation, the remaining intact nerve fibres take part in the reinnervation of the muscle fibres (Swash, 1987). Depending on the site and degree of injury may take up to two years to be complete.

All patients in the three groups who had their sphincters impaired appeared to have an established pudendal neuropathy compatible with neurogenic damage (Womack et al, 1986) derived from obstetric trauma or chronic straining at defaecation in long standing constipation. Therefore it was thought to be appropriate to treat these patients by stimulating the pudendo-anal reflex with an electrical stimulator. This has already proved successful in treating a generally younger group of female patients with neurogenic FI, due to damage to the pelvic floor and EAS after difficult and prolonged deliveries (Binnie et al, 1990).

The group of 24 patients described in this chapter consisted of mainly older patients, resistant to other treatment (medical, surgical and physiotherapy). All had the PARL prolonged but recognisably present (Kiss and Swash, 1984; Kiff and Swash, 1984). Thus stimulation of the PAR which is a particularly non-extinquishable reflex was possible. All patients admitted an improvement in their symptoms, more so the younger patients than the older ones. The main objective findings accompanying the treatment were a lengthening of the anal canal, an increase in the EAS pressures recorded in response to coughing as well as squeezing and an increase in MRP. The CP usually approximates to the maximal SQP (Swash and Mathers, 1988), since both characterise EAS contractile activity. The squeeze response relies on a patients capability of voluntarily contracting the EAS. However, the cough

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response is a reflex transmitted to the pelvic floor as a result of an increment of intra-abdominal pressure which provokes the contraction of the EAS without the involvement of the higher centres and is not so dependent on a patient's motivation. The MRP increase may be attributable to an improvement in the tonicity of the EAS contribution to it, which has been variously expressed as between 15-25% (Duthie and Watts, 1965).

The results from the stimulator group showed an increase in the functional anal canal length. Patients with FI who have undergone sphincteroplasty have been repeatedly shown to have an improvement in the functional length of the anal canal (Wexner et al, 1991). The effectiveness of the surgical procedure in promoting continence must be dependent on enhanced mechanical support for the anal canal barrier pressure zone (Schewer et al, 1989). In the stimulator cases, the lengthening of the functional canal accompanied increased EAS activity as evidenced by the greater cough and squeeze reflex responses and the associated increase in the MRP. A dynamic change rather than a mechanical one may thus have been achieved by this method which adopts a physiological approach to the restoration of continence.

In this chapter a general group of patients with FI has been investigated. It has been shown that by making a detailed study of the various aetiological factors of FI, a better understanding of the mechanisms involved may be achieved. FI is attributed to different dysfunctions of motor control, sensory awareness, compliance and rectal capacity. This suggests that these factors interrelate in an integrated and harmonious way for the preservation of function.

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CHAPTER 5

RADIOLOGICAL
VIDEOPROCTOGRAPHY
IN
PATIENTS WITH
FAECAL INCONTINENCE

5.1 SUMMARY

Twenty-four patients with neurogenic faecal incontinence, who showed weakness of their anal sphincters on manometric investigation and in whom pudendal neuropathy was elicited via a prolonged pudendo-anal reflex latency underwent radiological videoproctography before and after a course of the pudendo-anal reflex electrical stimulator. The pre-stimulator group consisted of rectocoeles (63%), patent anal canal at rest (75%), persistent impression of the puborectalis sling on defaecation (46%), descending perineum syndrome (12.5%). 50% had incomplete evacuation. From the videoproctographic anorectal images the anorectal angles (ARAs) were measured: at rest (88°), on squeezing (65°), on straining (93°) and on evacuation (95°). The pelvic floor level was elicited: at rest (2.5 cm below the pubococcygeal line), on ascent (1 cm upward movement, on voluntary contraction of the pelvic floor) and on descent (1 cm downward movement during attempted defaecation). This group in the post-stimulator videoproctography test consisted of fewer ($p<0.04$) patent anal canals.

The patients with neurogenic faecal incontinence studied did not present with obtuse anorectal angles. These angles, in contrast to the anal sphincter pressures described in the previous chapter, showed no change ($p>0.05$) after the pudendo-anal reflex stimulator trial. There was an increase in the pelvic floor ascent ($p<0.02$), whereas no change was recorded on either the pelvic floor level at rest or its descent ($p>0.05$).

The implication is that the ARAs were not influenced by the pudendo-anal reflex electrical stimulator either because the ARAs had not been impaired prior to the trial or pudendal nerve stimulation may not be effacious in improving the anorectal angles.

5.2   INTRODUCTION

Continence is an unconscious process, a complex phenomenon that is controlled partly by local reflex mechanisms and partly by higher centres, which in turn receive support from the conscious will (Duthie, 1971). It depends on the interaction of many factors, such as the consistency of stool, the coordinated activity as well as anatomical integrity of smooth and striated muscle in the anorectum and pelvic floor (Henry and Swash, 1985). The smooth muscle of the internal anal sphincter responds to local factors and reflexes mediated by the autonomic nervous system (Frenckner and Ihre, 1976). The striated musculature of the voluntary sphincter apparatus is under the control of spinal and cerebral centres through its somatic efferent and afferent connections (Kerremans, 1969).

A sensory deficit and damage to the internal or external anal sphincter, results in only minor degrees of incontinence. The internal sphincter maintains a closed canal and probably prevents any passage of flatus and liquid stool and therefore is considered important for fine control in continence (Kerremans, 1969). The external anal sphincter, by vigorous contraction, may preserve continence in situations in which the normal mechanisms may be severely challenged by profuse diarrhoea.

Read et al, (1984) in a study comparing the sphincter function in patients who were incontinent to liquids only to that in patients who were incontinent to both solids and liquids showed that incontinence to liquids was associated with a functional weakness of the internal sphincter while the external sphincter was weaker in patients who were incontinent to both solids and liquids. It is possible that solid, liquid and gas rectal contents may be

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identified by their ability to stimulate the stretch receptors in the rectal wall and as the gas and liquid enter the rectum more rapidly than the solid matter, this rapid rectal distention results in different sensory and motor responses from those occurring during the gradual distention (Rogers et al, 1988).

Intra-anal canal pressures are sustained via the tonic contraction of both the anal sphincters, external and to a larger extent internal sphincters (Duthie and Watts, 1965). The resting pressure in the anal canal is greater than that in the rectum in the resting state. Phillips and Edwards (1965) recording pressures simultaneously intra-anally and intrarectally found that no incontinence developed in normal subjects when the intrarectal pressure exceeded the pressure in the anal canal. Thus, the sphincters contraction alone is not the major factor maintaining incontinence. Milligan and Morgan (1934) found that in cases in which the puborectalis was injured during the EAS division for fistula-in-ano, incontinence was inevitable. This did not happen with the division of the EAS alone. Continence is therefore the result of physiological mechanisms maintaining a normal (60°-105°) anorectal angle (Hardcastle and Parks, 1970). If the puborectalis is damaged, the anorectal angle becomes more obtuse and gross faecal incontinence arises (Kerremans, 1969).

When continence is threatened by acts which result in increased intra-abdominal pressure overcoming the intra-anal canal barrier pressure, a reflex contraction develops within the anal sphincter muscles (Parks et al, 1962). Taverner and Smiddy (1959) showed increased motor unit firing in the pelvic floor and EAS muscles during coughing. This reflex was intact in patients with complete transection of the cord, it is therefore mediated within the cord (Melzack and Porter, 1964). The patient's awareness of rectal distention by the arrival of faecal contents is another factor of importance in the

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preservation of continence, as many patients who experienced incontinence had sensory deficit of rectal filling (Henry, 1987). An additional contribution to continence is provided by simple surface tension effect created by the close apposition of moist mucosal surfaces in the anal canal (Duthie, 1975).

The investigation of the rectum, pelvic floor and anal sphincter muscles both at rest and during defaecation is necessary to understand the interactions of the above mentioned factors and mechanisms in the maintenance of continence in patients with faecal incontinence (Henry et al, 1985). This has been made possible through the use, apart from the routine tests of anorectal manometry and electrophysiology, of defaecography. This technique has been developed by Mahieu and colleagues (1984), and it provides information about the level of the pelvic floor at rest, its ascent during voluntary squeezing and its descent on attempted defaecation; the anorectal angle at rest, on squeezing and straining; any anatomical deformity, and the ability of the patient to expel the simulated 'faecal' bolus.

Dynamic imaging of the anorectum by the use of videoproctography is essential to a proper understanding of defaecation (Finlay, 1988) as well as in investigating continence in faecally incontinent patients. It provides a more physiological examination, with the greatest detail being obtained in anorectal contour as it changes dynamically (Bartolo et al, 1985). It is used in this chapter, as a means of assessing the treatment applied to incontinent patients with electrical stimulation of the pelvic floor and external anal sphincter (EAS) musculature via the pudendo-anal reflex, in an attempt to activate and strengthen these muscles through the appropriate S2, S3 and S4 reflex arc (see Chapter 4).

5.3 MATERIALS AND METHODS

5.3.1 Subjects

Twenty four patients (male : female = 3 : 21), median age 66 years (95% CI : 51, 69 years), with faecal incontinence were recruited to the study. These patients showed weakness of their anal sphincters via manometry: Maximum anal canal resting pressure (MRP) : 60 cm H_2O (95% CI: 50, 60); Anal canal pressure on 'squeezing' (SQP) : 40 cm H_2O (95% CI:30, 60); Anal canal pressure on cough response (CP) : 50 cm H_2O (95% CI: 38, 62). These patients presented also with pudendal neuropathy elicited via the pudendo-anal reflex latency (PARL : 52 ms, 95% CI: 46, 57 ms).

In this series, the patients underwent videoproctography before and after a course of dorso-genital nerve stimulation by the pudendo-anal reflex electrical stimulator. The proctographic films obtained from each pre- and post-stimulator session of recording, were processed only after the completion of the study, to avoid any undue bias or psychological influence on the patient at the time of the examination. Ethical permission was obtained for this study by the Lothian Health Board Ethical Committee. Informed consent was also obtained from the patients.

5.3.2 Methods

A portable stimulator has been used, that provided a train of square wave stimuli to the dorso-genital nerve with fixed frequency of 1 Hz and duration of 0.1 ms (see Figure 2.2 in Chapter 2). Skin stimulus has been applied at the base of the glans penis (in males) and the clitoris (in females) as to that used for the PARL test (see Chapter 2) by saline soaked felt

electrodes. A sub-maximal tolerable stimulation voltage has been used approximately three times the sensory threshold depending on the individual's tolerability. A domiciliary self-administered treatment has been applied to each of the patients that lasted for 5-10 minutes on two to three occasions per day for a minimum of 8-week course.

For the videoproctography no bowel preparation has been required since the rectum is usually empty. The composition and preparation of the contrast medium aimed at getting a radioopaque substance with a consistency similar to that of normal stools. A suspension of 50 cc barium sulphate (Baritop^{TM} 100) mixed with potato mash and hot water, stirred gradually until a smooth thick paste is formed (approximately for every 30 ml of hot water 1 tablespoons of potato powder). The paste is poured into 50-cc wide-tipped syringes in which it cools to around body temperature and it hardens at which point it is injected into the rectum in a formed state through a short wide anal catheter (Polibar ACB^{TM}). Uniformity of the consistency of the barium mixture was preserved by having one individual preparing it in all the sessions.

The amount of contrast used has varied dependent upon the sensory awareness and tolerability of the individual. The proctometrogram test performed as a routine manometric test (see Chapter 2) gave useful information about the volume of rectal sensory threshold, the maximum tolerable rectal capacity and compliance providing the background knowledge for the performance of the proctographic test. For improved coating and for a sharper outline of the rectal mucosa a concentrated suspension of barium is placed in the anal catheter and injected into the rectum prior to the paste. A fine Foley catheter (8F/Paediatric) has been used as an anal canal marker. The patient has been then seated on a specially

designed commode (ELSAN^{TM}).

Lateral pelvic radiographs were taken of the patient in the sitting position at rest, during maximum 'squeeze' effort and on straining. These have been followed by a period of continuous videorecording during which the patient is ultimately asked to evacuate. The following parameters have been measured : anorectal angle (ARA) at rest; during 'squeezing'; on straining; during evacuation; pelvic floor (PF) level at rest; pelvic floor ascent during 'squeezing'; and pelvic floor descent on attempted defaecation.

Changes in configuration of the rectal wall during evacuation have been observed and the presence of a rectocoele, persistent impression of the puborectalis sling on defaecation (Figure 5.1), descending perineum syndrome (by definition: PF descent on straining greater than 2 cm; Bartram and Mahieu, 1985) and whether the anal canal has been patent or closed during the various expulsive manoeuvres have been recorded. An estimation of the efficiency of evacuation has also been made. The videoproctograms have been performed prior to and after the electrical stimulator treatment.

5.3.3 Statistical analysis

In the statistical analysis of the results the median values are presented with their 95% confidence interval (CI) and the non-parametric sign test has been used for paired comparison of the pre- and post-stimulator studies.

5.4 RESULTS

The level of the anorectal junction was taken as meaning the level of the pelvic floor. The parameters employed were the PF level at rest, the PF
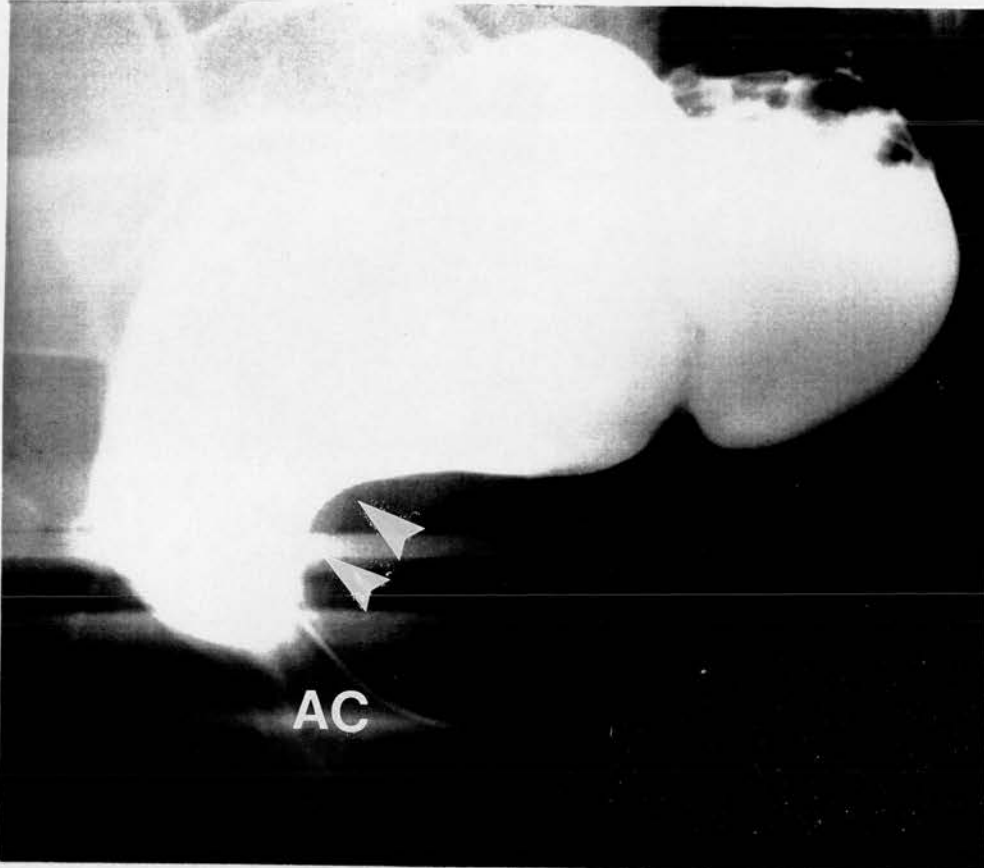
Figure 5.1 A radiological image recorded during video-proctography. The contrast medium is barium mixed with re-hydrated potato powder. A ureteric catheter is inserted via the anal canal serving as an anal canal marker (AC).
The patient on attempted defaecation was unable to proceed to rectal evacuation. The puborectalis impression was persistent (arrows) on attempted defaecation. The anal canal was patent at rest, as leakage of the contrast medium may be seen to have occurred in this proctogram.

ascent, PF descent and the descending perineum. Since by definition a descending perineum is considered present when the absolute movement of the anorectal junction on straining is greater than 2 cm, a correction for magnification has been made for this parameter only, the magnification factor being approximately 1.5. The values for the PF level in relation to the pubococcygeal line, the PF ascent (absolute movement of the anorectal junction on squeezing effort) and the PF descent (absolute movement of the anorectal junction on straining) have had no correction for magnification.

5.4.1 Pre-Stimulator Study

In the 24 cases studied by radiological videoproctography faecal incontinence was the main complaint. This group consisted of 15 rectocoeles (63%), 11 cases of persistent impression of the puborectalis sling on defaecation (46%) and 3 cases of descending perineum syndrome (12.5%). 12 cases had incomplete evacuation (50%) and 18 were cases of incontinence with the anal canal open at rest and during the expulsive manoeuvres (75%).

Anorectal Angles

The anorectal angle at rest was 88° (95% CI : 60°, 96°) on squeezing was 65° (95% CI : 54°, 76°), on straining 93° (95% CI : 74°, 115°) and on evacuation 95° (95% CI : 82°, 115°). Table 5.1.

Pelvic Floor Movements

The pelvic floor level at rest was 2.5 cm (95% CI : 2, 4.5 cm) below the pubococcygeal line, on squeezing 2 cm (95% CI : 1, 3 cm) still below the pubococcygeal line and on straining 4.5 cm (95% CI : 4, 5.5 cm)

again below this line. The PF ascent was 1.0 cm of upward movement (this was significant compared to the resting level, $p < 0.0002$) and the PF descent was 1.0 cm of downward movement (this again was significant compared with the level at rest, $p < 0.00001$). Table 5.2.

5.4.2 Post-Stimulator Study

After the 24 patients had completed a minimum of eight weeks course of dorso-genital nerve stimulation with the pudendo-anal reflex electrical stimulator they underwent repeat radiological videoproctography. There were now 15 cases of rectocoeles (62.5%), 6 cases of persistent impression of the puborectalis sling on defaecation (25%), 6 cases of descending perineum syndrome (25%), 7 cases of incomplete emptying of the barium-potato mixture on proctography (29%), and although no obvious incontinence during the test, 11 cases of an open anal canal (46%) during the various manoeuvres prior to evacuation.

Anorectal Angles

The ARA at rest was recorded as 85° (95% CI : 75°, 101°), on squeezing 68° (95% CI : 60°, 75°), on straining 105° (95% CI : 85°, 107°) and on evacuation 105° (95% CI : 95°, 130°). Table 5.1.

Pelvic Floor Movements

The PF level at rest was 3.5 cm (95% CI : 2.5, 4.0 cm) below the pubococcygeal line, on squeezing 2 cm (95% CI : 1.0, 4.0 cm) still below the pubococcygeal line and on straining 5 cm (95% CI : 5.0, 6.0 cm) again below this line. The PF ascent was 1 cm of upward movement (this was significant compared to the resting level, $p < 0.0001$) and the PF descent 1 cm

of downward movement (this was again significant compared with the level at rest, p<0.00001). Table 5.2.

5.4.3 Pre-Stimulator VS Post-Stimulator Studies

In this group of 24 patients during the post-stimulator test as compared with the pre-stimulator one, changes were noted concerning the impression of the puborectalis sling, the completeness of evacuation and the openness of the anal canal. In 11 cases there was persistent impression of the puborectalis sling in the pre-stimulator group, whereas 6 cases were recorded as having this feature of lack of puborectalis relaxation in the repeated post-stimulator study (p>0.05). 12 cases were reported as having incomplete evacuation during the pre-stimulator study, but 7 cases failed to complete evacuation in the post-stimulator study (p>0.05). In the pre-stimulator group there were 18 cases of an open anal canal prior to defaecation. However, only 11 of them had an open anal canal in the post-stimulator study (p<0.04).

Anorectal Angles

The ARA at rest during the pre-stimulator test was 88°, and was recorded as 85° on the post-stimulator test, the change being insignificant (p>0.05); on squeezing the ARA was 65° on pre- and 68° on post-stimulator tests (p>0.05); on straining the ARA was 93° on pre- and 105° on post-stimulator tests (p>0.05); and on evacuation the ARA was 95° on pre- and 105° on post-stimulator studies (p>0.05).

Pelvic Floor Movements

The PF level at rest was 2.5 cm below the pubococcygeal line on pre- and 3.5 cm on post-stimulator tests; on squeezing the PF level was

Table 5.1   The Anorectal angles (ARA) recorded by radiological videoproctography at rest, on voluntary contraction of the pelvic floor - 'squeezing', on straining and during defaecation both prior to and after a course of dorso-genital nerve electrical stimulation.

	PRE-STIMULATOR ARA		POST-STIMULATOR ARA	
	Median	95% CI	Median	95% CI
REST	88°	(60°, 96°)	85°	(75°, 101°)
SQUEEZE	65°	(54°, 76°)	68°	(60°, 75°)
STRAINING	93°	(74°, 115°)	105°	(85°, 107°)
EVACUATION	95°	(82°, 115°)	105°	(95°, 130°)

(The results are expressed in median values and their 95% confidence intervals.)

Table 5.2   The Pelvic Floor (PF)* level recorded by
radiological videoproctography at rest, on voluntary
contraction of the pelvic floor - 'squeezing', on
straining and during defaecation both prior to and
after a course of dorso-genital nerve electrical
stimulation.

	PRE-STIMULATOR PF		POST-STIMULATOR PF	
	Median	95% CI	Median	95% CI
REST cm	-2.5	(-4.5, -2.0)	-3.5	(-4.0, -2.5)
SQUEEZE cm	-2.0	(-3.0, -1.0)	-2.0	(-4.0, -1.0)
STRAINING cm	-4.5	(-5.5, -4.0)	-5.0	(-6.0, -5.0)
PF ASCENT cm	1.0	(0.5, 1.5)	1.0	(1.0, 2.0)
PF DESCENT cm	-1.0	(-0.5, -2.0)	-1.0	(-0.5, -2.5)

* The PF level at rest , on squeezing, and straining presented with a negative sign (-)
when this level lies below the pubococcygeal line. However, the PF ASCENT recorded with a
positive sign ('+' omitted) reflects an upward PF movement, whereas the PF DESCENT with a
negative sign (-) represents a downward PF movement, both related to anorectal junction
level at rest.

2 cm below the pubococcygeal line on pre- and post-stimulator tests; on straining the PF was 4.5 cm below the pubococcygeal line on pre- and 5 cm on post-stimulator studies. There was no significant change in the PF descent comparing the post- with the pre-stimulator studies. However, the PF ascent (Figure 5.2) was significantly increased in the post-stimulator study as compared with the pre-stimulator one ($p < 0.02$).

5.5 DISCUSSION

The rectum acts as a reservoir for faecal matter until evacuation is socially convenient. The rectum should therefore empty efficiently and completely when required. Evacuation depends on complex interactions between the sphincteric and reservoir components of the continence mechanism. These interactions are the subject of considerable physiological investigation (Kumar and Wingate, 1985). With greater understanding of the physiology of continence a developing interest in disorders of continence such as the faecal incontinence has arisen. Interaction among the rectum, the pelvic floor and the anal sphincters is a dynamic process and detailed information about this is obtained from studies conducted during defaecation rather than in static situations (Bartram et al, 1988). Videoproctography has been recently developed as a technique of dynamic assessment of anorectal physiology (Womack et al, 1985), including a combination of this with simultaneous EMG and pressure recordings.

Videoproctography is a simple method, relatively objective and more sensitive than clinical evaluation in the detection and description of defaecation disorders on examining evacuation under 'physiological'
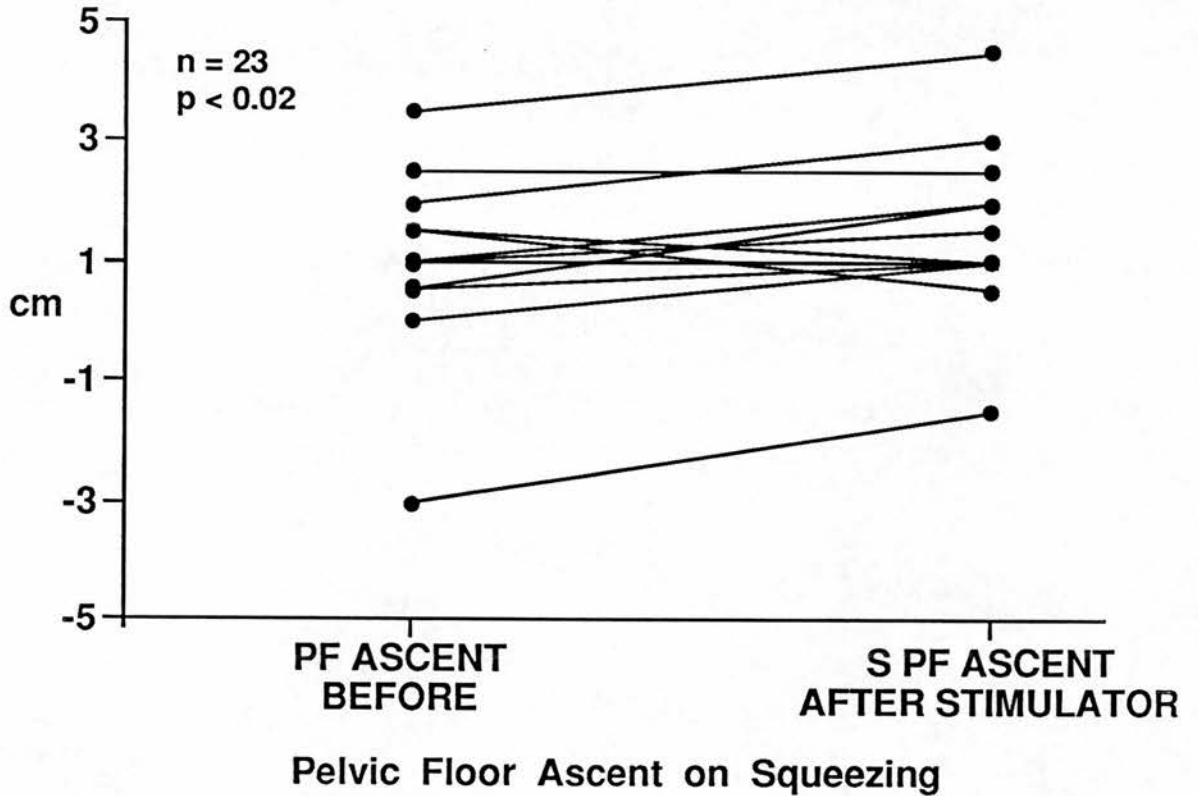
Figure 5.2   The pelvic floor ascent recorded by
radiological videoproctography during a maximal
voluntary squeeze contraction of the anal
sphincter before (PF ASCENT) and after (S PF
ASCENT) the course of dorso-genital nerve
stimulation, showing the p value (statistical
analysis used the sign test for paired
comparison).

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conditions (Mahieu et al, 1984). It allows recording of the proctographic parameters, ARA and PF, to be made providing simultaneous information about any present structural defects like rectocoeles, rectal intussusception and prolapse. It allows a means of comparison of the above mentioned proctographic parameters in the same patients before and after treatment. In this chapter, it has also allowed documentation of proctographic changes in faecally incontinent patients after a trial with the pudendo-anal reflex electrical stimulator.

The post-stimulator study showed no significant change in the presence of rectocoeles, the puborectalis sling impression on defaecation and the completeness of evacuation. However, the patency of the anal canal had significantly changed after the stimulator trial. Although it was open in most of these patients with incontinence, and as such attributable to the lack of control of continence, it significantly altered becoming closed in many of these patients after the stimulator treatment. This is a result of an increase in the tone of the anal sphincters which is in agreement with the greater maximum resting pressure achieved after the stimulator trial reported in Chapter 4.

A number of patients had persistent impression of the puborectalis sling and these patients evacuated incompletely which may be the result of psychological inhibition. The lack of relaxation during defaecation can be attributed to the fact that the patients had to perform a very private act in circumstances that are artificial and lack social privacy. A small number of them (21%) performed evacuation better the second time (during the post-stimulator study) simply because they knew what to expect and in that way felt more relaxed, thus there was no persistent impression of the puborectalis sling on defaecation and they achieved complete rectal emptying.

In the group studied the ARAs at rest and on squeezing were not the obtuse ones reported by others (Mahieu et al, 1984). This unexpected finding may have resulted from the fact that the patients for the videoproctography were selected blindly and the measurements of the ARAs were only disclosed after the completion of the study. However, the patients were all faecally incontinent, with low anal canal resting, cough and squeeze pressures and had been selected as a group with severe incontinence already known to be resistant to treatment (Pescatori et al, 1989). This signifies that although the external anal sphincter was weak and pudendal neuropathy was present, the puborectalis muscle was not particularly affected (Bartolo et al, 1983; 1986). It was capable of maintaining a fairly 'acute' ARA and also responded changing the ARA significantly during the 'squeeze' command in both the pre-stimulator ($p < 0.0001$) as well as the post-stimulator ($p < 0.00001$) studies. There was no significant difference in the dynamic change in the pre-stimulator ARAs compared with the ARAs in the post-stimulator study. This may depend upon the fact that the ARAs were not abnormally obtuse in this group of faecally incontinent patients in the first instance, who may have had predominantly a lesion of their anal sphincters. On the other hand, this may have resulted from an insignificant change produced by the stimulator, in the presence of normal ARAs.

The PF level at rest, on voluntary contraction of the pelvic floor musculature - 'squeezing' and during straining showed no significant change ($p > 0.05$) during the post-stimulator trial compared with the pre-stimulator one. However, the PF ascent, reflecting the absolute movement of the anorectal junction during the squeezing effort, improved significantly ($p < 0.02$) after the use of the stimulator.

In Chapter 4, the results of anorectal manometry and the

electrophysiology of the pudendo-anal reflex electrical stimulator trial were discussed for patients with neurogenic faecal incontinence and evidence of pudendal neuropathy. Improvements in the anal canal pressures such as the MRP, SQP, CP, were noted signifying a greater tone achieved after activation of the S2, S3 and S4 reflex arc by repetitive stimulation of the pudendal nerve. As a result of this an increase in the functional anal canal length was achieved. The improvement in the anal sphincters tone corresponded in the videoproctographic study with greater PF ascent. Therefore, at the end of the electrical stimulator trial for patients with faecal incontinence, these patients had a capacity for a better control of continence since they had a significantly improved anal sphincter and pelvic floor tone.

In contrast to previous studies of dynamic proctography performed in patients with faecal incontinence (Mahieu et al, 1984), in which patients had more obtuse ARAs compared with normal controls, the patients studied in this chapter presented with less obtuse angles. This group, therefore, seemed to have the puborectalis muscle preserved, or at least not affected by the pudendal neuropathy that appeared to be the cause of damage to the external anal sphincter (Neill and Swash, 1980). There may be two reasons for this. The first is that the damage, if any, of the puborectalis muscle could be minimal compared to the external sphincter one and thus insufficient to show on the videoproctographic image of ARA. The second reason could be that the puborectalis muscle is not supplied by the pudendal nerve as is the case of the external anal sphincter (Percy et al, 1981).

Swash and colleagues (1981) have studied the innervation of these muscles and showed that the puborectalis and EAS muscles are innervated by different motor nerves, although both originate in the same spinal cord segments. An electrophysiological study of the motor nerve supply to these

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muscles showed that the puborectalis was innervated by a branch of the sacral nerve (S3 and S4) which lies above the pelvic floor. The pudendal nerve, on the other hand, supplied the ipsilateral EAS muscles but not the puborectalis muscles (Percy et al, 1981).

On the other hand, an experimental study of the EAS in the monkey (Wunderlich and Swash, 1983) has shown substantial overlap in the pudendal innervation on the two sides of the sphincter. This has been related to the interdigitations of muscle fascicles across the midline anteriorly in this muscle. This functionally important overlap in the innervation facilitates the accomplishment of reinnervation from the opposite side when there is pudendal nerve damage as may happen in the incontinent patient (Swash, 1985). Thus, the EAS may be influenced by electrical stimulation more efficiently compared with other pelvic floor muscles.

As long as there is no interruption in the continuity of the pudendal nerve as was the case in the 24 patients studied in this chapter, it is possible to achieve improvement in the tonicity of the anal sphincter and pelvic floor muscles as evidenced by the enhanced PF ascent and closure of the anal canal in an attempt to restore continence.

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CHAPTER 6

THE DETERMINATION OF ANAL SPHINCTER THICKNESS BY ULTRASONOGRAPHY

A. TECHNIQUE - ENDOPROBE SIZE

B. ANAL SPHINCTERS IN NORMAL SUBJECTS

C. ANAL SPHINCTERS IN FAECAL INCONTINENCE

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The method of anal endosonography has already been outlined in Chapter 2. In this section the technique is applied in normal subjects and those with faecal incontinence after a preliminary evaluation of the effects of probe size.

6A. THE ENDOPROBE SIZE

6A.1 SUMMARY

Anal sphincter thickness was measured by ultrasonography in 38 patients using a narrow 1 cm tip diameter endoprobe and a larger 2 cm one. The two different sizes were used to determine any variation in sphincter thickness due to stretch effects.

The internal anal sphincter (IAS) was significantly decreased in thickness ($p < 0.01$) using the 2 cm endoprobe. The external sphincter (EAS) thickness was not significantly different using either probe. The larger 2 cm endoprobe alters the thickness of the IAS, possibly as a result of the IAS being more susceptible to stretch change from its small thickness (0.1-0.4 cm), approximately 20 times less than the diameter of the larger probe used. Alternatively the difference due to stretching may depend on the smooth muscle 'elastance' property of the IAS. The EAS striated muscle is less subject to distention effects because of its greater thickness and its tonic control.

The conclusion is that a 1 cm endoprobe is more desirable for detecting the thickness of the IAS and measuring it, since it causes less sphincter disturbance.

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6A.2   INTRODUCTION

Anal endosonography is a simple minimally invasive technique which can be used to visualise the anal sphincters and can be advantageous in evaluating the anorectum. The first ultrasonic studies of the human gut wall thickness were made many years ago (Wild, 1950). Until recently, technical shortcomings of the equipment have prevented the clinical use of ultrasound as a means of imaging the anal sphincters, so that disruption of a sphincter was determined from clinical examination, pressure studies and by concentric electromyogram mapping. Modern endoprobes allow high resolution ultrasound images of the separate sphincter muscles to be obtained (Law and Bartram, 1989).

When an endoprobe is introduced into the anal canal, it is bound to distend the canal to some extent. Different groups of investigators have used different sizes of endoprobes. We were interested to discover if the larger sizes of probes available, would have any stretch effect on the sphincters, altering their thicknesses. For this reason, two ultrasound endoprobes of different tip diameter were used in evaluating how the thickness of the anal sphincters might respond to the stretch effects of the probe size.

6A.3   MATERIALS AND METHODS

6A.3.1   Subjects

Anal endosonography was conducted on thirty-eight patients using the following two probes : (1) a Bruel & Kjaer 6.5-MHz radial rotating

endoprobe of maximum diameter 1 cm, and (2) a 7-MHz radial rotating endoprobe of maximum tip diameter 2 cm (Figure 6.1). The 1 cm probe tip was fitted with a rigid plastic cone filled with degassed water to provide protection for the rotating probe and effective acoustic coupling within the anal canal. The 2 cm probe tip was protected by a disposable latex tube containing degassed water. Both endoprobes were used in each patient, at the same visit to the hospital.

6A.3.2 Methods

Each lubricated endoprobe was inserted into the rectum with the patient in the left lateral position and serial images were obtained on slow withdrawal of the endoprobe from the rectum down the anal canal. Video-recordings of the ultrasound scanning were obtained for all the patients and were stored for further analysis and study. Hard copy was acquired on single sided emulsion film and measurements of sphincter thickness were made to +/- 0.2 mm.

The smooth muscle of the internal anal sphincter was clearly identifiable as a homogenous hypoechoic circular band extending caudally to a level just proximal to the anal verge. The striated muscle of the external anal sphincter had a different acoustic texture, with mixed echogenicity and linear pattern, giving a 'streaky' appearance. Between the two sphincters there was a narrow echogenic band that represented the intersphincteric plane. Immediately adjacent to the endoprobe tip was a hypoechoic layer of mucosa, continuous with the rectal mucosa. Between the mucosa and the IAS was the more echogenic submucosa, which became progressively denser and thicker caudally (Figure 6.2).

It was possible to identify clearly the hypoechoic layer of the IAS lying
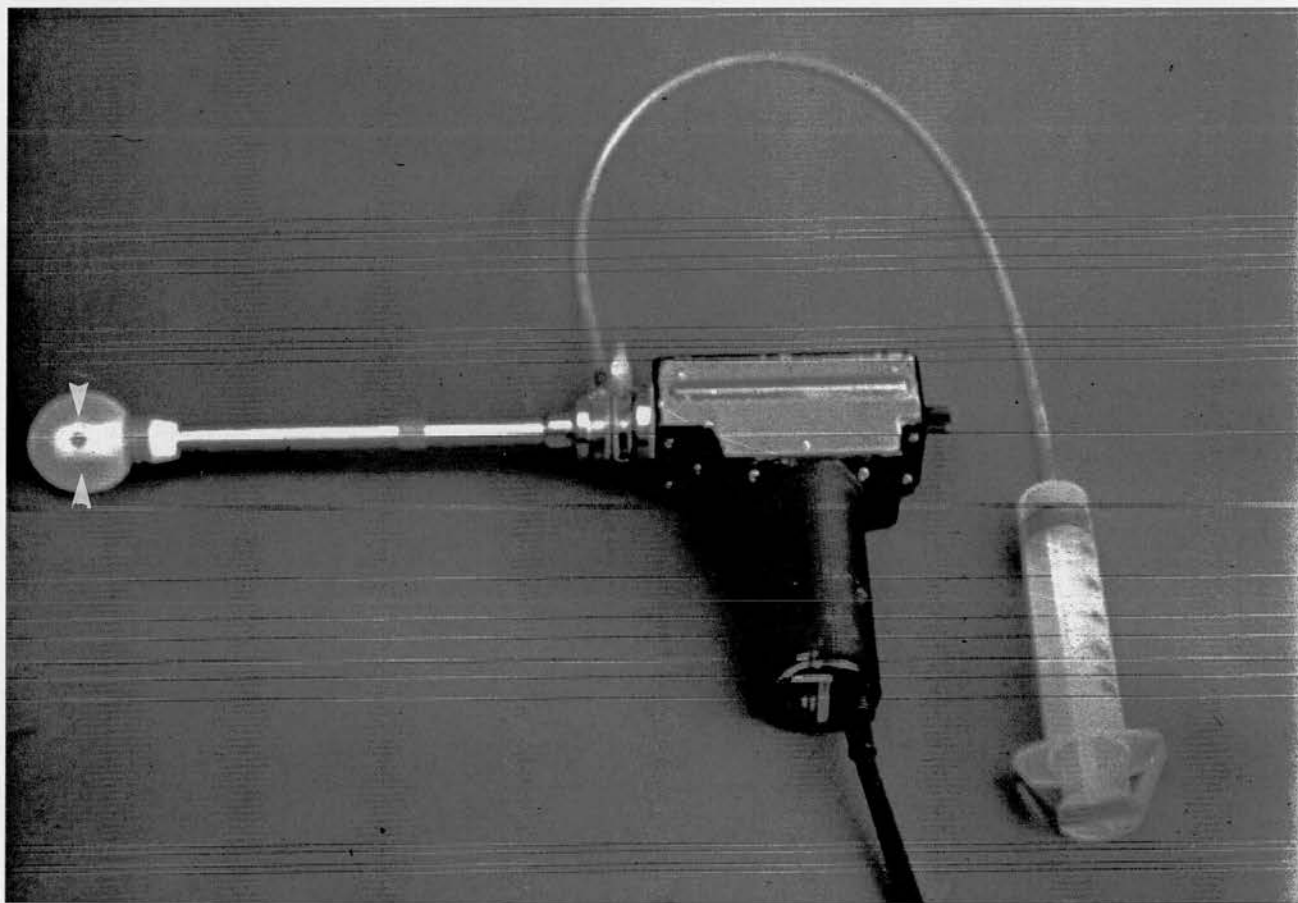
Figure 6.1 The endosonography probe that has been used for scanning the anal sphincters. The tip end of the above probe measures 2 cm in diameter (indicated by arrows). The 7-MHz radial rotating endoprobe was protected by a disposable latex tube containing degassed water. The other probe used (Bruel and Kjaer) operated according to similar principles. However, the tip end of the second 6.5-MHz radial rotating probe was fitted with a rigid plastic cone also filled with degassed water but with a diameter of 1 cm only. Both probes were inserted into the anal canal. The one illustrated has a pistol grip for support and the attached syringe and tubing allow the introduction of degassed water.

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ANTERIOR

External anal sphincter
and
Longitudinal muscle

Intersphincteric plane

Internal anal sphincter

Submucosa

Mucosa

Coccyx

POSTERIOR
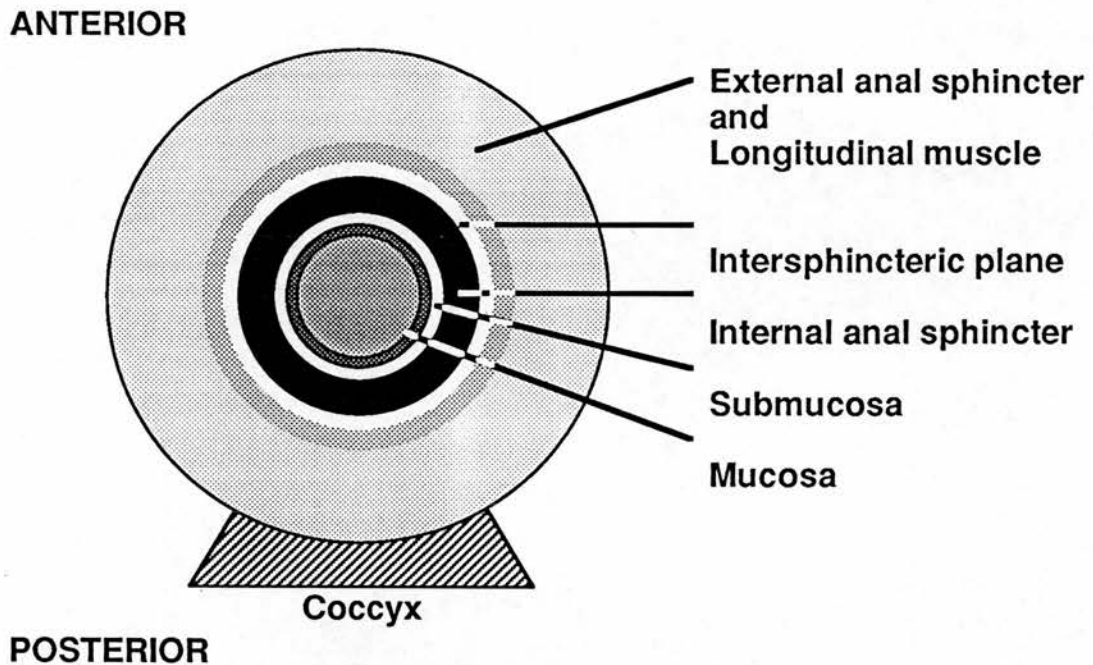
Figure 6.2   Diagrammatic representation of the
different layers of the anal canal as visualised by
ultrasonography. Immediately adjacent to the endoprobe
tip is a hypoechoic layer of mucosa. Between the mucosa
and the internal anal sphincter is the more echogenic
submucosa, which becomes thicker caudally. The smooth
muscle of the internal anal sphincter is clearly
identifiable as a homogenous hypoechoic circular band.
The striated muscle of the external anal sphincter has
a different acoustic texture, with mixed echogenicity
and linear pattern, giving a 'streaky' appearance.
Between the two sphincters there is a narrow echogenic
band that represents the intersphincteric plane and is
indistinguishable ultrasonographically from the
hyperechoic external anal sphincter.

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between the two more echogenic structures of the submucosa and the intersphincteric plane, and thus the measurements of the IAS thickness were made fairly simple and accurate. On the other hand the EAS thickness measurements were not as easy to acquire since the EAS was adjacent to the hyperechoic intersphincteric plane, therefore there is hardly a distinctive line between the two layers of muscle. The solution to this was to measure the thickness of the EAS at the very distal part of the anal canal and to relate its outer border to the anterior border of the coccyx. The point must be made of the subjectivity in measuring the thickness of the muscle in that way depended on individual anatomical considerations. The thickest terminal portion of the internal sphincter was measured at the mid-anal canal. In the lowermost part of the anal canal, the thickness of the EAS was measured, using the bony boundaries of the coccyx (Figure 6.3).

6A.3.3 Statistical Analysis

Statistical analysis of the results used the sign test for paired comparison, median values and their 95% Confidence Interval (CI).

6A.4   RESULTS

The 1 cm and 2 cm endoprobes were used in anal ultrasonography to make comparisons of the IAS (Figure 6.4) and EAS thicknessess.

6A.4.1 The 1 cm endoprobe results were as follows :
IAS thickness = 0.27 cm (95% CI : 0.26, 0.31), and
EAS thickness = 0.79 cm (95% CI : 0.76, 0.86).
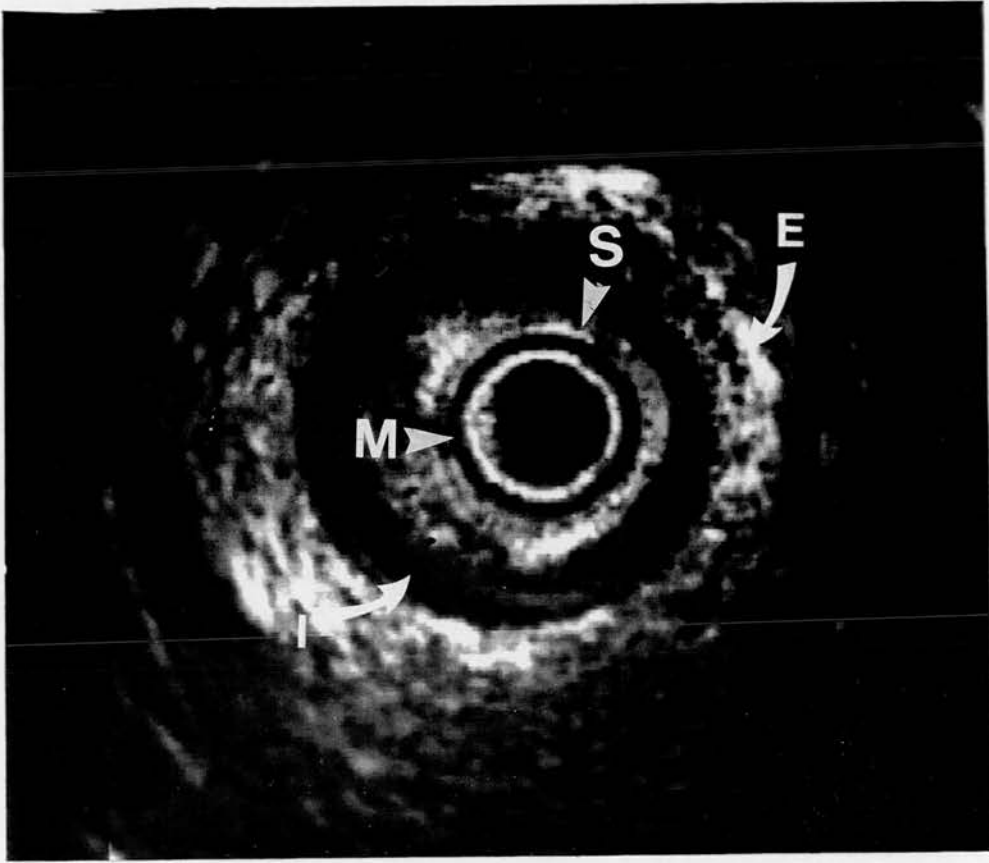
Figure 6.3 Anal endosonography in middle anal canal showing the orientation of the normal anatomy. Adjacent to the endoprobe is a thin hypoechoic layer of the anal mucosa (M). The hyperechoic submucosa (S) is thicker than the mucosa and is the second layer seen. The internal sphincter (I) is measured as the thickness of the hypoechoic band that lies between the hyperechoic layers, the submucosa and intersphincteric plane. The intersphincteric plane and the external sphincter are both hyperechoic and indistinguishable sonographically. The external anal sphincter thickness is therefore measured as the thickness between the hypoechoic internal anal sphincter and the hypoechoic coccyx to which the middle portion of the external anal sphincter is attached.

(E = external anal sphincter).

Internal Sphincter Thickness
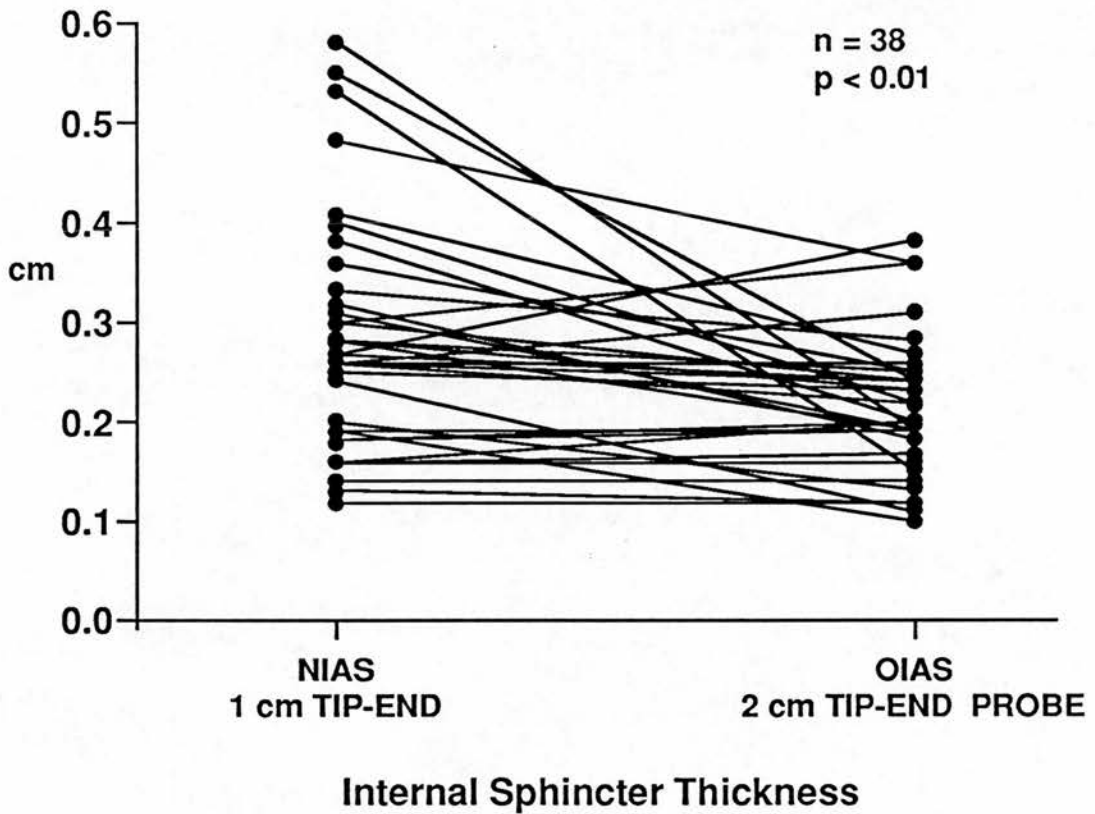
Figure 6.4   The Internal Anal Sphincter thickness
recorded   during anal endosonography   through   the
use   of a 1 cm tip-end probe (NIAS) and 2 cm   tip-
end   probe (OIAS), showing the number of   patients
tested and the p value (statistical analysis   used
the sign test for paired comparison).

6A.4.2 The 2 cm endoprobe results were as follows :

IAS thickness = 0.21 cm (95% CI : 0.19, 0.24), and

EAS thickness = 0.75 cm (95% CI : 0.73, 0.84).

There was no difference in the measurements of EAS thickness, using either endoprobe (p>0.05), whereas the IAS was found to be thinner in appearance (p<0.01) when measured using the 2 cm diameter endoprobe.

6A.5   DISCUSSION

We have used ultrasonic visualization of the sphincters in patients with various disease states and have measured the thicknesses of both the IAS and EAS using two endoprobes.

The larger 2 cm endoprobe alters the thickness of the IAS by about 30%, but had no measurable effect on the EAS. We would expect the IAS to be more susceptible to stretch change than the EAS because of its small size. This is approximately 20 times less than the diameter of the larger probe used. In addition, the difference due to stretching may also depend on the smooth muscle 'elastance' property of the IAS (Kerremans, 1969). On the contrary, the EAS striated muscle may be less subject to distention effects because of its tonic control which allows adaptation to take place.

Our conclusion is that a 1 cm diameter endoprobe is more desirable for imaging the anal sphincters and for measuring their thicknesses, since it causes them less disturbance than the 2 cm probe. In view of the fact that various rectal endoprobes with tip diameters ranging from 1 cm to over 2 cm are in common use, it is important that the size of the probe used should be recorded when reporting anal sphincter measurements.

6B. ANAL ENDOSONOGRAPHY IN NORMAL SUBJECTS

6B.1 SUMMARY

The anal sphincter thickness was measured ultrasonographically in 30 asymptomatic subjects using a 1 cm tip diameter endoprobe. The age range for the 13 males was 20-51 years, for the 17 females 20-75 years; 23 of the subjects were young (20-23 years) and 7 were older (41-75 years). Scans were videorecorded and film hard copies were acquired from which measurements of sphincter thickness were made.

The external anal sphincter (EAS) in the male group was significantly thicker than in the female group ($p < 0.02$), whereas the internal anal sphincter (IAS) showed no significant difference in respect of gender ($p > 0.05$). The EAS was significantly thinner with age ($p < 0.005$), presumably following the diminution of striated muscle bulk in the ageing process. The IAS appeared significantly thicker with age ($p < 0.0002$), which could be explained by degenerative or infiltrative changes in its internal structure.

Throughout the group the EAS thickness correlated inversely to the IAS thickness ($p < 0.001$), implying a reciprocal relationship whereby increased thickness of one sphincter compensates for any reduction in the other. Appropriate sphincter manometry was performed and showed a significant correlation between the anal canal resting pressure and the sum of the thicknesses of the two sphincters ($p < 0.001$). Thus, the visualised thickness of the two sphincters together reflects their capacity for tonic activity in control of continence.

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6B.2 INTRODUCTION

The control of continence is vested in the responses of the anal sphincters and pelvic floor muscles, which maintain a tonic contraction under the influence of their innervation (Swash, 1987). Until recently there has been no means of imaging the anal sphincters, so that actual disruption of a sphincter was determined from clinical examination, pressure studies and by concentric electromyogram mapping (Bartolo et al, 1983). However, with the development of anal endosonography, high resolution ultrasound images of the separate sphincter muscles may be obtained (Law and Bartram, 1989).

Rectal endosonography was first described in 1956 (Wild and Reid), but remained neglected for many years owing to the limitations of the technology then available. However, over the past ten years this has developed considerably, and rectal ultrasonography now has an established role in the examination of the prostate (Rifkind, 1985) and has been used in staging rectal cancer (Beynon, 1989).

The purpose of this part of the chapter, is to examine age and gender change in both sphincters, internal and external, and correlate each sphincter with its dynamic activity. Animal work suggested that the external anal sphincter increases its thickness with age (Knudsen et al, 1991) and in the rat is influenced by oestrogen and ovariectomy (Knudsen et al, 1991) while Bartram and colleagues have shown an age change in respect of the internal anal sphincter in humans (Burnett and Bartram, 1991).

6B.3   MATERIALS AND METHODS

6B.3.1   Subjects

Thirty subjects, 13 males aged from 20 to 51 years and 17 females aged from 20 to 75 years were recruited having given informed consent. Subjects were selected from asymptomatic normal volunteers and those attending the hospital (WGH) for conditions unrelated to anorectal dysfunction. Ethical permission for this protocol was given by the Ethics Committee of the Lothian Health Board and all the subjects gave written informed consent.

6B.3.2   Methods

Anal endosonography has been conducted using a specially designed hard sonolucent plastic cone attachment to a 6.5-MHz radially rotating endoprobe of maximum diameter 1 cm (Bruel & Kjaer, ultrasound scanner type 1846) so as to cause minimal disturbance to the anal sphincters. The plastic cone, filled with degassed water, provided protection for the rotating probe and effective acoustic coupling within the anal canal. The lubricated cone was inserted in the rectum with the patient in the left lateral position and serial images were obtained on slow withdrawal of the endoprobe from the rectum down the anal canal.

Anal manometry was performed in all the above subjects using a station pull through technique with a waterfilled latex balloon 4 mm in diameter connected to a pressure transducer. The maximum anal canal pressures at rest and during voluntary contraction were determined in an

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attempt to examine whether sphincter thickness related to the intraluminal pressure as a facet of the dynamic property of the muscle.

6B.3.3 Statistical Analysis

The statistical analysis was performed using the non-parametric Mann-Whitney test, the median and its 95% Confidence Interval (CI), the Pearson correlation coefficient and p values.

6B.3.4 Data Analysis

Video-recordings of the ultrasound scans were obtained from all the subjects recruited and were stored for further analysis and study. Using the recorded information on the video-tape, it was possible to study in detail any stage of the stored anorectal images. Film hard copies were acquired at different levels of the rectum and anal canal, firstly intra-rectally, then in the middle of the anal canal and, lastly, at the level of the coccyx. In considering the anatomical concepts (Oh and Kark, 1972) of the related structures, a diagrammatic representation of the sonographic anatomy of the normal anal canal layers was created (see Figure 6.2). The sonographic anatomy of the anal canal has been described in detail in the previous part of this chapter (see Chapter 6A).

The videorecording of the ultrasound scanning of the anal canal, has enabled us to acquire continuous imaging of the anal canal muscles, at the same time recording the movement of these muscles during voluntary contraction of the anal sphincters and any change in their thickness during this. In this way, continuous recording of muscle changes following commands e.g. 'squeeze', were obtained.

6B.4 RESULTS

6B.4.1 Anorectal manometry

In the male group, the maximum resting pressure was 120 cm H_2O (95% CI : 85, 137 cm H_2O) and the maximal external anal sphincter contraction on voluntary 'squeeze' was 170 cm H_2O (95% CI : 131, 180 cm H_2O). In the female group, the maximum resting pressure was 120 cm H_2O (95% CI : 100, 130 cm H_2O) and the maximal contraction of the external sphincter on 'squeeze' was 110 cm H_2O (95% CI : 100, 140 cm H_2O).

There was no significant difference in the measurement of the anal canal pressure between the two groups ($p > 0.05$), however the external sphincter contraction on 'squeeze' was significantly greater in the male group compared with the female one ($p < 0.005$).

6B.4.2 External Anal Sphincter

GENDER : The EAS thickness in the male group was 0.87 cm (95% CI : 0.80, 0.91 cm), whereas in the female group it was 0.75 cm (95% CI : 0.70, 0.80 cm). Thus the male group had significantly greater ($p < 0.02$) thickness of the EAS than the female group.

AGE CHANGE : The group was further divided into two categories, one that included all young subjects (23 young = 12 males, 11 females) and, a second one that consisted of 7 older subjects (6 females, 1 male). A significant difference in the thickness of the EAS was found

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between the young and the older subjects (p<0.005) the EAS being thinner in the older (0.68 cm) as compared with the younger (0.86 cm) subjects. The EAS thickness in the overall group (males and females) inversely correlated with age (p<0.001). This indicates a tendency to a 'thinner' EAS in the older population.

THE EAS THICKNESS VS ITS TONIC ACTIVITY : When attempts were made to relate the EAS thickness to the squeeze pressures representing the activity of this muscle, no significant correlation was found (p>0.05) in either male or female groups.

6B.4.3 Internal Anal Sphincter

GENDER : The IAS thickness was 0.20 cm (95% CI : 0.13, 0.25 cm) in the male population, and 0.21 cm (95% CI : 0.19, 0.27 cm) in the females, which was not significantly different (p>0.05).

AGE CHANGE : The IAS thickness in the younger group was contrasted to that of the older subjects. There was a very significant (p<0.0002) difference between the IAS thickness of the young (0.20 cm) and that of the older (0.30 cm) groups. A significant correlation (p<0.001) was revealed between the IAS thickness and the age of the subjects confirming that older subjects had thicker IAS than younger ones.

THE IAS THICKNESS VS ITS TONIC ACTIVITY : The IAS thickness was compared to the maximal resting pressure derived by anorectal manometry and no significant correlation (p>0.05) was obtained in either the male or the female group.

6B.4.4 The Relationship Between The Internal And External Anal Sphincters

DYNAMIC OBSERVATIONS OF IAS AND EAS THICKNESS

During videorecording of the ultrasound scans the subject was asked to 'squeeze' thus to initiate EAS activity and increase the tone in the anal canal, with the endoprobe in situ imaging both the IAS and the EAS. The IAS appeared to become thinner as if being displaced by the EAS, during squeezing. At the same time the echogenicity of the EAS increased. As soon as the individual was asked to relax and without moving the endoprobe, the IAS regained its original position and thickness (Figure 6.5).

THE INTERRELATIONSHIP OF THE THICKNESS OF IAS AND EAS

When the thicknesses of the two sphincters were compared a significant ($p<0.001$) inverse correlation was observed in the anal sphincter thicknesses in the 30 subjects that were studied (Figure 6.6). This implies a reciprocal relationship between the two sphincters, i.e. a thicker EAS relating to a thinner IAS and vice versa.

THE IAS AND EAS THICKNESSESS VS THEIR TONIC ACTIVITY

Since both muscles contribute to the resting pressure in the anal canal it has been of interest to relate the thickness of these muscles as a whole, to the intra-anal maximum resting pressure which reflects the tonic activity of both muscles in the control of continence. A significant correlation ($p<0.001$) was observed between the anal canal resting pressure and the sum of the thicknesses of the two sphincters (Figure 6.7).

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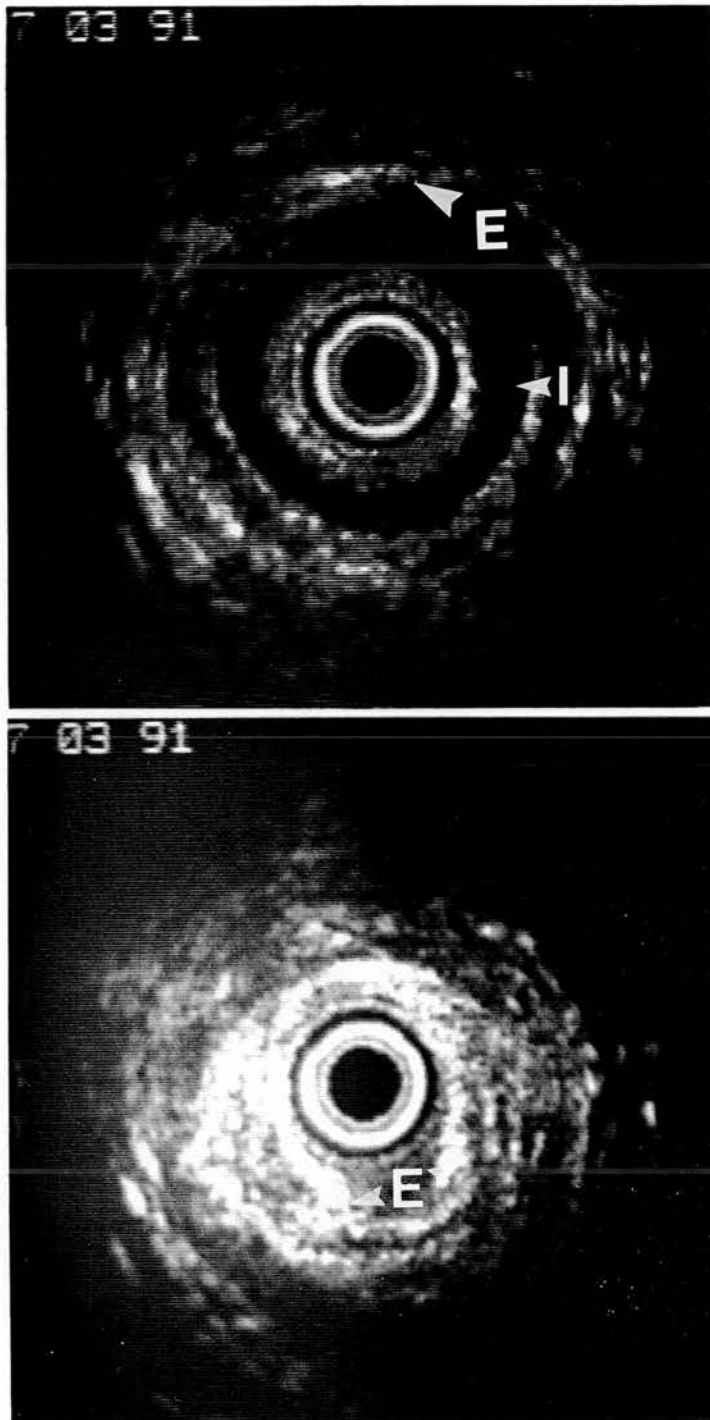
Figure 6.5 Anal endosonography in middle anal canal of a
healthy volunteer.

Top: The hypoechoic band of the internal sphincter (I) and
the hyperechoic external anal sphincter (E) are identified. The
anal scan was obtained at rest.

Bottom: The individual has been asked to contract the anal
sphincter, having maintained the endoprobe at the same level.
However, during the voluntary 'squeeze' of the anal sphincter,
the external sphincter has become 'brighter' and has encircled
the endoprobe in a powerful way displacing the internal anal
sphincter which is not seen in this scan.
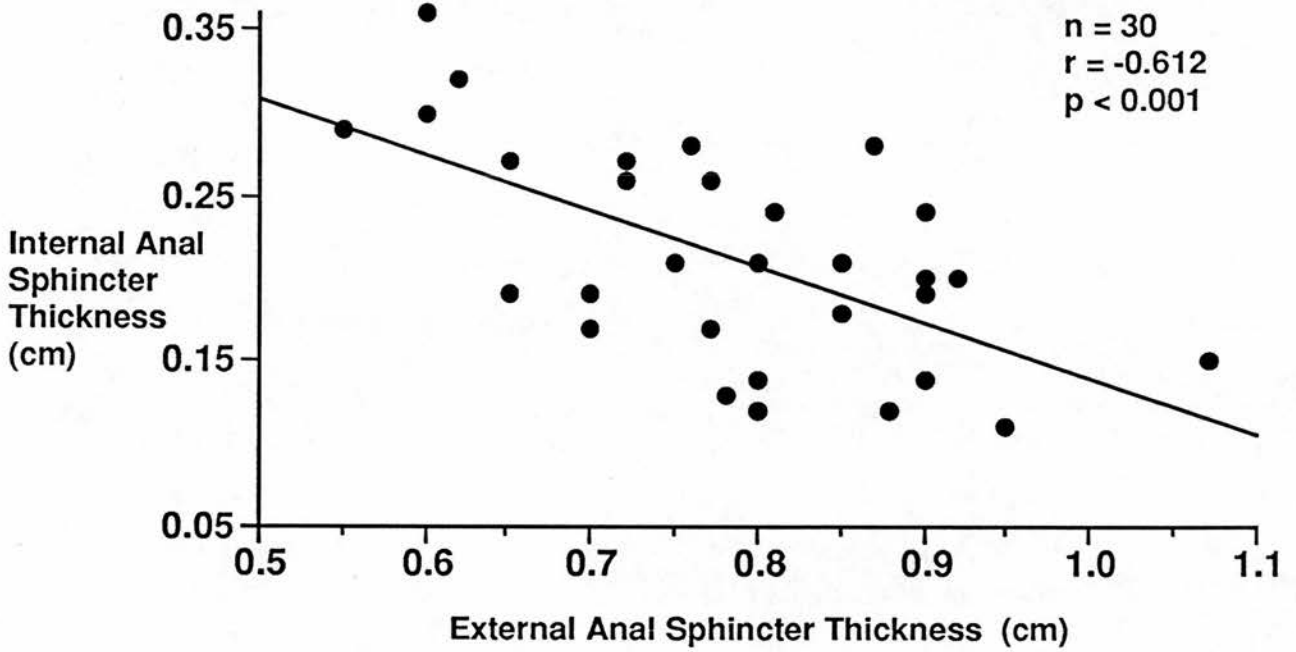
Figure 6.6   The relationship between the internal
and external anal sphincter thickness in   30
healthy   volunteers.   It shows   a   reciprocal
relationship between the thicknessess of   the
sphincters whereby a 'thicker' external sphincter
associates with a 'thinner' internal one. (The
Pearson correlation coefficient and its p value
are shown.)

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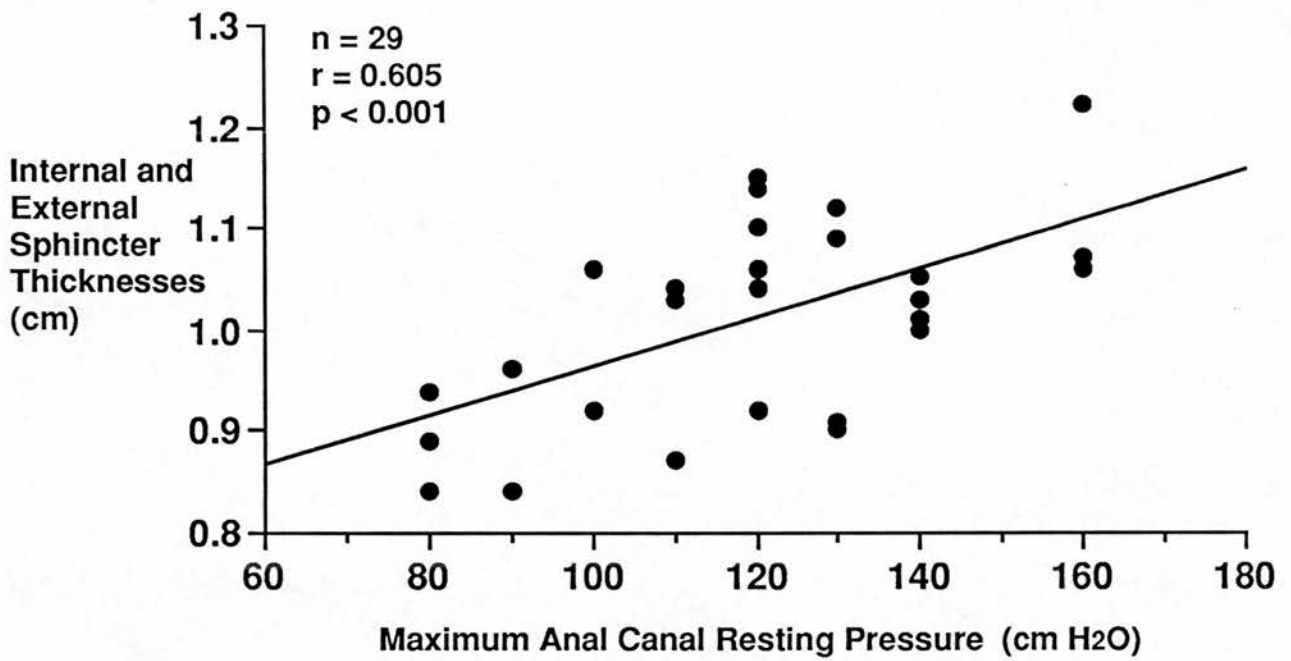
Figure 6.7 The relationship between the sum of the internal and external sphincter thicknessess and maximum resting pressure in the anal canal, in 29 healthy volunteers. The direct relation of the anal sphincters thickness to their tonic activity presented above suggests an affinity and synergy in function. (The Pearson correlation coefficient and its p value are shown).

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6B.5 DISCUSSION

Anal endosonography is a simple minimally invasive technique which has been found to be well tolerated by the subjects examined. The studies were all made using a 1 cm endoprobe since it has been shown (Papachrysostomou et al, 1991) that varying probe sizes lead to different measurements of sphincter thickness. In previous studies (Law and Bartram, 1989) much attention has been devoted to the appearance of the IAS and to detectable defects of the EAS (Bartram and Burnett, 1991). The present study consisted of an assessment of both the IAS and EAS, comparing these results with the manometric ones to assess structure and function of the sphincters in the same subject.

Swash and colleagues (Laurberg et al, 1989) have shown that the internal anal sphincter, considered important in the control of continence, is subject to fibro-fatty degeneration and cellular infiltration in the older normal population. This may explain the increase in the IAS thickness in the older age group as compared with the young males and females. This may also explain the apparently increased IAS thickness seen by Bartram and colleagues (1991) and ourselves (Burnett and Bartram, 1991). Gender however did not appear to influence the thickness of the IAS in the normal population. Changes in the architectural structure of the internal anal sphincter such as that occuring as an age change in normal subjects might imply hypertrophy of this muscle.

In contrast to the IAS, the EAS thickness has a subjectivity in its measurement. This is because it is dependent on the anatomically variable level of the coccyx with respect to which the measurements were made. The EAS nevertheless showed a significant reduction in size with age, and

contrary to the case of the IAS revealed differences in respect of gender. This observation is compatible with the general reduction in the striated muscle bulk of the human body with age and is at variance with studies in the rat (Knudsen et al, 1991) that showed an increase in the EAS thickness with age. The increase of the thickness in the male population compared to the female group observed is in agreement with other studies that showed the male external sphincter to be different in shape, length and greater in barrier pressures than that of nulliparous females (Sun and Read, 1989).

The present study shows that the thicknesses of the IAS and the EAS are inversely related to one another, as measured at rest. We envisage that this comes about by a normally 'thick ' EAS supporting the 'thinner' IAS. With the diminution of the EAS with age the increasing thickness of the IAS expands and replaces it. The EAS in health may first play a protective role, whereby it lends mechanical support to the IAS and thus gives it added effectiveness (Swash, 1990). With age this tends to be lost.

Furthermore, the reciprocal change in the appearance of a more prominent EAS and a lessened IAS during dynamic activity supports the concept of a compensatory mechanism between these two structures in health. This phenomenon is compatible with physiological observations made by other investigators who suggested a mutual relationship between the EAS and the IAS, such that the EAS protects the IAS giving it a basis on which to function (Swash, 1990). The balanced function of both sphincters contributing to the intraluminal barrier pressure is equally expressed by the balance in their morphological appearance. Hence it is the sum of the two sphincter thicknesses that has been shown to have a direct relation to this pressure, and not either sphincter separately. Thus the measurement of these two structures may be of diagnostic value and it may be as great interest to

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see whether this is disturbed in the incontinent patient.

The reciprocal relationship between the thicknesses of the anal sphincters furthermore seems to be an important factor in the maintenance of continence. Additional studies are required to determine the thickness of these sphincters in incontinent patients. Anal endosonography is an effective method of investigating the structure and function of the sphincters and for providing valuable information about their role in continence.

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6C. ANAL ENDOSONOGRAPHY IN FAECAL INCONTINENCE

6C.1 SUMMARY

In this part of the chapter ultrasonography of the anal sphincters is evaluated in patients with faecal incontinence (FI). The method allows comparisons to be made between the results of endosonography and anorectal manometry in patients with dysfunction such as faecal incontinence. Twenty-eight female patients all exhibiting faecal incontinence and seventeen asymptomatic normal controls were recruited to the study.

The external anal sphincter (EAS) did not differ significantly in thickness in the incontinence group compared with the overall normal group ($p > 0.05$). The internal anal sphincter (IAS), however, appeared 'thicker' in the incontinence group when compared with its thickness in the normal group ($p < 0.005$). The intra-anal canal maximum resting, squeeze and cough pressures were significantly lower in the incontinence group ($p < 0.002$; $p < 0.00001$; $p < 0.03$) compared with those in the normal control group. An inverse correlation ($p < 0.02$) has been found (see second part of this Chapter 6B) between the thicknesses of the IAS and the EAS in the normal population. In the FI group the two sphincters have been found to show a direct relationship ($p < 0.001$). In contrast to the normal group which showed a direct correlation between the sum of the thicknesses of the two sphincters and the maximum resting pressure reflecting continence control, in FI there was no such direct relationship. The lack of correlation between the thickness of the sphincters with their tonic activity may depend on the variability in the structure of the sphincters in FI.

6C.2 INTRODUCTION

Idiopathic faecal incontinence is known to be due to weakness of the striated muscles of the pelvic floor (Swash, 1985), and recent histological and electrophysiological evidence suggests that the cause of this weakness is denervation (Neill et al, 1980) . It has been proposed that the denervation results from repeated traction of the pelvic nerves (Womack et al, 1986) as the perineum descends during chronic straining at stool (Bartolo et al, 1983), and that this may even occur during prolonged childbirth (Snooks et al, 1984). However, trauma producing tears of the external sphincter during childbirth remains the commonest injury of this muscle (Laurberg et al, 1988).

In the aetiology of faecal incontinence, apart from spinal cord mechanisms, other direct causation is the result of injury, partly either due to perineal trauma, non-penetrating violent injury, or occasional inadvertent surgical mishap as may happen during dilatation procedures for dealing with fissure or haemorrhoids (e.g., Lord's dilatation). Structural changes in the internal sphincter have also been reported (Swash et al, 1988). The suggestion has been made that the so-called idiopathic or neurogenic faecal incontinence (Laurberg et al, 1988), is accompanied by fibro-fatty degeneration in the internal sphincter. The presence of zones of atypical appearance and the effects of damage to the nerves might not merely reflect an innervation problem, but could be accompanied by degenerative changes in the muscle (Lubowski et al, 1988).

It is now possible to determine disruption of the anal sphincters using

anal endosonography in addition to the conventional investigations which included manometric studies and concentric electromyogram mapping (Bartolo et al, 1983). Endosonographic diagnostic techniques (Law et al, 1991) employ ultrasound as a means of obtaining information about the structure of organs (see first part of this Chapter 6A).

One of the most important applications of ultrasonography is to produce images of soft-tissue structures. Therefore, this has allowed its use in prostatic (Rifkind, 1985) and rectal cancer (Beynon et al, 1989) investigations. Furthermore, with the development of anal endosonography, high resolution ultrasound images of the separate sphincter muscles can be obtained (Law and Bartram, 1989). In addition to that, multiple areas of damage, atrophy or other change are apparent as supposed scars on visualisation of the sphincter muscle by ultrasound (Bartram and Burnett, 1991).

The opportunity has been taken in this study to assess whether there were changes in the anal sphincter muscles in FI, either zonally by reason of patchy change or by changes in their thickness, which might suggest atrophy or the opposite by relative widening, suggesting possible infiltration or degeneration (Lubowski et al, 1988). Furthermore, an assessment of the anal sphincter muscles dynamic properties was made by measuring the intra-anal canal pressures. These results were correlated with the thickness of the anal sphincters measured by ultrasonography. The appearances and dimensions of the sphincters were compared in female patients with neurogenic FI and in normal female controls.

6C.3 MATERIALS AND METHODS

6C.3.1 Subjects

Twenty-eight female patients, median age 63 years (95% CI : 48, 73 years) all exhibiting faecal incontinence were recruited to the study. Twenty-five patients had vaginal deliveries (89%), of those 9 had more than two children (32%), 4 had forceps deliveries (14%) and 2 were nulliparous (7%). These patients who had been suffering from faecal incontinence from 4 months to 20 years did not appear to have evidence of trauma or neurological disease as a cause of their incontinence. The appearance of the internal and external anal sphincters in these patients were compared against 17 asymptomatic normal females, median age 22 years (95% CI : 21, 45 years) who had no history of anorectal pathology or surgery. Twelve of the control female group were nulliparous (71%), whereas five females were parous (29%) but with no history of traumatic or prolonged labour. This protocol was approved by the Ethical Committee of Lothian Health Board and the subjects recruited to the study gave written informed consent.

6C.3.2 Methods

Anal endosonography was carried out using a 6.5-MHz radial rotating endoprobe (Bruel & Kjaer). This was fitted with a specially designed hard sonoluscent plastic cone giving a maximum tip diameter of 1 cm, so as to cause minimal disturbance to the anal sphincters. The plastic cone protects the rotating cone and was filled with degassed water to provide effective acoustic coupling within the anal canal. The lubricated cone was inserted in

the rectum with the patient in the left lateral position and serial images were obtained on slow withdrawal of the endoprobe from the rectum down the anal canal.

The sonographic anatomy of the anal canal has been given in detail in the first part of this Chapter 6A. The anal canal wall layers, as visualised by the ultrasound endoprobe, were the hypoechoic mucosa (immediately adjacent to the plastic cone of the endoprobe), the more echogenic submucosa (denser and thicker), the smooth muscle (homogenous hypoechoic circular band) of the internal anal sphincter, the intersphincteric plane and the striated muscle ('streaky' appearance with mixed echogenicity) of the external anal sphincter. The coccyx as visualised in the distal anal canal, posteriorly, served as the boundary to the EAS, at which point the EAS sphincter thickness was measured.

Video-recordings of the ultrasound scanning were obtained for all the subjects recruited and were stored for later detailed analysis and study. Film hard copies of the anorectal images were acquired. The thickest portion of the internal sphincter is elicited from the mid-anal canal ultrasonic image, whereas the external anal sphincter thickness was determined at the distal anal canal by the coccyx (see Figure 6.5).

Anal manometry was performed in every subject recruited in the study. A station pull through technique was used with a water-filled microballoon, 4 mm in diameter, connected to a pressure transducer. The maximum anal canal pressures at rest (MRP) and during voluntary contraction (SQP) as well as during coughing (CP) were elicited.

6C.3.3 Statistical analysis

Statistical analysis of the results used the median and its 95%

Confidence Intervals (CI), the non-parametric sign test for paired comparison, the Mann Whitney test for unpaired comparison, the Pearson correlation coefficient and its p value.

6C.4 RESULTS

6C.4.1 Anorectal Manometry

The FI group had significantly lower intra-anal canal pressures compared with the normal control group (Table 6.1). The maximum resting pressure was significantly ($p < 0.002$) lower in the FI group, 70 cm H_2O, (95% CI : 60, 100 cm H_2O), whereas in the normal group it was 120 cm H_2O (95% CI : 100, 130 cm H_2O). The SQP, 40 cm H_2O (95% CI : 30, 60 cm H_2O) and CP, 60 cm H_2O (95% CI : 55, 70 cm H_2O) were similarly lower in the FI group compared with the SQP, 110 cm H_2O (95% CI : 100, 140 cm H_2O) and CP, 70 cm H_2O (95% CI : 60, 100 cm H_2O) in the normal control group ($p < 0.00001$; $p < 0.03$, respectively).

6C.4.2 External Anal Sphincter

EAS THICKNESS : The EAS thickness in the FI group was 0.78 cm (95% CI : 0.72, 0.86 cm), and in the normal group was 0.75 cm (95% CI : 0.70, 0.80 cm), thus no substantial difference was observed ($p > 0.05$).

THE EAS THICKNESS VS ITS TONIC ACTIVITY : In the FI as well as in the normal control groups there was no direct relation

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Table 6.1   Anal sphincter thicknessess recorded during anal endosonography. Anal canal pressures are also recorded at rest, during maximum contraction on coughing and maximal conscious squeeze of the anal sphincter.

	FAECAL INCONTINENCE GROUP		NORMAL GROUP	
	MEDIAN	95% CI	MEDIAN	95% CI
AGE years	63	(48, 73)	22	(21, 45)
IAS cm	0.30	(0.26, 0.33)	0.21	(0.19, 0.27)
EAS cm	0.78	(0.72, 0.86)	0.75	(0.70, 0.80)
IAS+EAS cm	1.04	(0.95, 1.18)	0.98	(0.90, 1.03)
MRP cm H2O	70	(60, 100)	120	(100, 130)
SQP cm H2O	40	(30, 60)	110	(100, 140)
CP cm H2O	60	(55, 70)	70	(60, 100)

IAS=internal anal sphincter thickness; EAS=external anal sphincter thickness; IAS+EAS=the sum of the thicknessess of the internal and external anal sphincters; MRP=maximum resting anal canal pressure; SQP=anal canal pressure increment on maximum voluntary contraction of the anal sphincter; CP=anal canal pressure increment on maximum contraction of the anal sphincter during coughing. (The results are expressed as: median and its 95% confidence interval.)

between the thickness of the EAS and the anal canal pressures elicited during voluntary contraction of the EAS (SQP and/or CP) representing the functional activity of the muscle.

6C.4.3 Internal Anal Sphincter

IAS THICKNESS : The IAS thickness in the FI group was 0.30 cm (95% CI : 0.26, 0.33 cm) , compared with 0.21 cm (95% CI : 0.19, 0.27 cm) in the normal control group. Thus the FI group had significantly greater ($p < 0.005$) thickness of the IAS than the normal control group.

THE IAS THICKNESS VS ITS TONIC ACTIVITY : In the FI as well as in the normal control groups there was no direct relation between the thickness of the IAS and the anal canal pressure at rest (MRP) which is mainly composed by the tonic activity of the IAS.

6C.4.4 The Relationship Between The Internal And External Anal Sphincters

THE INTERRELATIONSHIP OF THE THICKNESS OF IAS AND EAS
In comparing the thicknesses of the two sphincters together (Figure 6.8), in the 28 patients with FI, a significant direct relationship was obtained ($p < 0.01$). This contrasted with the findings in the 30 normal controls in whom a significant inverse correlation was observed (see Figure 6.6) in their sphincter thicknesses. Thus, a 'thicker' EAS relates to a 'thicker' IAS in the FI group, whereas in the normal group, a thicker EAS relates to a thinner IAS.

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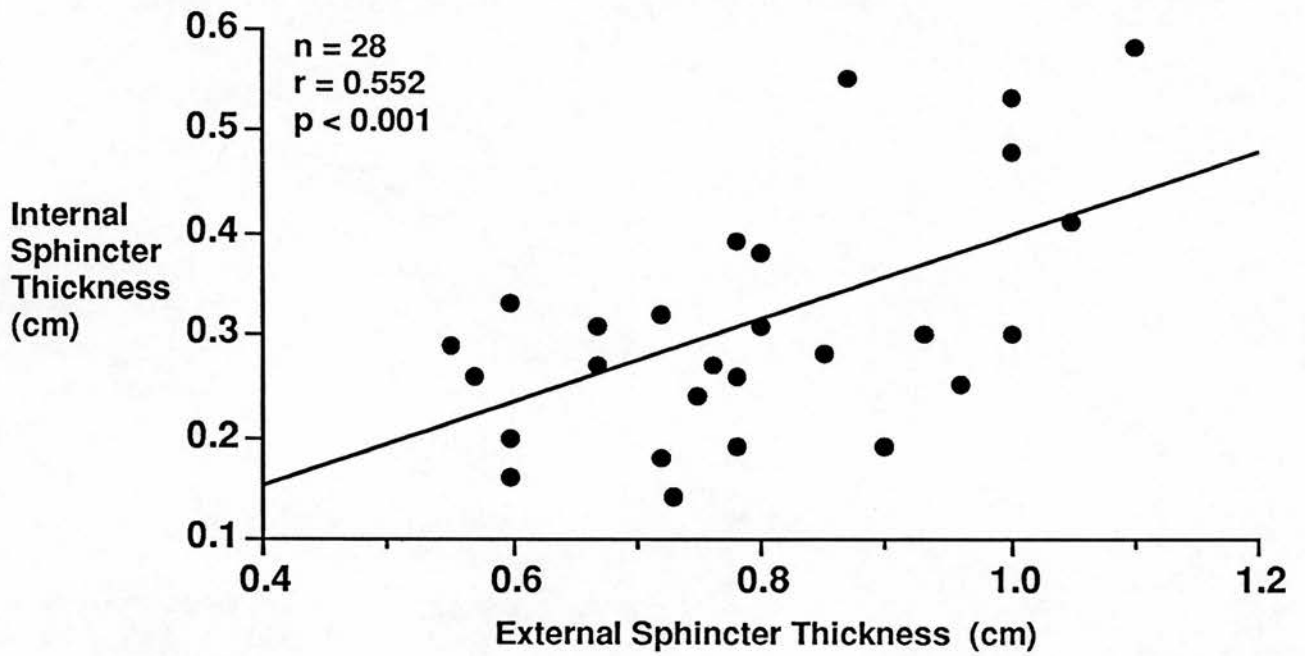
Figure 6.8   The relationship between the internal
and external anal sphincter thickness in   28
patients with faecal incontinence. It shows a
direct   relation between the thisknessess of the
sphincters whereby a 'thicker' external sphincter
associates with a 'thicker' internal one. (The
Pearson correlation coefficient and its p value
are shown.)

THE IAS AND EAS THICKNESSESS VS THEIR TONIC ACTIVITY

Furthermore, the thicknesses of the two sphincters added together in the FI group showed no direct relationship to the anal canal maximum resting pressure, whereas, in the normal group the intra-anal canal pressure at rest, directly related to the thicknesses of the sphincters added together (see Figure 6.7). Thus, while the thicknesses of the two sphincters represented the function of these muscles in healthy subjects, this was not the case in the FI group. The apparent thicknesses of the internal and external anal sphincters did not represent the function of these muscles. Seemingly the affinity of the IAS and EAS morphological appearance and their balanced function is disturbed. Thus, this uniformity in structure and function is interrupted in FI.

6C.5 DISCUSSION

The anal sphincters maintain a tonic contraction under the influence of their innervation which is an important part of the mechanism for the control of continence. The integrity of the innervation of the pelvic floor musculature therefore becomes important in the assessment and understanding of pelvic floor disorders, especially incontinence (Swash, 1989; Henry and Swash, 1985). The smooth muscle and tonic nerve supply of the IAS is almost certainly adrenergic (Kerremans and Penninckx, 1970; Lubowski et al, 1987; Speakman et al, 1990). The striated muscle of the EAS is known to be innervated by the inferior rectal branches of pudendal nerves, which originate from the anterior primary rami of S2, S3, and S4 segments of the spinal cord (Reeve, 1981).

Faecal continence depends not only on the EAS, but also on the puborectalis muscle (Parks, 1975), as part of the pubo-anal sling which maintains the anorectal angle. In neurogenic faecal incontinence there is denervation of the EAS and pelvic floor muscles (Kiff and Swash, 1984), as well as damage to the IAS (Speakman and Kamm, 1991) which is likely to produce or be the result of autonomic denervation (Snooks and Swash, 1986). It is possible that the IAS damage is due to a mechanical effect resulting from loss of support from the surrounding EAS (Lubowski et al, 1988).

Anal endosonography has been used, in this chapter, as a method of examining the configuration of the IAS and the EAS in FI and comparing the results of ultrasonography and manometry in patients with anorectal dysfunction with asymptomatic controls. The different layers of the anal canal wall produce detectable echoes sufficiently different from those of their surrounding tissues to allow measurements of the thickness of the IAS to be made. In the case of the EAS the coccyx provided the external boundary to the sphincter.

In the two groups studied here, there was a difference in the age of each group. This was partly due to the fact that it is not easy to recruit older females with no anorectal symptoms whether parous or nulliparous in a study of this kind as a control group. Moreover, the females who suffer from incontinence are in the majority older people. In considering the above, the fact that the external sphincter thickness was not any different in the incontinent group compared with the control one, may be fallacious.

In the second part of this Chapter 6B it has been shown that there is an inverse relation of the EAS thickness to age. Older people had 'thinner' EAS compared with younger people, which is compatible with the general

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reduction in the striated muscle bulk of the human body as a result of the ageing process. Thus, the FI group appeared to have 'thicker' EAS than one would expect them to have according to senescence. It is recognised in ultrasonography that as the amount of structure in tissue increases, the attenuation rises, e.g. in scar tissue and that is said to be due to the increased level of collagen resulting in more scattering of the ultrasound (McDicken, 1991). Therefore, the EAS may appear 'thicker' in older people with incontinence because of its structural changes.

Another important point is that, as some of these patients had suffered from incontinence of some duration, they may have practised pelvic floor exercises consciously or subconsciously and have often had prior attempts to influence continence by such exercises in a physiotherapy department. Despite the fact that they did not regain continence through this, it may have caused an increase in the muscle bulk probably insufficient to relieve their symptoms.

The IAS, which is considered important in the control of continence, is subject to fibro-fatty degeneration, cellular infiltration, and collagenosis and that this occurs with age (Klosterhalfen et al, 1990) and in patients with faecal incontinence (Lubowski et al, 1988). This may explain the increase in the IAS thickness in the older age group compared with the younger one, studied in the second part of this Chapter 6B. The IAS in the FI group also appeared 'thicker' compared with the control group. A reconsideration of the age difference between the two groups, already discussed in connection with the EAS, suggests that the IAS 'thicker' appearance in the FI group may be simply the result of the age trend.

However, Swash and colleagues (Lubowski et al, 1988) concluded, having studied asymptomatic older subjects and incontinent subjects,

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showed that similar structural changes were apparent in both groups. In health, the increase of the IAS thickness with age seems compensatory as is already discussed earlier in this Chapter 6B. Thus, the IAS increases in thickness as the EAS decreases and the two together maintain an adequate thickness correlating well with the anal canal resting pressure and therefore with their tonic activity.

In contrast to this, in incontinence the IAS increased thickness did not appeared to be compensatory. The lack of correlation in the FI group of the combined sphincter thicknesses with the anal canal resting pressure measurements may imply failure of the adaptive mechanism already described as a protection against age changes in normal subjects (Loening-Baucke and Anuras, 1984; 1985). The change in the IAS appearance in the older subjects and in incontinence suggests a prominent response of this sphincter in both situations. This signifies its importance in the control of continence.

However, the IAS failure to compensate in incontinence may also be attributed to concomitant changes in the EAS, 'thicker' in this group possibly as a result of scarring. This explains why the thickness of the IAS and the EAS related inversely to one another in compensatory fashion in healthy individuals, but that this relationship was not maintained in the diseased anorectum where the tendency was for both muscles to increase their thickness proportionally.

It seems that the principles outlining the function of these muscles and their structure are important and differ in disease from those in health. The protective role of the EAS in health, whereby this muscle lends support to the IAS and gives it added effectiveness (Swash, 1987) is not preserved in disease. The increase in thickness of both muscles may also be due to the

simultaneous process of degeneration or infiltration by the collagen of scar tissue and fat, replacing muscle tissue rather than increasing its fibre numbers or size.

Continence functions are important in the maintenance of confidence and social acceptability (Mandelstam, 1985). Published reports showed the incidence of FI to be higher than one might expect because people do not seek medical advice, partly because of embarassment (Brocklehurst, 1975). The use of endosonography may allow early detection of impairment in sphincter appearance and function as the changes in the sphincter thickness in the patients with FI compared with the asymptomatic controls form an interesting spectrum varying not only in sphincter capability but in sphincter appearance. It would be of interest to know when the anal sphincters' appearance alters in relationship to the early development of FI. Because of the embarassment this problem causes to patients they rarely seek medical advice at an early stage of their disability. Thus, little is known as yet of the appearance of these muscles soon after the impairment of their functions.

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CHAPTER 7

ISOTOPE PROCTOGRAPHY IN CONSTIPATION

A. A METHOD

B. ITS USE IN CONSTIPATED SUBJECTS

This chapter describes the development of a method for the examination of constipated subjects by isotope proctography. The first part concentrates on visualising dynamic changes of the anorectum in response to expulsive manoeuvres. The second part applies the method quantitatively in constipated subjects and makes comparison with radiological videoproctography.

7A. A METHOD OF COMPUTERISED ISOTOPE DYNAMIC PROCTOGRAPHY

7A.1 SUMMARY

Patients with longstanding constipation were examined by radio-isotope proctography. A radio-labelled synthetic potato mash was inserted intrarectally and the dynamic changes of simulated defaecation recorded using a Gamma-camera. The stored data produced computer imaging which illustrates the changes in the anorectal angle and pelvic floor. The anorectal angles were: at rest 105° (101°, 116°), on voluntary contraction of the pelvic floor 91° (81°, 98°), on straining 120° (107°, 137°) and during evacuation 126° (116°, 153°). The pelvic floor movements were: pelvic floor ascent on voluntary contraction 28mm (9, 34), pelvic floor descent on straining -8mm (-14, -4) and descent during evacuation -27mm (-34, -11). Useful additions to previous methods are measurement of the completeness of rectal evacuation 58% (42, 77), of the defaecation time 64 seconds (50, 138) and defaecation rate 0.9 %/sec (0.4, 1.4).

7A.2 INTRODUCTION

The rectum acts as a reservoir for faecal matter until evacuation is socially convenient. The rectum must, therefore, empty efficiently and completely when required. Evacuation depends on complex interactions between the rectum, the pelvic floor and the anal sphincters (Parks et al, 1966). These interactions are part of a dynamic process; thus the dynamic study of defaecation (Bartram et al, 1988) is considered more informative than studying static situations (Brown, 1965; Kerremans, 1969).

The mechanisms which facilitate defaecation are inter-related and complex (Phillips and Edwards, 1965). A more sophisticated understanding of ano-rectal physiology has been made possible by the introduction of methods designed to give quantitative as well as qualitative information about the dynamics of ano-rectal motility (Brown, 1965; Kerremans, 1969). The most commonly available examination at the present for the investigation of the physiology of defaecation is defaecating radiological videoproctography (Mahieu et al, 1984). The primary use of this is in determining the presence of structural defects such as rectal intussusception or occult rectal prolapse (Finlay, 1988). Radiological proctograms have also been used to calculate resting and straining ano-rectal angles (Mahieu et al, 1984; Ekberg et al, 1985; Skomorowska et al, 1987; Shorvon et al, 1989) but did not measure the ability of the rectum to evacuate. This is valuable information in patients with constipation, or those who find defaecation difficult. A patient is defined as constipated if straining at stool for more than 25% of defaecating time or, alternatively, passes two or fewer stools per

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week (Devroede, 1988). A definition of constipation must include, notionally, the ideas of delay in colonic emptying as well as of problems in evacuating a full rectum, namely, straining. The implication from the above definition is that this disorder may be the consequence either of pelvic floor dysfunction or of delay in transit of faecal material through the colon.

Scintigraphic techniques have been used by several investigators to outline the 'neo-rectum' following ileo-anal pouch anastomosis and the efficiency of its evacuation (O'Connell et al, 1986). Another method assesses the anorectal angle scintigraphically (Barkel et al, 1988) by balloon inserted intrarectally and filled with water containing Technetium-99m to outline the rectum. Scintigraphic assessment of 'faecal' bolus expulsion (O'Connell et al, 1986) has also been performed using an artificial radio-labelled 'stool' by inserting a 7.5% colloidal dispersion of aluminium magnesium silicate, Technetium-99m and aluminium powder to make a thick paste. This technique showed that about 73% of radio-labelled artificial stool was usually evacuated.

A new method of illustrating changes in the anorectal angle and pelvic floor in constipated patients is therefore presented which combines elements of both the foregoing techniques (O'Connell et al, 1986; Barkel et al, 1988). The aims were to outline the anorectum and to simulate the passage of a 'faecal' bolus during certain manoeuvres which may occur in normal and/or abnormal defaecation.

7A.3 MATERIALS AND METHODS

7A.3.1 Subjects

The clinical protocol was approved by the Ethical Committee of Lothian Health Board and by ARSAC (Administration of Radioactive Substances Advisory Committee). Twelve constipated subjects (3 males, 9 females), median age 48 years (95% CI : 36, 53 years) were recruited to the study. The patients had been suffering from constipation for 3 to 30 years. There were four females of childbearing age in the study, all of whom had the possibility of pregnancy excluded prior to the study.

7A.3.2 Methods

The radio-pharmaceutical used was rehydrated potato labelled with 99m-Technetium Methylene Diphosphonate (99mTc MDP). The volume of the potato paste used in each subject was determined by prior balloon proctometrogram studies which measured the maximum rectal capacity. This simulates the usual state of filling of the rectum at the time of defaecation (Mahieu, 1989). The radio-pharmaceutical was prepared by adding approximately 200 MBq of 99mTc MDP to a volume of warm water determined by the proctometrogram, thus allowing for each patient's individual rectal capacity. The dehydrated potato powder was slowly added while constantly stirring to produce a smooth thick paste (30 ml of warm water to 1 tablespoons of potato powder). A Foley catheter (12CH) filled with approximately 20 MBq 99mTc MDP was used as the anal canal marker.

The patients were given prior bowel preparation in the form of suppositories (Carbalax [TM] containing 1.72g Sodium Acid Phosphate) to

ensure an empty rectum before the insertion of the isotope-labelled paste and to avoid dilution of the isotope activity with any residual faecal matter. For introduction of the paste into the distal bowel, the subjects lay on their left side with hips fully flexed. A 15 cm long tube (E-Z-EM) was inserted 10 cm per anum and the labelled potato paste introduced using 50 ml syringes. The volume introduced approximated to the maximum tolerable capacity.

Thereafter the patient was seated upright on a commode with a plastic bag lining the collection pan. The computer was then set for the dynamic acquisition of 2-sec images over five minutes per session. Further sessions were allowed when required. Recordings of rectal images were performed using a small field (OHIO Nuclear Series 100 or ELSCINT DYMAX) Gamma camera equipped with a GAP (General All Purpose) collimator connected to a computer in the left lateral seated position at rest and during various expulsive manoeuvres following commands for activities such as 'squeezing', and/or coughing for maximal contraction of the anal sphincter and straining at stool. Each subject was then asked to defaecate at will. At the termination of the study, if the evacuation of the isotope paste was not complete, the residue was washed out. It is known that little of the radio-activity is absorbed by the rectal mucosa; moreover it remains in situ for less than 15 minutes. Thus the effective dose equivalent (EDE) is extremely low (EDE<0.3 mSv) irrespective of the duration of observation. In contrast, fluoroscopy in the lateral projection is associated with an EDE of approximately 1 mSv per minute (Padovani et al, 1987). Additional information, in the case of incomplete defaecation, could be obtained by screening and calculating the activity in the plastic liner containing the excreted 99mTc MDP labelled paste.

7A.3.3 Statistical Analysis

The statistical analysis used the median value and its 95% confidence intervals.

7A.3.4 Data Analysis

The data were stored for processing. Specially written software allowed the ano-rectal angles and changes in the pelvic floor level to be graphically displayed and measured as well as the percentage of activity evacuated within the defaecation time.

The stored data were then analysed by comparing the pre- and post-evacuation counts. The percentage of evacuation obtained from the scintigraphic data was calculated for the period of time during which the evacuation had taken place. On the lateral pre-evacuation and post-evacuation images, radioactivity clearly outlined the rectum and the anal canal. Some activity passed into the sigmoid colon proximal to the rectum. These areas were identified on the frames by the angulation of the ano-rectum below and that of the recto-sigmoid above. Using the 'regions of interest' (ROI) programme on the computer, radioactivity in the rectum could be separated from that in the anal canal. A third region of interest included the overall radioactivity in the anorectum taken as a whole. The ROIs thus defined were applied to the dynamic emptying data and separate emptying curves for the areas of interest were obtained (Figure 7.1). The time taken for evacuation was determined visually on the emptying curves, from the time at which defaecation commenced. Completion of defaecation was indicated by the evacuation curves at the point when the isotope activity had dropped to a plateau level. The defaecation rate was derived by dividing the percentage of the activity evacuated by the time taken for evacuation.

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The rectum was outlined by the insertion of the radio-labelled paste, while the outline of the anal canal was achieved using a fine Foley ('WSD', 7L31, 12CH) catheter containing isotope material (approximately 20 MBq of 99mTc MDP). From the lateral position with a clear outline of the anorectum, it is possible to mark the theoretical line of the muscular pelvic floor by projecting a horizontal line through the anorectal junction at rest. The computer 'memorises' this level. Thereafter measurements are made of the degree of pelvic floor ascent on squeezing and coughing by relating this line at rest to the upward movement of the anorectal junction. Similar measurements are obtained of the degree of pelvic floor descent on straining and evacuation in relationship to the downward movement of the anorectal junction, again compared with the pelvic floor level at rest.

The anorectal angles (ARA) were recorded as the upper ARA and the lower ARA. The upper ARA is formed by the intersection of the axis of the rectum with that of the anal canal. The lower ARA is defined as the angle between the posterior rectal wall and the axis of the anal canal as they intersect at the level of the anorectal ring. Using a specially prepared computer programme it has been possible to observe objectively variation in the anorectal angles imaged by the method described during resting (Figure 7.2), coughing, squeezing (Figure 7.3), straining and evacuation (Figure 7.4).

7A.4 RESULTS

The results of the study are summarised in Table 7.1.
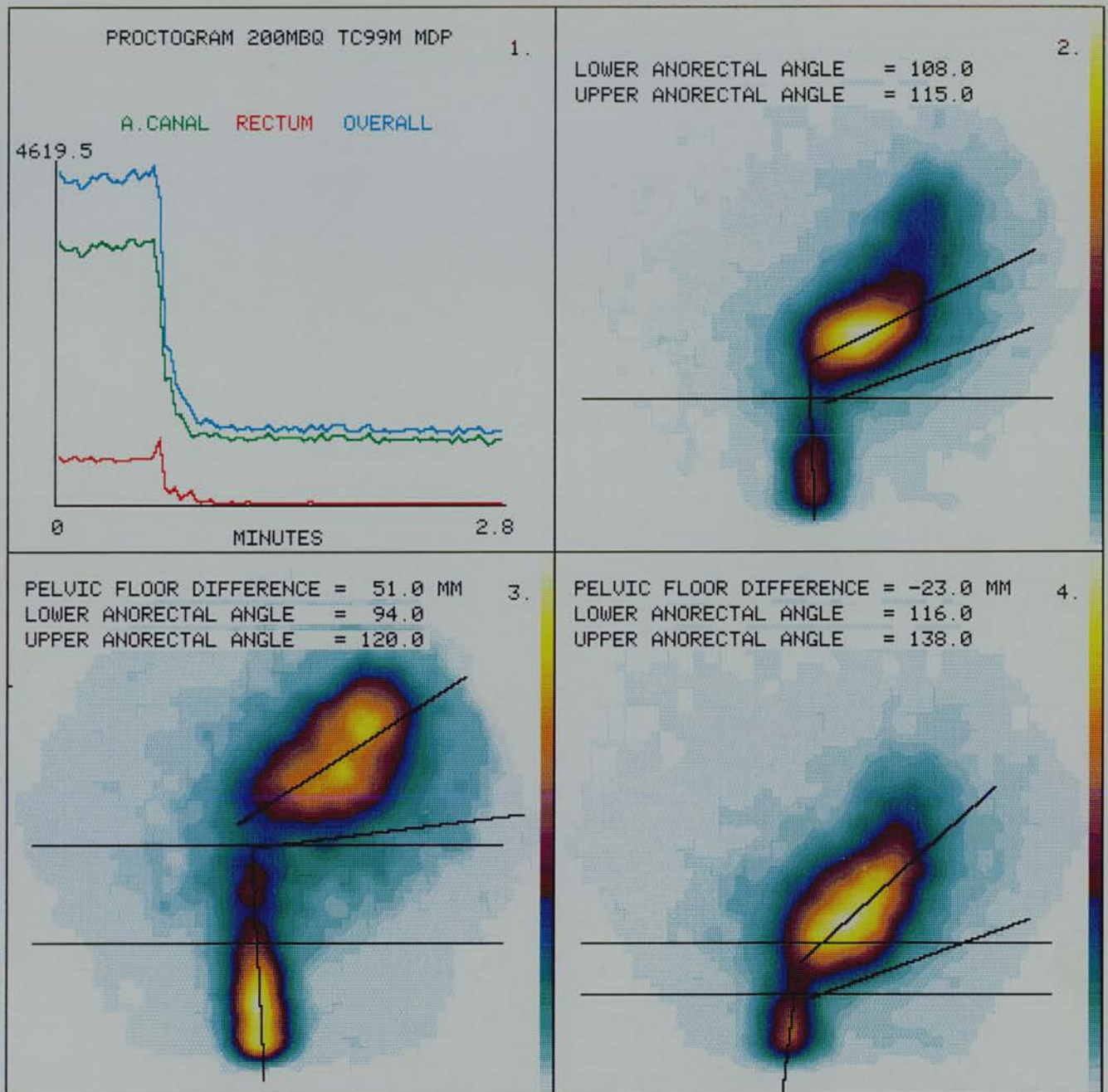
FIG 7.1 PROCTOGRAM CURVES RECORDING ISOTOPE ACTIVITY IN THE ANAL CANAL RECTUM AND
OVERALL ANORECTUM (Y AXIS) AGAINST DEFAEC. TIME. EVACUATION BEGINS AT ARROW.

FIG 7.2 ISOTOPE ANORECTAL IMAGE AT REST. THE PELVIC FLOOR LEVEL IS SET TO ZERO AT
THE ANORECTAL JUNCTION. THE UPPER AND LOWER ARAS ARE MEASURED.

FIG 7.3 ANORECTAL IMAGE ON 'SQUEEZING'. POSITIVE DIFFERENCE INDICATES PELVIC FLOOR
ASCENT. ARAS 'ACUTE' COMPARED TO REST.

FIG 7.4 ANORECTAL IMAGE ON EVACUATION. NEGATIVE DIFFERENCE INDICATES PELVIC FLOOR
DESCENT. ARAS MORE OBTUSE COMPARED TO REST. (7.1 - 7.4 REPRESENT A SINGLE STUDY)

Table 7.1 Anorectal angles (both upper and lower) measured by isotope proctography at rest, during contraction of the external sphincter on voluntary 'squeezing' and coughing, on straining and evacuation. Pelvic floor ascent (positive sign omitted) and descent (negative '-' sign shown) obtained again during isotope proctography. Defaecation time and rate and the percentage of the evacuated activity are derived.

	LARA	UARA
REST	105°(101°, 116°)	122°(105°, 131°)
SQUEEZ.	91°(81°, 98°)	103°(88°, 112°)
COUGH.	105°(92°, 118°)	121°(103°, 132°)
STRAIN.	120°(107°, 137°)	136°(115°, 149°)
EVAC.	126°(116°, 153°)	139°(133°, 156°)

PF ASCENT ON SQUEEZING	28	mm	(9 , 34)
PF " ON COUGHING	4	mm	(-1 , 9)
PF DESCENT ON STRAINING	-8	mm	(-14 , -4)
PF " ON EVACUATION	-27	mm	(-34 , -11)

% EVACUATION	58	%	(42 , 77)
DEFAECATION TIME	64	sec	(50 , 138)
DEFAECATION RATE	0.9	%/s	(0.4, 1.4)

LARA=lower anorectal angle; UARA=upper anorectal angle; PF ASCENT=pelvic floor ascent; PF DESCENT=pelvic floor descent; % EVACUATION=percentage of evacuated activity. The % of the activity evacuated, the defaecation time and rate are derived from nine patients who evacuated during a single session of 5 minutes duration.

Anorectal angles are measured in degrees, the pelvic floor movement in millimetres, the defaecation time in seconds and the defaecation rate in percentage per second.

The results are presented: median (95% confidence intervals of the median).

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7A.4.1 Lower anorectal angle

In the constipated patients studied, the resting anorectal angle was 105° (101°, 116°), decreasing by 14°(10°, 27°) during 'squeeze' and by 5° (1°, 8°) on coughing. During straining it was increased by 15°(1°, 24°) and on evacuation it was increased by 16°(11°, 38°).

7A.4.2 Upper anorectal angle

The resting upper anorectal angle was 122°(105°, 131°), in the constipated patients studied, was decreased by 20°(13°, 30°) during 'squeezing' and by 5°(-4°, 7°) on coughing. It was increased on straining by 8° (5°, 18°) and again it was increased during evacuation by 22°(13°, 37°).

7A.4.3 Pelvic floor movement

The pelvic floor movements were upwards on 'squeezing' by 28mm (9, 34) and were upwards in most cases on coughing by 4mm (-1, 9) compared with the pelvic floor level at rest. The pelvic floor movements were downwards on straining by -8mm (-14, -4) and on evacuation by -27mm (-34, -11). (The negative sign signifies a downward movement as compared to the level at rest).

7A.4.4 Defaecation assessment

The percentage of the evacuated activity achieved in this group as well as the defaecation time and rate are given in Table 7.1. Three patients (25%) were not able to evacuate during the procedure and they had to use suppositories to empty the isotope paste. Nine patients (75%), however, evacuated the isotope paste and seven of them (78%) had done so in less than 70 seconds.

7A.5   DISCUSSION

Isotope proctograms were obtained using radiolabelled rehydrated potato mash and recording a series of consecutive images, to outline changes in the anorectal angle and movement of the pelvic floor on expulsion of the labelled simulated 'faecal' material. At the same time the capacity of constipated subjects to evacuate the simulated faecal bolus and any retrograde movement were studied. Observations on changes in the anorectal angle and pelvic floor have previously been made during radiological videoproctography, developed particularly to detect any anatomical and pathological changes at defaecation (Poon et al, 1991) a method that has been considered unpleasant and has caused concern because of the high dose of radiation involved, especially to the pelvic organs (Womack and O'Connell, 1991). Moreover, x-ray techniques involving the use of barium are not a very reliable means of estimating the 'normal' ability of patients to achieve defaecation, in view of the highly abnormal characteristics of the radio-opaque barium used as a stool marker.

An assessment can also be made   of the anorectal angle and the pelvic floor changes by our method. These are recorded simultaneously while assessing completeness of evacuation in a single dynamic study. This was simpler for patients who are thus exposed to one test only and one which minimises the amount of radiation exposure (EDE<0.3 mSv). Although the method allows measurements of both the upper and lower anorectal angles, we agree with other investigators that the lower anorectal angle measurement may be a more sensitive indicator of anorectal movements

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during the various expulsive manoeuvres (Bartram et al, 1988). The lower, or by others the posterior, anorectal angle reflects movements of the posterior wall of the rectum and does not depend on the shape of the rectum which may be altered with the position of the body, whether standing or sitting as happens with the upper or central anorectal angle (Shorvon et al, 1989).

The serial changes in the anorectum recorded in 2-second images can be analysed quantitatively. Comparison with videoproctography, has shown that isotope proctography gives comparable or possibly more sensitive results in detecting the angle changes at defaecation (Papachrysostomou et al, 1991).

Isotope proctography is thus a useful method of investigating constipation, providing information about evacuation, pelvic floor movement and the anorectal angle as a means of assessing anorectal function. Finally even the protracted defaecation associated with gross constipation can be studied safely because of the low dose of radiation involved. Potential applications for the isotope method include assessing various forms of abnormal defaecation, such as obstructive defaecation or anismus compared with slow transit constipation. It may be of value to differentiate reduced movements of the pelvic floor or increased anorectal angles due to sphincter and pelvic floor laxity resulting from pudendal neuropathy associated with chronic straining in slow transit constipation, or distinguish the more acute anorectal angle of a non-relaxing pelvic floor in obstructive defaecation (Papachrysostomou et al, 1991).

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7B. ISOTOPE PROCTOGRAPHY IN CONSTIPATED SUBJECTS A COMPARISON WITH RADIOLOGICAL VIDEOPROCTOGRAPHY

7B.1 SUMMARY

Twelve patients with longstanding constipation were examined by isotope proctography. Radio-labelled potato mash was inserted rectally to provoke the urge to defaecate and various expulsive manoeuvres were recorded using a Gamma-camera. The method illustrated the alteration in the anorectal angles (ARA) which became more acute on 'squeezing', less so on coughing and more obtuse on straining, maximally so on evacuation. The pelvic floor (PF) movements were consistently upwards on squeezing, less so on coughing, downwards on straining, maximally so on evacuation. The results were comparable with those obtained by radiological videoproctography ($p < 0.01$), but the isotope method allowed greater discrimination for both ARA and PF movement changes. A useful addition was the measurement of the completeness of evacuation and the time involved in this. It allowed correlations to be made between the pelvic floor descent ($p < 0.05$) and anorectal angle ($p < 0.02$) with evacuation.

7B.2   INTRODUCTION

Radiological proctograms have been used to visualise changes in the anorectal angles (ARA) and movements of the pelvic floor (PF), as well as to determine the presence of structural defects such as rectal intussusception or occult rectal prolapse (Broden and Snellman, 1968). An isotope method, using an intra-rectally inserted balloon filled with water containing Technetium-99m to outline the rectum, has been evolved to assess the changes in the ARA and PF movement during different manoeuvres (Barkel et al, 1988). Scintigraphic assessment of 'faecal' bolus expulsion has also been performed (O'Connell et al, 1986), in particular in ileo-anal pouch anastomosis after colon resection for inflammatory bowel disease, using a colloidal dispersion of aluminium magnesium silicate labelled with Technetium-99m (see the first part of this chapter 7A).

The method now described is introduced as allowing the simulation of defaecation by an isotopically-labelled 'faecal' bolus (Papachrysostomou et al, 1991). Using a specifically prepared computer programme, it has been possible to observe variations in the ARA and PF movements at rest, during maximal contraction of the anal sphincter on coughing and voluntary 'squeezing', on straining and during evacuation, while simultaneously recording the adequacy of rectal evacuation and the defaecation time involved.

The study now evaluates the data obtained by this technique and makes comparisons with radiological videoproctography, in a series of constipated subjects.

7B.3   MATERIALS   AND   METHODS

7B.3.1   Subjects

The clinical protocol was approved by the Ethical Committee of the Lothian Health Board and by ARSAC (Administration of Radioactive Substances Advisory Committee). Twelve constipated subjects (3 males; 9 females), median age 48 years (95% CI : 36, 53 years) were recruited to the study. The patients had been suffering from constipation from 3 to 30 years. Six patients with similar symptomatology were studied by radiological videoproctography, for a comparison of the two methods. These six 'control' patients (1 male; 5 females) median age 50 years (95% CI : 37, 70 years). There were 4 females of childbearing age in the study, all of whom had the possibility of pregnancy excluded prior to the study.

7B.3.2   Methods

Isotope Proctography

The radiopharmaceutical used was rehydrated potato labelled with approximately 200 MBq of 99m-Technetium Methylene Diphosphonate (99mTc MDP). The volume of the potato paste used in each subject was determined by prior balloon proctometrogram studies, thus allowing for each patient's individual rectal capacity. A Foley catheter (12CH) filled with approximately 20 MBq 99mTc MDP, was used as the anal canal marker.

Prior to insertion of the radiolabelled potato paste rectally, the patients were given bowel preparation in the form of suppositories, as described in the previous part of this Chapter 7A. Recordings of rectal

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images were performed with the patient seated upright on a commode using a Gamma camera equipped with a GAP collimator connected to a computer set to acquire consecutive 2-second frames for five minutes per session, during various manoeuvres such as contraction of the anal sphincter during voluntary 'squeezing' and on coughing and during straining. The subject was then asked to defaecate at will. In the case of incomplete evacuation any residual isotopic material was washed out, to minimise radiation. Extra sessions were allowed if required (Papachrysostomou et al, 1991).

The stored data were then analysed by comparing the pre- and post-evacuation counts. The percentage of evacuated activity was calculated from the change in the counts for the period during which the evacuation had taken place (see Figure 7.1).

On the lateral anorectal images, radioactivity clearly outlined the rectum and the anal canal. The ARA, which will be referred in this part of the chapter is the angle recorded as the one formed by the axis of the anal canal and by a line parallel to the posterior rectal wall (i.e. lower ARA), for the reasons discussed in the first part of this chapter (Chapter 7A). Using the computerised program it has been possible to measure changes in the ARAs imaged during the various expulsive manoeuvres (see Figures 7.2-7.4).

The PF ascent on 'squeezing' and coughing and descent on straining and during evacuation are recorded from the movement upwards or downwards of the anorectal junction away from its position at rest (see Figures 7.2-7.4).

Radiological Videoproctography

Radiological proctography required no bowel preparation. The composition and preparation of the contrast medium aimed at getting a

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radio-opaque substance with a consistency similar of normal stools. The amount of contrast used depended upon patient's tolerability. The method of radiological videoproctography has been described in detail in Chapter 5, where it has been used to study patients with faecal incontinence.

7B.3.3 Statistical analysis

The statistical analysis of the results obtained by both methods used the median and its 95% confidence intervals (CI). Statistical significance of the differences of data was assessed using the non-parametric Mann-Whitney test for unpaired and the sign test for paired comparison of observations. Correlations were assessed by the Pearson correlation coefficient and p values.

7B.4   RESULTS

7B.4.1   Anorectal Angles

The measurements of the ARA studied by isotope proctography in 12 subjects with constipation are presented in Table 7.1. The ARA measurements altered during various manoeuvres and evacuation, showing a significantly more acute ARA on 'squeezing' ($p < 0.0005$) but less so on coughing ($p > 0.05$) compared with the resting ARA and more obtuse on straining ($p > 0.05$) and significantly so on evacuation ($p < 0.0005$).

The ARA measurements, in the six patients studied by radiological videoproctography, showed similar though less significant dynamic changes on 'squeezing' ($p > 0.05$), straining ($p < 0.05$) and evacuation ($p > 0.05$) compared to those studied by the isotope method (Table 7.2).

Table 7.2 Anorectal angle measurements and pelvic floor movements obtained during isotope and radiological proctographies, recorded at rest, on maximal contraction of the anal sphincter on voluntary 'squeeze', during straining and on evacuation.

	ISOTOPE PROCTOGRAPHY	RADIOLOGICAL PROCTOGRAPHY
	ARAs	ARAs
R	105°	88°
SQ	91° (p<0.0005)	75° (p>0.05)
ST	120° (p>0.05)	103° (p<0.03)
EV	126° (p<0.0005)	115° (p>0.05)
	PF mm	PF mm
SQ	19 (p<0.0005)	23 (p>0.05)
ST	- 7 (p<0.04)	-30 (p<0.03)
EV	-24 (p<0.0005)	-22 (p>0.05)

ARA=anorectal angle; PF=pelvic floor; R=at rest; SQ=on squeezing; ST=on straining; EV=on evacuation. The negative sign in the pelvic floor movement signifies downward movement compared to its position at rest. (The p values presented are derived from comparing the changes of the anorectal angles and the pelvic floor movements compared to the anorectal position at rest, with the use of sign test for paired comparison.)

However, comparing the ARAs (median and its 95% CI) at rest, on squeezing, straining and evacuation obtained during isotope proctography with those on radiological videoproctography (Figure 7.5), a highly significant correlation was derived ($p < 0.01$).

7B.4.2 Pelvic Floor Movements

The measurements of PF movements obtained during isotope proctography are also summarised in Table 7.1. These PF movements altered during the various expulsive manoeuvres showing an upwards movement for 'squeezing' ($p < 0.0005$) and coughing ($p > 0.05$), as compared to the resting position, indicated by a positive sign (see Figure 7.3), and a downwards movement for straining ($p < 0.04$) and evacuation ($p < 0.0005$) indicated by a negative sign (see Figure 7.4). The radiological technique measures the PF ascent as the movement of the anorectal junction on squeezing ($p > 0.05$) and the descent as the position of the anorectal junction on straining ($p < 0.03$) and during evacuation ($p > 0.05$) both relative to the pubococcygeal line, whereas the isotope method reflects movement of the anorectal junction away from its resting position. Comparison between the two methods (see Table 7.2) for the PF ascent on squeezing and the PF descent on evacuation showed no significant difference ($p > 0.05$).

7B.4.3 Defaecation Assessment

The 9 constipated subjects only evacuated approximately 58% of the isotope 'faecal' bolus (95% CI : 42, 77%). The defaecation time was 64 seconds (95% CI : 50, 138 sec). The defaecation rate was calculated at 0.9%/sec (95% CI : 0.4, 1.4 %/sec). The other three patients emptied 10% or less of the evacuated activity and their performance was consider poor.

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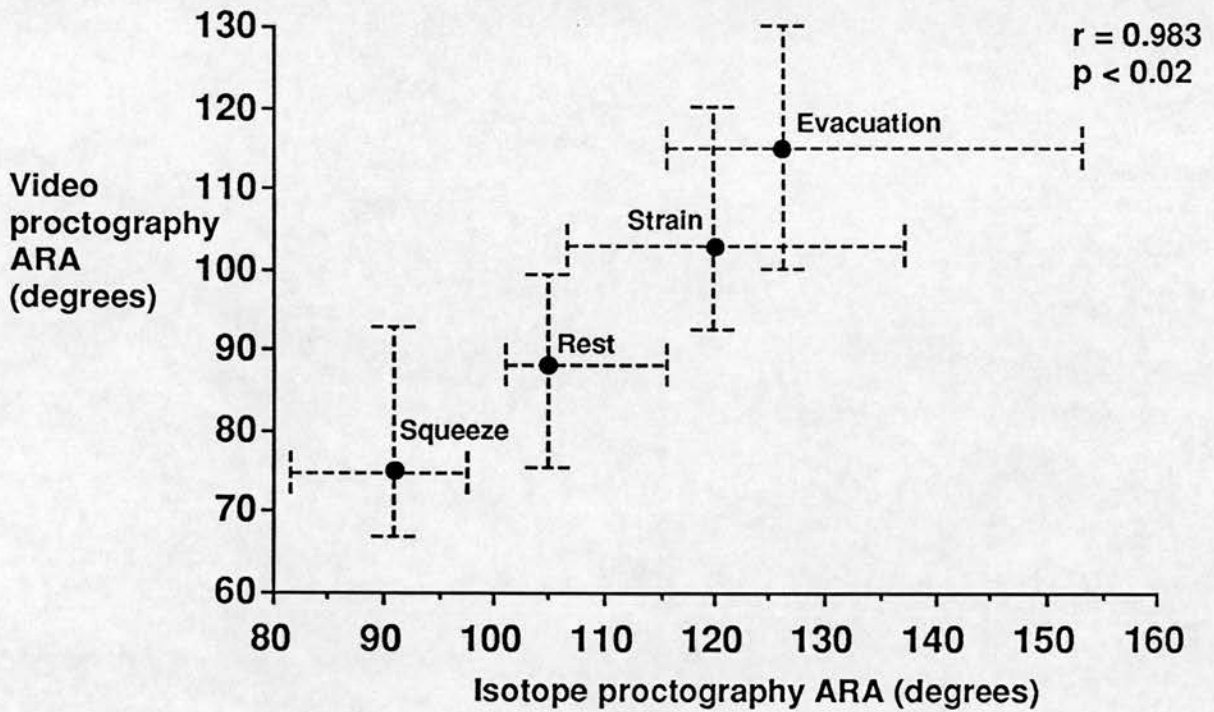
Figure 7.5 The comparison of the anorectal angle measurements obtained during isotope proctography and the anorectal angle measurements obtained during radiological videoproctography, at rest, on maximal contraction of the anal sphincter during voluntary 'squeezing', on straining and evacuation. (The black spots represent the median values and the dotted lines represent the 95% confidence interval of the median. The Pearson correlation coefficient and its p value are illustrated.)

7B.4.4   Defaecation Assessment And The Anorectum

The percentage of the activity evacuated, in the 12 constipated subjects, correlated with the   ARA on straining ($p < 0.05$; Figure 7.6) and also correlated with the PF descent on evacuation ($p < 0.05$; Figure 7.7).

7B.5   DISCUSSION

In the investigation of the aetiology of constipation it becomes necessary to study the pelvic floor and anorectal changes as well as the ability of the subject to evacuate adequately a 'full' rectum (Turnbull et al, 1988). Observations on changes in the ARA and PF have previously been made during radiological videoproctography, a method that has been developed particularly to detect anatomical and pathological changes at defaecation (Mahieu, 1989). As a method it may be considered unpleasant for the patient and concern has been expressed because of the high dose of radiation involved (Padovani et al, 1987), especially to the pelvic organs (EDE of approximately 1 mSv per minute). Moreover, radiological techniques involving the use of barium are not a reliable means of estimating the 'normal' ability of patients to achieve defaecation, in view of the highly abnormal characteristics of the radio-opaque barium used as a stool marker.

The information obtained by isotope proctography studying patients with constipation and those who find defaecation difficult is thus valuable as a tool of investigation and management. It quantitatively assesses the changes in the anorectum during simulated defaecation, such as widening the ARA and descent of the PF, as well as recording the adequacy of defaecation.

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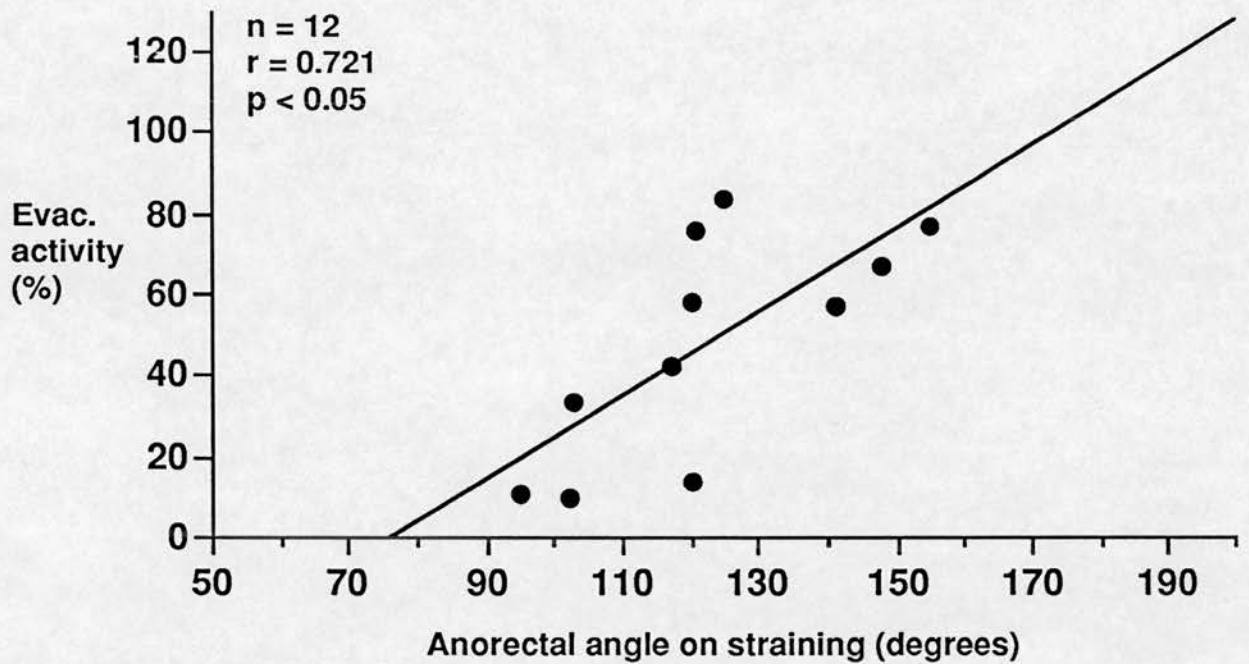
Figure 7.6 The relationship between the anorectal angle measurement on straining, obtained during isotope proctography and the percentage of the activity evacuated during the named procedure in 12 constipated patients. The more obtuse the anorectal angle on straining the more successful evacuation is achieved. (The Pearson correlation coefficient and its p value are illustrated.)
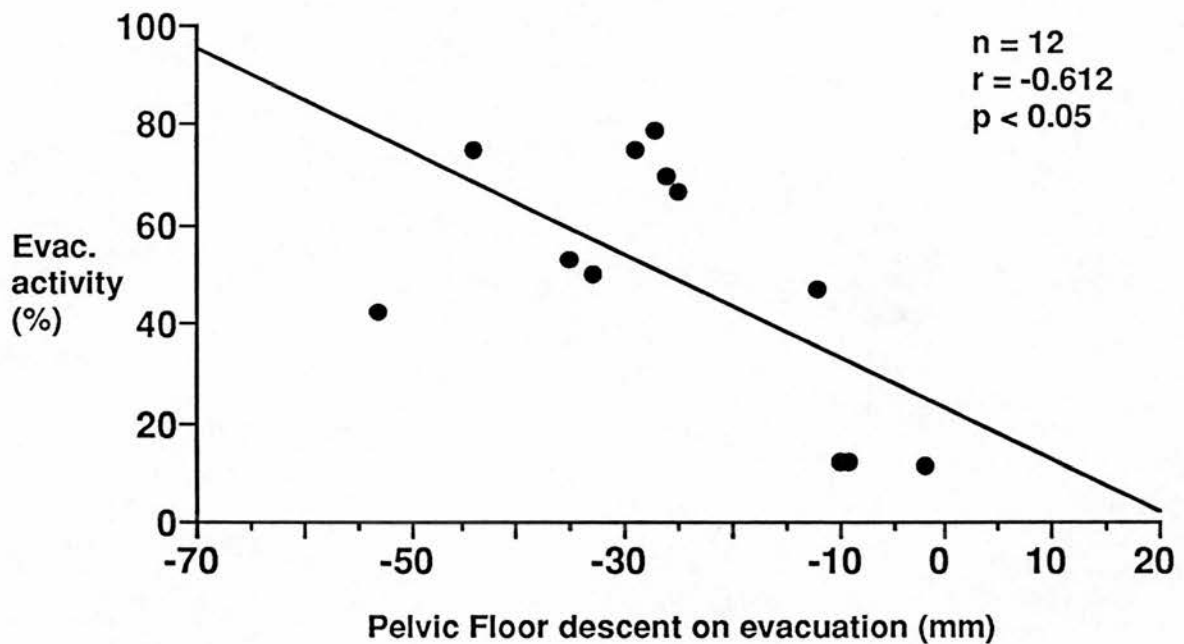
Figure 7.7   The relationship between the pelvic floor descent on evacuation and the percentage of the activity evacuated, during isotope proctography, in the 12 constipated subjects. The greater the pelvic floor descent the more successful evacuation is achieved. No inappropriate upward movement of the pelvic floor is illustrated (all presented with negative signs) and one patient with a greater than 50 mm descent (obvious abnormal perineal descent) had inadequate rectal emptying. (The Pearson correlation coefficient and its p value are illustrated.)

The widening of the ARA together with greater PF descent should facilitate more complete or adequate evacuation. Thus the quantitative measurement of the adequacy of defaecation should enable discrimination to be made from the incomplete evacuation associated with a non relaxing pelvic floor. In this series the patients were able to evacuate about 58% of the 'faecal' bolus, which approximates that for normal controls, who evacuated about 60% (studied similarly by O'Connell). The same normal controls also took less time (40 sec) to defaecate, compared with the constipated subjects studied. The defaecation rate was slower in the constipated patients when compared to the one quoted (1.5 %/sec) for normal controls (O'Connell et al 1986). All these parameters can be recorded simultaneously in a single dynamic study which is simpler for patients, who are exposed to one test only that minimises the amount of radiation (EDE<0.3 mSv) exposure. Moreover, the physical characteristics of the artificial stool used in isotope proctography closely mimic the natural substance.

For those measurements which can be obtained by both techniques the method gives comparable results of the ARA measurements to conventional radiological videoproctography. However, the changes of the ARA showed more sensitive discrimination for each performance with the isotope method as compared to the radiological one. The PF movements studied by isotope proctography reflected the true movement of the anorectal junction, during the various manoeuvres compared to its position at rest, with more effective movements upwards and downwards during the extremes of squeeze and evacuation. This is also a more sensitive method of recording the PF movement than the one employed by the radiological videoproctography, which records the PF ascent or descent as the anorectal junction position at squeezing or on evacuation respectively, relative to the

pubococcygeal line. The latter is unable to depict the true movement of the anorectal junction during the various manoeuvres because superimposing the anorectal images on different manoeuvres is virtually a technical impossibility.

Isotope proctography is therefore a useful method of assessing anorectal function since it provides information about the relationship of rectal evacuation to the ARA and to PF descent. Even the most protracted forms of defaecation associated with gross constipation can be studied safely because of the low dose of radiation involved. Although, it successfully demonstrates quantitative changes in the parameters described, isotope proctography lacks thus far, the diagnostic applications which the radiological method has for making observations of structural changes (Poon et al, 1991). The possibility exists however, that by isotope mucosal coating this may become a future development.

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CHAPTER 8

OBSTRUCTIVE DEFAECATION

8.1 SUMMARY

Twenty-two constipated patients with features of obstructive defaecation (OD) had colonic transit studies, ano-rectal manometry, pelvic floor electromyography, rectal balloon expulsion test and isotope proctography with simultaneous electromyography and intrarectal telemetry (Group I). They were compared with seven constipated patients free of obstructive defaecation features (Group II). Eleven asymptomatic subjects (Group III) were recruited to allow comparisons to be made of the anorectal function in health and disease.

Pelvic floor EMG revealed increased 'straining EMG activity' in all OD patients, while no such 'abnormality' was detected in any of the other group of constipated patients or of the normal volunteers. The OD patients had impaired rectal sensation compared with the normal volunteers and were unable to perform a complete rectal evacuation (% EVAC 54%) on isotope proctography. The defaecation time was more prolonged (120 sec) with a lower defaecation rate (0.5 %/sec) compared with the constipated subjects of the Group II. The anorectal angle (ARA) on straining did not change ($p>0.05$) in the OD group, but became more obtuse in Group II ($p<0.02$). In the OD group (I) a number of patients had an abnormal pelvic floor descent, whereas a few had immobile perineum. Simultaneous recording of intrarectal pressures (IRP) and external anal sphincter (EAS) EMG showed an increase of these parameters on attempted defaecation in both constipated groups. The proctographic parameters (% evacuation, defaecation time and rate) provided useful characteristics of the OD problem and were correlated with the ARAs, the EAS EMG voltage on attempted defaecation and the

rectal capacity. The ARAs correlated with the PF movement and the Anismus index. This index is a valuable means of assessment in constipated patients and was high in the OD group compared with the second group of patients (p<0.0001) and the normal control one (p<0.0001). The index in the OD group correlated with the IRP (p<0.02).

The defaecation process is thus a complex phenomenon which can be affected by derangements of rectal sensation, capacity and compliance as well as by the abnormal activity of the pelvic floor and anal sphincter musculature.

8.2   INTRODUCTION

Constipation is a common and serious problem in young women of child-bearing age (Watier et al, 1983; Turnbull et al, 1989). Dietary fibre is regarded by many as a panacea in the treatment of adult constipation, but some patients with a severe form of constipation, find that they are not helped by it and it may even make their symptoms worse (Turnbull et al, 1986). Others remain resistant to all forms of treatment except enemas and large doses of saline cathartics and ultimately some require a colectomy to relieve the situation (Preston et al, 1984).

Constipation is not a disease but a symptom of several disorders. When conventional investigations reveal no anatomic abnormalities or organic causes (Kamm et al, 1988), constipation is considered to be nonorganic, or functional (Thompson and Heaton, 1980). Two types of nonorganic constipation can be distinguished: the slow-transit type or colonic

inertia and outlet obstruction or obstructive defaecation (Preston and Lennard-Jones, 1981; 1985). The latter is an abnormal function of the pelvic floor muscles. Straining during defaecation provokes a contraction instead of relaxation of these muscles, thus creating a functional outlet obstruction.

There is no consensus regarding the pathophysiology of constipation; studies have suggested that it may be related to abnormally high sphincter pressures (Meunier et al, 1979), an internal anal sphincter that fails to relax on rectal distention (Martelli et al, 1978) impaired rectal sensitivity (Kamm and Lennard-Jones, 1990), reduced colonic propulsion (Ritchie, 1968), a functional obstruction of the sigmoid colon (Chowdhury et al, 1976), failure of relaxation or paradoxical contraction of the puborectalis and/or external anal sphincter (Preston and Lennard-Jones, 1981), or a combination of these abnormalities.

Among patients with chronic constipation, a group can be identified, as mentioned above, in whom disturbed relaxation of the striated pelvic floor and anal sphincter musculature leads to functional obstruction of defaecation at the pelvic outlet (Meunier, 1986). This phenomenon has been termed anismus (Preston and Lennard-Jones, 1985), or spastic pelvic floor syndrome (Bleijenberg and Kuijpers, 1985), but its underlying pathophysiological basis is not known. The term anismus was derived by analogy with the involuntary contraction of the pelvic floor muscles said to occur in vaginismus (Preston and Lennard-Jones, 1985).

Patients with anismus are usually female and present in childhood or early adult life. There is evidence of associated urological symptoms (MacDonald et al, 1991) but seldom evidence of neurological or gastroenterological disease (Mathers et al, 1988). Electrophysiological assessment shows paradoxical puborectalis and external anal sphincter

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contraction during attempted defaecation. There is evidence that chronic straining at stool for many years may lead to stretch-induced damage to the pudendal innervation of the external anal sphincter (Snooks et al, 1985).

The symptoms of obstructive defaecation (OD) may present as the descending perineum syndrome (Parks et al, 1966), solitary rectal ulcer syndrome (Rutter, 1975), irritable bowel syndrome (Lennard-Jones, 1983; 1985), complete rectal prolapse, mucosal prolapse, rectal intussusception, or idiopathic faecal incontinence (Finlay and Brown, 1988). Common symptoms comprise a sensation of incomplete emptying at stool, excessive straining during attempts to defaecate and in some cases a desire to evacuate the rectum with no result (Bartolo et al, 1983; 1985).

Continence in normal subjects is thought to be the result of sustained contraction of the internal anal sphincter and the striated pelvic floor muscles. The central portion of the levator ani muscle, the puborectalis, acts as a sling pulling the anorectal junction forward to create an angle between the rectum and anal canal. This angulation is probably an important factor in the maintainance of normal continence (Parks, 1975).

Another important factor in the maintainance of continence is the reflex contraction of the pelvic floor that occurs in response to raised intra-abdominal pressure - for example during coughing (Parks et al, 1962). During normal defaecation both the internal and external sphincters relax, and the anorectal angle straightens with relaxation of the puborectalis (Kerremans, 1969). It has been suggested that downward pressure on the puborectalis muscle results in an urge to defaecate with a wave of rectal contractions that may lead to external sphincter relaxation (Scharli and Keisewetter, 1970). Is this the reflex mechanism by which the striated muscle of the anus relaxes on defaecation?

Observations have been made suggesting that paradoxical contraction of the puborectalis muscle is not a specific finding and that it is not the sole cause of constipation in patients with anismus (Hallan et al, 1988), in fact the same paradoxical increase in puborectalis activity has been observed in normal subjects during straining (Jones et al, 1987). However, the incidence of this finding in a population has not been formally assessed. Surgical division of the puborectalis muscle in the management of constipation associated with paradoxical contraction of this muscle has failed to produce marked functional improvement (Barnes et al, 1985). Thus, is that a sign of refractoriness to the treatment of this phenomenon or a predisposing factor not yet revealed by investigations or could it be that this paradoxical activity is not important in the pathogenesis of anismus? (Miller et al, 1991).

Simple paradoxical increase in external anal sphincter activity during straining has been observed in constipated patients and in some controls (Read et al, 1986). Is this paradoxical phenomenon of the external anal sphincter additionally important in the pathogenesis of the obstructive defaecation syndrome? Is it a single abnormality or a part of a more complex phenomenon? How important may be the lack of inhibition of the striated muscles of the pelvic floor in general in the process of defaecation?

The above mentioned questions along with other relevant observations are to be discussed in the following chapter. It now became important to consider whether any changes detectable in these constipated patients with dyschezia, would throw more light in the mechanism and pathogenesis of the phenomenon of functional constipation.

8.3   MATERIALS AND METHODS

8.3.1   Subjects

Group I - patients with evidence of OD

Twenty-two patients with functional constipation were studied, all exhibiting symptoms of obstructive defaecation. Eighteen of them were women (82%), and four were men (18%). Eight of the eighteen women were nulliparous and females of childbearing age had the possibility of pregnancy excluded prior to the study. The patients median age was 44 years (95% CI: 36, 46 years), duration of symptoms from 1 year to 33 years, and defaecation frequency from once in 2 days to no bowel movement without the help of laxatives/enemas. These patients had been having difficulty in evacuating the bowels, often irrespective of whether the stools are hard or loose. The patients complained of infrequent defaecation (45%), lack of responsiveness to laxatives or enemas (32%), incomplete evacuation (59%) and the feeling of obstruction at defaecation (27%). All patients described prolonged straining at stool despite an urge to defaecate, some having to resort to anal digitation to aid evacuation of stool (14%). Amongst primary complaints were abdominal pain (59%), abdominal distention (9%), nausea (5%) and perineal pain (64%). All had been assessed clinically by the referring consultant surgeon or gastroenterologist. Barium enema examination and sigmoidoscopy did not show any organic abnormalities. Objective evidence of severe constipation was obtained by estimating the delivery of radiopaque markers in the faeces after ingesting 50 plastic radiopaque markers.

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Group II - Patients with constipation

The second group of patients studied were constipated subjects who had been suffering from infrequent defaecation. This group consisted of seven women (one of them nulliparous) with median age of 38 years (95% CI: 30, 56 years). These patients have suffered from constipation from 1 year to 20 years, with a defaecation frequency from once every 2 days to once a month. Four of them were on regular laxatives. All of them admitted straining at stool and six of them had abdominal and/or perineal discomfort.

Group III - Asymptomatic subjects

Eleven asymptomatic volunteers were recruited to the study and acted as normal controls. These subjects did not have any history of anorectal or colonic problems. Among these controls nine were women (82%) all nulliparous, and two were men (18%). The median age of the control group was 21 yrs (95% CI: 21, 22 yrs). The control subjects underwent routine anorectal manometric and electrophysiological tests (see Chapter 2), for which all gave written consent. The clinical protocol of this study was approved by the Ethical Committee of the Lothian Health Board. The defaecating proctography test was avoided in this group, because of strict control concerning exposure to radiation in volunteer asymptomatic subjects. However, they all had the rectal balloon expulsion studies. The performance of anorectal studies in this control group allowed observations to be made as to whether there is electrophysiological evidence of functional obstruction or other abnormalities in the anal sphincter function.

8.3.2 Methods

Anorectal manometry and Electrophysiology

All the recruited patients underwent anorectal manometric and electrophysiological investigation by tests detailed in Chapter 2. An inhibitory recto-sphincteric reflex was demonstrated in each case, thus no patient suffered from neither congenital nor acquired aganglionosis with or without megarectum. Rectal balloon expulsion tests were performed. With the patient in the left lateral position, a lubricated rubber balloon attached to a plastic catheter was inserted to lie in the rectal ampulla. The balloon was filled with saline upto 140 mls, provided the patient at this level achieved adequate rectal sensation and the patient was then asked to strain with maximal effort to expel the balloon. If unsuccessful, tension was applied to the balloon catheter, this being recorded, so to achieve expulsion of the balloon.

Isotope Proctography

Dynamic scintigraphic proctography was performed in each patient. During this test the radiopharmaceutical used, approximately 200 MBq 99m-Technetium Methylene Diphosphonate (99mTc MDP), was prepared as described in chapter 7. After the insertion per rectum of the isotope 'potato paste' at a volume approximated to the maximum tolerable capacity, a Foley catheter (12CH) filled with approximately 20 MBq 99mTc MDP, was used as the anal canal marker. In order to acquire more information about any changes in the anorectal angle and pelvic floor descent, or assessment of the competeness of evacuation along with the defaecating time and rate involved, the anal sphincter activity and anorectal

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function during simulated defaecation, electromyographic and intrarectal pressure tests were performed simultaneously. With the patient seated upright on a commode recordings were made of the rectal images, EMG of the external anal sphincter and intrarectal pressures, at rest and following commands such as 'squeeze', cough, straining and evacuation.

EMG activity was recorded from the external anal sphincter using teflon coated fine wire stainless steel electrodes, with their tip ends (0.25 cm) bared and hooked over, to prevent displacement of the electrodes in the muscle. The wire electrodes were inserted into the external anal sphincter, through the skin 1 cm lateral to the anal margin. Ground electrode was attached to the upper thigh. The wires were connected to an isolated EMG integrator (Ormed 4880, MX216) and the recorder calibrated to a range of 0 - 500 μV. The measurement of intra-rectal pressure, during voiding of the rectal contents, was achieved by a pressure sensitive radiotelemetry capsule (Remote Control Systems Ltd). The radiotelemetry capsule is stabilised in a water bath at 37 degrees of Celsium, for at least 4 hours, before calibrating in a pressure chamber against a manometer. The capsule was introduced in the rectum, the signal emitted by it, was received by an omnidirectional antenna strapped over the patient's sacrum (Remote Control Systems Ltd).

8.3.3 Statistical Analysis

The statistical analysis of the results used the median values and their 95% confidence interval (CI), the Spearmans correlation coefficient and its p value, the non-parametric Mann-Whitney test for unpaired comparison and the sign test for paired comparison of observations.

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8.4   RESULTS

8.4.1   Group I - Constipated Subjects With OD Features

Anorectal Manometry and Electrophysiology

All these patients were unable to expel the rectal balloon, therefore suggesting lack of relaxation of the pelvic floor or inappropriate contraction of the sphincter muscles on straining. The anorectal manometry (Table 8.1) revealed the maximum resting pressure (MRP) as 120 cm H_2O (95% CI: 110, 140 cm H_2O) and squeeze pressure (SQP) as 80 cm H_2O (95% CI: 50, 120 cm H_2O). The recto-sphincteric inhibitory reflex was present in all of them. The rectal sensation via proctometrogram was elicited at 140 mls (95% CI: 110, 180 mls) the maximum tolerable rectal capacity was 425 mls (95% CI: 335, 490 mls) and the rectal compliance 6 ml/cm H_2O (95% CI : 4, 7 ml/cm H_2O). The pudendo-anal reflex latency was 48 ms (95% CI: 42, 50 ms). Ten patients had a normal latency and twelve a delayed one. Integrated EMG revealed the straining activity of the pelvic floor muscles to be paradoxically increased; the Anismus index was 67% (95% CI: 50%, 80%). This paradoxical EMG voltage increase was found to be significant ($p < 0.001$).

Isotope Proctography

The adequacy of rectal evacuation (%EVAC), the defaecation rate (%EVAC/sec) and the defaecation time involved were calculated as described in Chapter 7 (Figure 8.1). The %EVAC was 54% (95% CI: 44,

72%), the defaecation rate was 0.5 %/sec (95% CI: 0.2, 1 %/sec) and the defaecation time was 120 seconds (95% CI: 52, 208 sec). The ARAs at rest, on squeezing, straining and evacuation (Figures 8.2-8.4) are referred to as the 'lower anorectal angles' i.e. the ones formed by the anal canal midline and by a parallel line to the posterior rectal wall (see Chapter 7). The ARA at rest was 103° (95% CI : 92°, 106°), the ARA on straining was 112° (95% CI: 96°, 117°) and on evacuation the ARA was 126° (95% CI: 120°, 131°). The pelvic floor (PF) level was recorded with a negative sign on downward movements compared with its level at rest. The PF on straining was -9 mm (95% CI: -9, -5 mm); 4 patients performed an inappropriate upward movement and 2 patients had no movement recorded of the PF on straining. On evacuation the PF descent was -33 mm (95% CI : -46, -23 mm). The IRP at rest was 5 cm H_2O (95% CI: 5, 12 cm H_2O), on straining 30 cm H_2O (95% CI: 20, 40 cm H_2O) and on evacuation 38 cm H_2O (95% CI: 20, 44 cm H_2O). The EAS EMG at rest was 18 μV (95% CI: 10, 22 μV), on straining was 40 μV (95% CI: 25, 100 μV) and on evacuation was 75 μV (95% CI: 40, 100 μV). (Table 8.2).

8.4.2   Group II - Constipated Subjects With No OD

Anorectal Manometry and Electrophysiology

Anorectal tests (Table 8.1) showed the MRP as 120 cm H_2O (95% CI: 80, 125 cm H_2O), and the SQP as 70 cm H_2O (95% CI: 45, 105 cm H_2O). The recto-sphincteric reflex was present virtually excluding the diagnosis of aganglionosis, as the cause of the constipation. The proctometrogram showed the rectal sensory threshold as 90 ml (95% CI: 52, 208), the maximum tolerable rectal capacity as 280 ml (95% CI: 183, 429)

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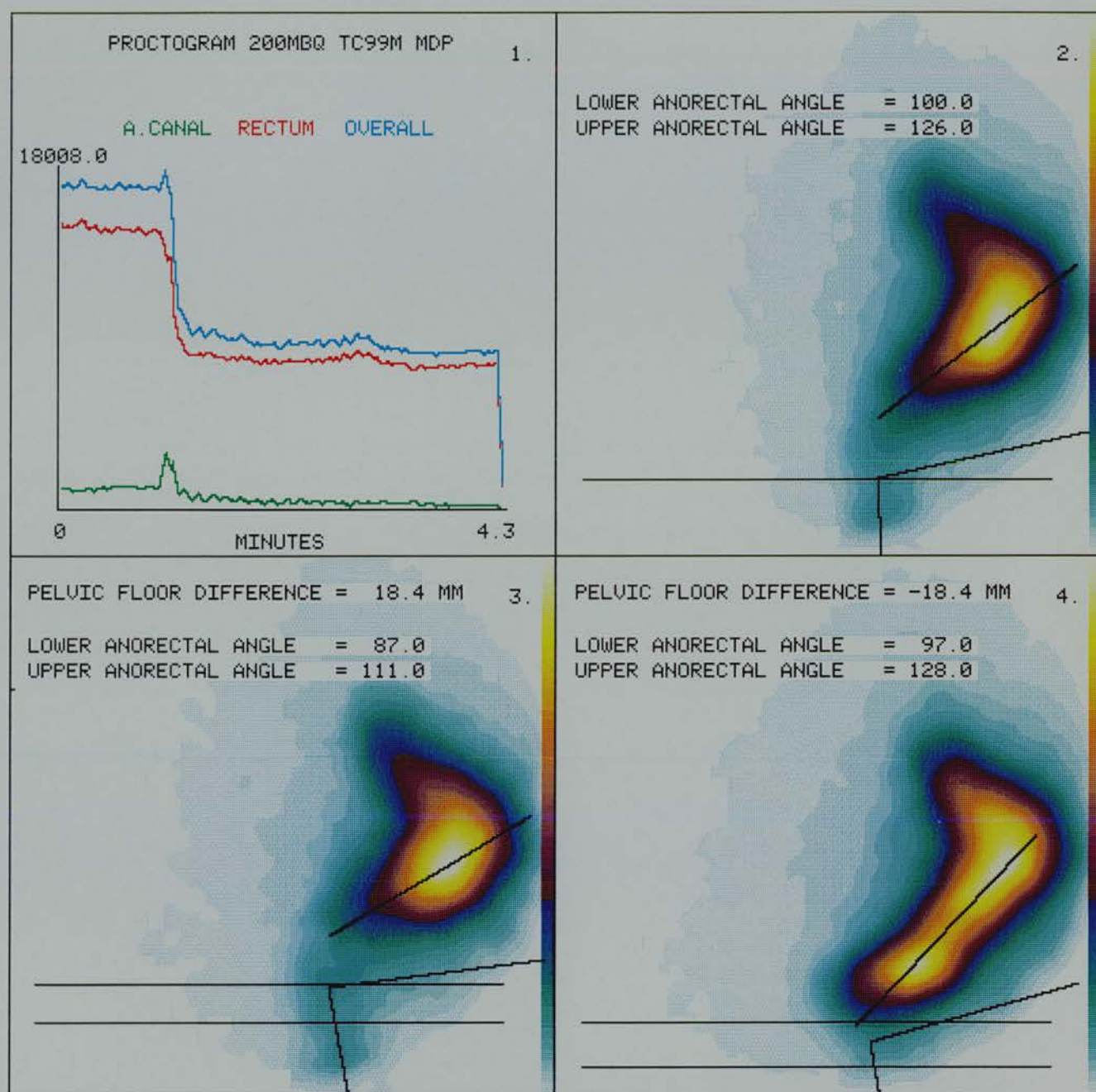
FIG 8.1 PROCTOGRAM CURVES RECORDING ISOTOPE ACTIVITY IN THE ANAL CANAL RECTUM AND
OVERALL ANORECTUM (Y AXIS) AGAINST DEFAEC. TIME. EVACUATION BEGINS AT ARROW.

FIG 8.2 ISOTOPE ANORECTAL IMAGE AT REST. THE PELVIC FLOOR LEVEL IS SET TO ZERO AT
THE ANORECTAL JUNCTION. THE UPPER AND LOWER ARAS ARE MEASURED.

FIG 8.3 ANORECTAL IMAGE ON 'SQUEEZING'. POSITIVE DIFFERENCE INDICATES PELVIC FLOOR
ASCENT. ARAS 'ACUTE' COMPARED TO REST.

FIG 8.4 ANORECTAL IMAGE ON EVACUATION. NEGATIVE DIFFERENCE INDICATES PELVIC FLOOR
DESCENT. ARAS 'ACUTE' COMPARED TO REST. (8.1 - 8.4 REPRESENT A SINGLE STUDY)

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and the rectal compliance 5 ml/cm H_2O (95% CI: 3, 7). Electrophysiological tests showed the pudendo-anal reflex latency as 40 ms (95% CI: 37, 45 ms). Integrated EMG revealed no significant increase in the straining EMG voltage; the Anismus index was 0 % (95% CI: -14, 13 %).

Isotope Proctography

Isotope dynamic proctography showed (Table 8.2) the %EVAC as 57% (95% CI: 49, 69 %), the defaecation rate 1.8 %/sec (95% CI: 0.7, 2.2 %/sec) and the defaecation time as 32 sec (95% CI: 32, 62 sec). The ARA at rest was 111° (95% CI: 91°, 116°), on straining 120° (95% CI: 104°, 142°) and on evacuation 132° (95% CI: 127°, 156°). The PF descent on straining was -6 mm (95% CI: -14, 4 mm) and on evacuation was -18 mm (95% CI: -50, 13 mm). The IRP at rest was 8 cm H_2O (95% CI: 5, 20 cm H_2O), on straining was 15 cm H_2O (95% CI: 10, 43 cm H_2O) and on evacuation 25 cm H_2O (95% CI: 12, 53 cm H_2O). The EAS EMG at rest was 40 μV (95% CI: 10, 100 μV), on straining was 30 μV (95% CI: 30, 50 μV) and on evacuation 45 μV (95% CI: 30, 100 μV).

8.4.3 Group III - Control Subjects

Anorectal Manometry and Electrophysiology

The MRP was 110 cm H_2O (95% CI: 89, 131 cm H_2O), while the SQP was 140 cm H_2O, (95% CI: 98, 182 cm H_2O). The inhibitory recto-sphincteric reflex was demonstrated in all cases. The proctometrogram showed the rectal sensory threshold as 80 ml (95% CI: 60, 140 ml), the maximum tolerable rectal capacity as 450 ml (95% CI: 239, 490ml) and the compliance as 5 ml/cm H_2O (95% CI: 5, 8 ml/cm H_2O). Electrophysiological

tests detected a pudendo-anal reflex latency of 39 ms (95% CI: 38, 40 ms). With the subject on the left lateral position using the anal plug surface EMG electrode (Chapter 2), measurements were made of the resting EMG activity of the EAS 20 μV (95% CI: 19, 30 μV) and of the straining EMG activity of the EAS again 20 μV (95% CI: 19, 30 μV). Thus, no paradoxical increase in the EAS voltage was revealed during straining and the Anismus index was calculated as 0 %. Therefore, the incidence of the above phenomenon in the control subjects was virtually zero. (Table 8.1). Each of the control subjects had the rectal balloon expulsion test and had no difficulty in expelling the rectal balloon.

8.4.4 Group I, Group II and Group III

Anorectal Manometry and Electrophysiology

There were no significant differences in the two constipated groups in the MRP, the SQP, the rectal sensory threshold, the maximum rectal capacity and compliance ($p > 0.05$). However, the SQP was significantly greater in the normal controls compared with the OD group ($p < 0.05$) and the Group II ($p < 0.03$). The OD patients had significantly greater volume of rectal sensory threshold compared with normal controls ($p < 0.01$), no such difference was observed in the Group II and III. The pudendo-anal reflex latency was also significantly delayed in the OD (I) group ($p < 0.01$) but no such difference was revealed in the Group II. Although the voltage of the integrated EMG at rest was not any different in the two groups ($p > 0.05$), the EMG voltage on straining was significantly greater in the OD group ($p < 0.0003$) and the Anismus index was therefore higher in the OD group ($p < 0.0001$). On the contrary in the normal control group (III) the index was

Table 8.1 Anal canal pressure measurements; rectal sensation, capacity and compliance; pudendo-anal reflex latency; and anismus index; all recorded in the three groups, Group I - constipated subjects with obstructive defaecation features, Group II - constipated subjects with no obstructive features on defaecation, Group III - normal controls.

	Group I	Group II	Group III
MRP cmH_2O	120 (110,140)	120 (80,125)	110 (89,131)
SQP cmH_2O	80 (50,120)	70 (45,105)	140 (98,182)
RSEN ml	140 (110,180)	90 (52,208)	80 (60,140)
RCAP ml	425 (335,490)	280 (183,429)	450 (239,490)
RC ml/cmH_2O	6 (4, 7)	5 (3, 7)	5 (5, 8)
PARL ms	48 (42, 50)	40 (37, 45)	39 (38, 40)
AI %	67 (50, 80)	0 (-14, 13)	0 (0, 0)

MRP=maximum anal canal resting pressure; SQP=anal canal pressure increment on maximal contraction of the external anal sphincter during voluntary 'squeeze'; RSEN=rectal sensory threshold measured in millilitres; RCAP=maximum tolerable rectal capacity measured in millilitres; RC=rectal compliance; PARL=pudendo-anal reflex latency measured in milliseconds; AI=anismus index illustrated as the percentage of:

$$AI = \frac{\text{straining EAS EMG voltage - resting EAS EMG voltage}}{\text{squeezing EAS EMG voltage - resting EAS EMG voltage}} \times 100$$

The results are expressed as: median values (95% confidence interval of the median).

Table 8.2   The percentage of the activity evacuated, the defaecation time and rate; the anorectal angles at rest, on straining and during evacuation; the pelvic floor descent on straining and evacuation; the intrarectal pressures at rest, on straining and evacuation; and the external anal sphincter EMG at rest, on straining and during evacuation in the two groups, Group I - constipated subjects with obstructive defaecation features and Group II - constipated subjects without obstructive features on defaecation.

		Group I			Group II		
EVAC. %	54	(44	,	72)	57	(49	,	69)
DTIME sec	120	(52	,	208)	32	(32	,	62)
DRATE %/sec	0.5	(0.2,		1)	1.8	(0.7,		2.2)
ARA at rest	103°	(92°	,	106°)	111°	(91°	,	116°)
ARA strain.	112°	(96°	,	106°)	120°	(104°	,	142°)
ARA evac.	126°	(120°	,	131°)	132°	(127°	,	156°)
PFD str. mm	-9	(-9	,	-5)	-6	(-14	,	4)
PFD evac mm	-33	(-46	,	-23)	-18	(-50	,	13)
IRP R. cmH$_2$O	5	(5	,	12)	8	(5	,	20)
IRP ST cmH$_2$O	30	(20	,	40)	15	(10	,	43)
IRP EV cmH$_2$O	38	(20	,	44)	25	(12	,	53)
EAS EMG R. μV	18	(10	,	22)	40	(10	,	100)
EAS EMG ST μV	40	(25	,	100)	30	(30	,	50)
EAS EMG EV μV	75	(40	,	100)	45	(30	,	100)

EVAC.%=percentage of the activity evacuated; DTIME= defaecation time in seconds; DRATE= defaecation rate in percentage per second; ARA=anorectal angles formed by the midline in the anal canal and by the parallel line to the posterior rectal wall illustrated at rest, on straining and evacuation; PFD= pelvic floor descent on straining and evacuation measured in millimetres, negative sign indicates a downward movement of the pelvic floor compared with its level at rest; IRP= intarectal pressure measured with the use of the radiotelemetering capsule at rest, on straining and evacuation; EAS EMG= the external anal sphincter EMG measured in microvolts with the use of a wire electrode, at rest, on straining and evacuation. The results are expressed as median (95% confidence intervals of the median).

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nil, as no increased EMG voltage was observed on straining compared with the resting one.

Isotope Proctography

The %EVAC was not any different in the two constipated groups studied ($p > 0.05$). The defaecation rate, however, was significantly lower ($p < 0.01$) and the defaecation time was more prolonged ($p < 0.03$) in the I (OD) group. In the Group I, the increment of the ARA on straining (ARA on straining - ARA at rest) was significantly smaller compared with the Group II ($p < 0.04$). The PF descent on straining and evacuation was greater in the Group I ($p < 0.01$) compared with the PF descent in Group II ($p > 0.05$). The IRP was significantly increased on straining in both the I and II groups ($p < 0.04$; $p < 0.0001$, respectively), whereas an increased IRP during evacuation was observed only in the OD group ($p < 0.0001$). The EAS EMG showed a significant increase on straining from the resting position ($p < 0.0002$) in the OD group; the increase in the voltage during evacuation compared with the resting voltage was greater in the OD group ($p < 0.01$).

8.4.5 Group I - Proctographic Parameters

The defaecation rate was inversely proportional to the maximum resting anal canal pressure ($p < 0.03$; Figure 8.5). A proportional increase in the ARA on straining was observed compared with the ARA at rest ($p < 0.001$), whereas the ARA increment during evacuation related to the initial measurement of the ARA at rest ($p < 0.02$). The ARA on straining correlated with the PF movement on straining ($p < 0.001$; Figure 8.6) and the

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n = 22
r = -0.5
p < 0.03

Defaecation Rate (% / sec)

Maximum Resting Anal Canal Pressure (cm H2O)
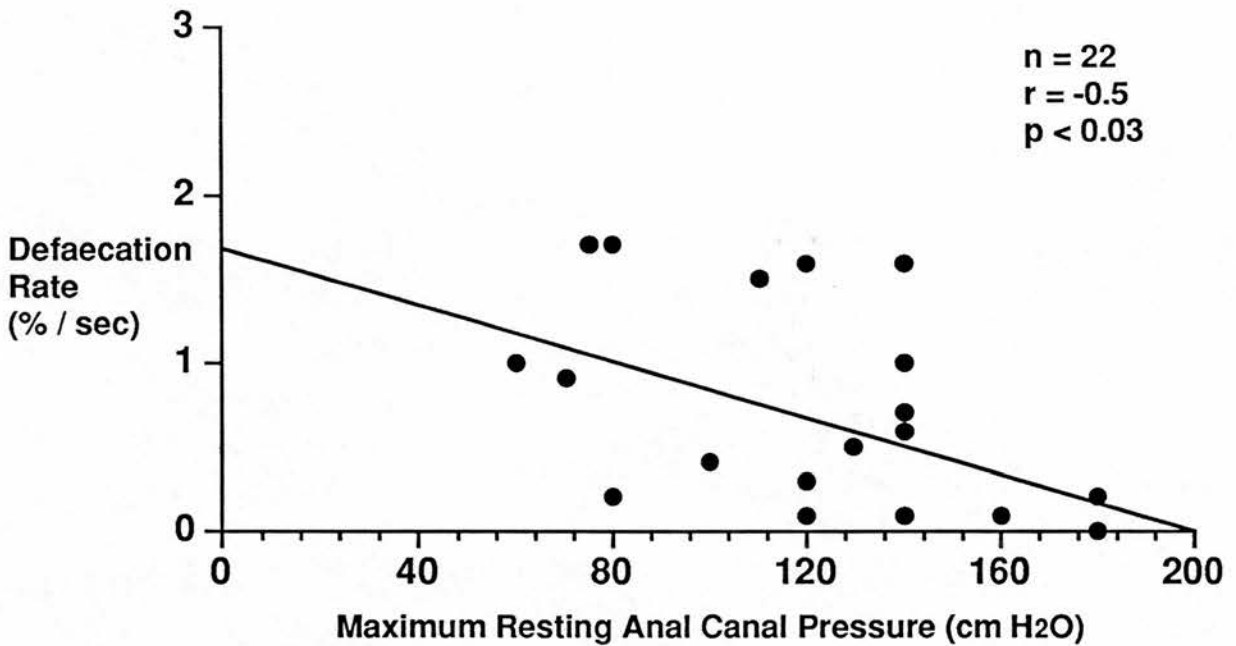
Figure 8.5 The relationship between the defaecation rate and the maximum anal canal resting pressure in the 22 constipated subjects with obstructive defaecation features. Patients with high intra-anal pressures achieved a low defaecation rate. This may be attributed to the fact that these patients do not relax the external anal sphincter during defaecation. Thus, as the internal anal sphincter relaxes due to rectal distention, higher anal canal pressures are maintained due to inappropriate external sphincter contraction, which, as shown, influences the rate of defaecation.(Spearmans correlation coefficient and its p value are illustrated).

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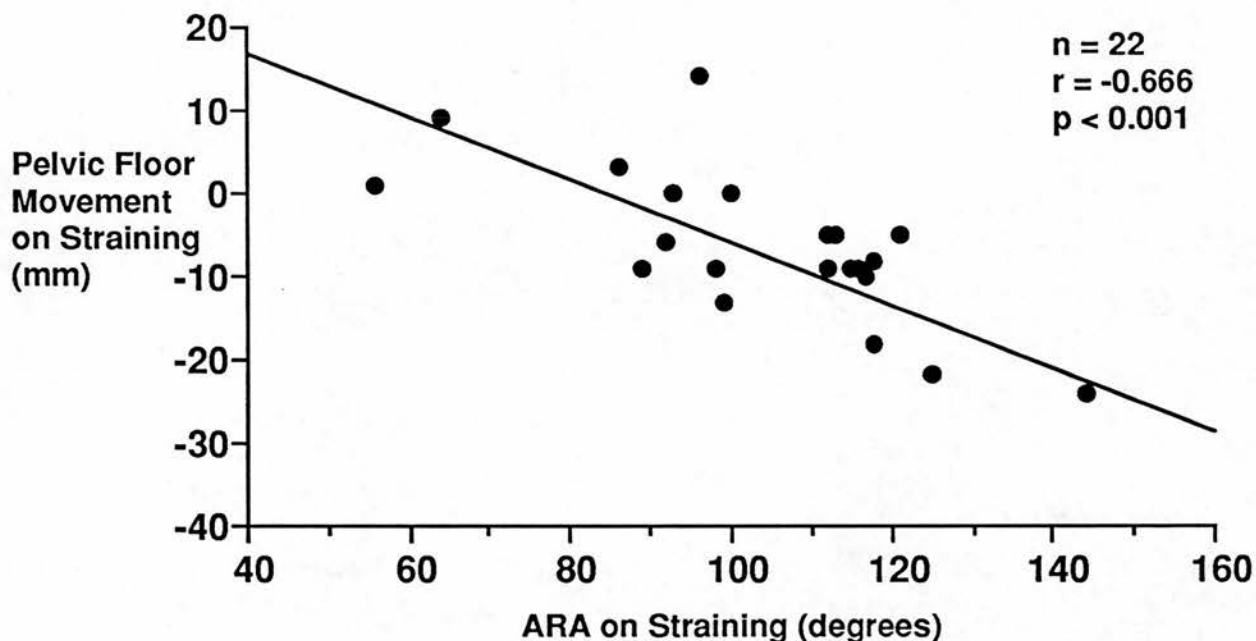
Figure 8.6 The relationship between the pelvic floor movement and the anorectal angle (ARA) on straining in the 22 constipated subjects with features of obstructive defaecation. Patients with an upward pelvic floor movement (compared with pelvic floor level at rest) presented with acute anorectal angles on straining. The patients with a greater pelvic floor descent achieved a more obtuse anorectal angle on straining. (Spearmans correlation coefficient and its p value are illustrated).

ARA achieved on evacuation correlated with the PF descent on evacuation ($p < 0.01$). The Anismus index was inversely proportional to the IRP during evacuation ($p < 0.02$; Figure 8.7).

8.4.5.1 PELVIC FLOOR DESCENT

In the Group I, three patients (14%) presented during isotope proctography with 'immobile perineum' (PF descent on evacuation less than 1 cm). In these patients the %EVAC was in a range of 8 to 47%; the defaecation rate was within 0.1 and 1.0 %/sec; the defaecation time was 48 to 160 sec; the ARA at rest was 62° to 98°; the ARA on straining 56° to 115°; the ARA on evacuation was 96° to 116°. Nine patients (41%) had an abnormal perineum descent (PF descent on evacuation greater than 4 cm). Thirteen patients (59%) had PF movement on evacuation greater than 1 cm and lesser than 4 cm. These two subgroups were significantly different not only in the PF descent on evacuation ($p < 0.0004$), but in the resting EAS EMG voltage ($p < 0.04$) and in the straining EAS EMG voltage ($p < 0.02$). These EAS EMG voltages at rest and on straining were greater in the 'abnormal perineal descent subgroup'. There was a greater increment in the ARA angle on evacuation in the 'abnormal perineal descent' subgroup compared with the subgroup with a 'normal pelvic floor descent' ($p < 0.01$). This greater ARA increment on evacuation correlated with the ARA at rest ($p < 0.01$; Figure 8.8). On the other hand, in the subgroup with a 'normal PF descent' the ARA on evacuation correlated with the PF descent on evacuation ($p < 0.03$; Figure 8.9). This PF descent correlated to the ARA at rest ($p < 0.001$; Figure 8.9).
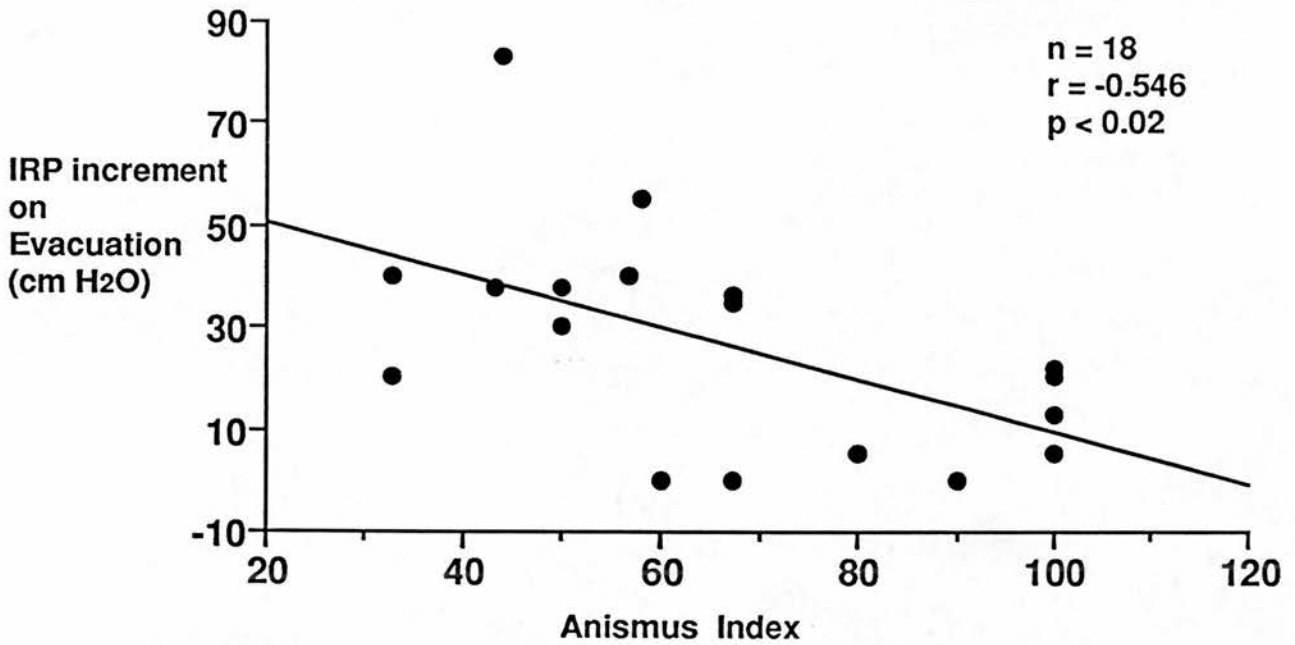
Figure 8.7 The relationship between the intrarectal pressure increment during evacuation and the anismus index in 18 constipated subjects with features of obstructive defaecation. Patients with high anismus index achieved only a minimal increment in the intrarectal pressures. This may be attributed to incoordinated abdominal and sphincter activity during defaecation. (Spearmans correlation coefficient and its p value are illustrated).

70
60
50
40
30
20
10

ARA
Increment
on
Evacuation
(degrees)

n = 9
r = -0.949
p < 0.02

60   70   80   90   100   110   120

Resting ARA (degrees)
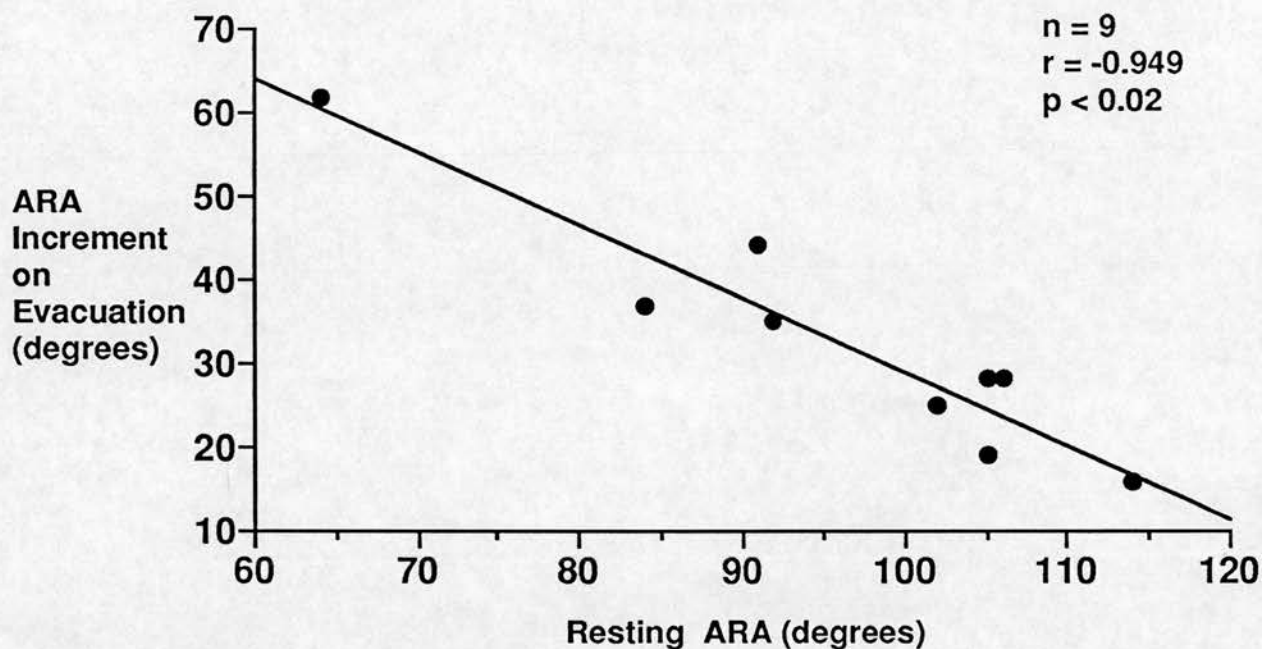
Figure 8.8   The relationship between the
increment of the anorectal angle   (ARA)   on
evacuation and the anorectal angle at rest in the
9 constipated subjects with features   of
obstructive defaecation and abnormal   perineum
descent. Patients, in this subgroup, with more
obtuse anorectal angle at rest achieved a minimal
increment in their angle during evacuation. This
may be attributed to the weakness of the pelvic
floor muscles. Patients with abnormal perineum
descent may show weakness in their pelvic floor
musculature   after longstanding straining   at
defaecation. (Spearmans correlation coefficient
and p value are illustrated).

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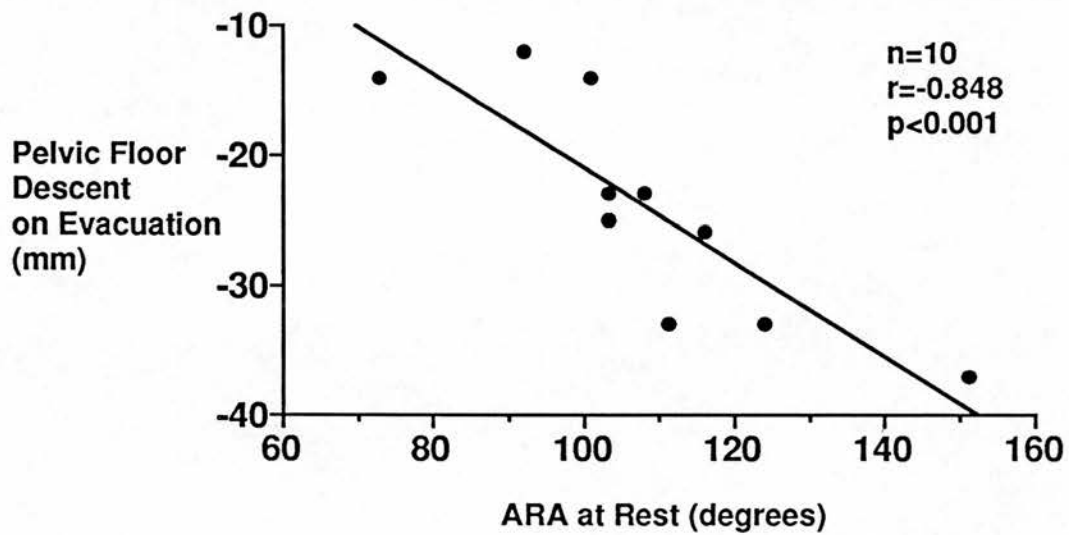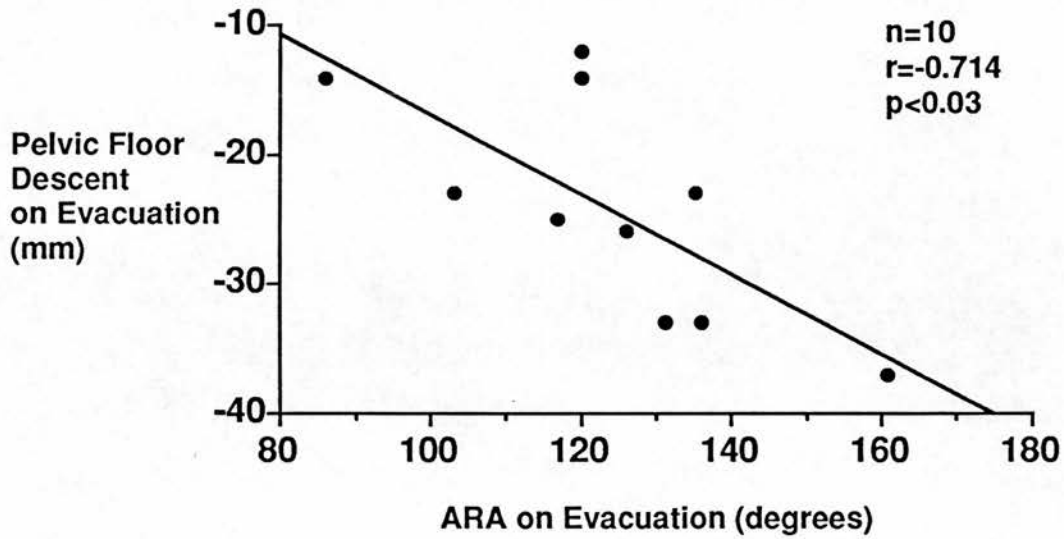
Figure 8.9 The relationship between the pelvic floor descent on evacuation and the anorectal angle (ARA) during evacuation (upper diagram) and at rest (lower diagram), in the 10 constipated subjects with features of obstructive defaecation and a 'normal' pelvic floor descent. Patients with more acute anorectal angles on evacuation achieved a minimal pelvic floor descent. These patients with a minimal pelvic floor descent on evacuation had more acute anorectal angles at rest. (Spearmans correlation coefficients and their p values are illustrated).

8.4.5.2 DEFAECATION ASSESSMENT

Seven patients in the OD group (32%) had a 'satisfactory' rectal emptying of 78% (95% CI: 73, 89%) on simulated defaecation. The remaining fifteen patients (68%) had an incomplete evacuation of 47% (95% CI: 11, 55%). This was a significant difference in the two subgroups ($p < 0.0002$). Similarly, the defaecation rate was lower in the patients with incomplete evacuation ($p < 0.02$). In the patients with a more satisfactory evacuation the %EVAC was inversely related to both rectal capacity ($p < 0.02$; Figure 8.10) and compliance ($p < 0.04$; Figure 8.10); the Anismus index inversely correlated to the ARA on evacuation ($p < 0.02$; Figure 8.11). The majority of the OD patients who had incomplete rectal emptying showed a correlation between their defaecation rate with the ARA increment on straining ($p < 0.05$); their Anismus index related to the ARA at rest (Figure 8.12; $p < 0.01$).

8.4.6 Group II - Proctographic Parameters

The %EVAC correlated with the straining ARA (Figure 8.13; $p < 0.03$). The ARA on straining correlated with the ARA at rest (Figure 8.13; $p < 0.01$). The defaecation rate was inversely related to the straining EAS EMG voltage (Figure 8.14; $p < 0.01$) and in an analogous way the EAS EMG voltage on straining correlated with the defaecation time ($p < 0.01$).
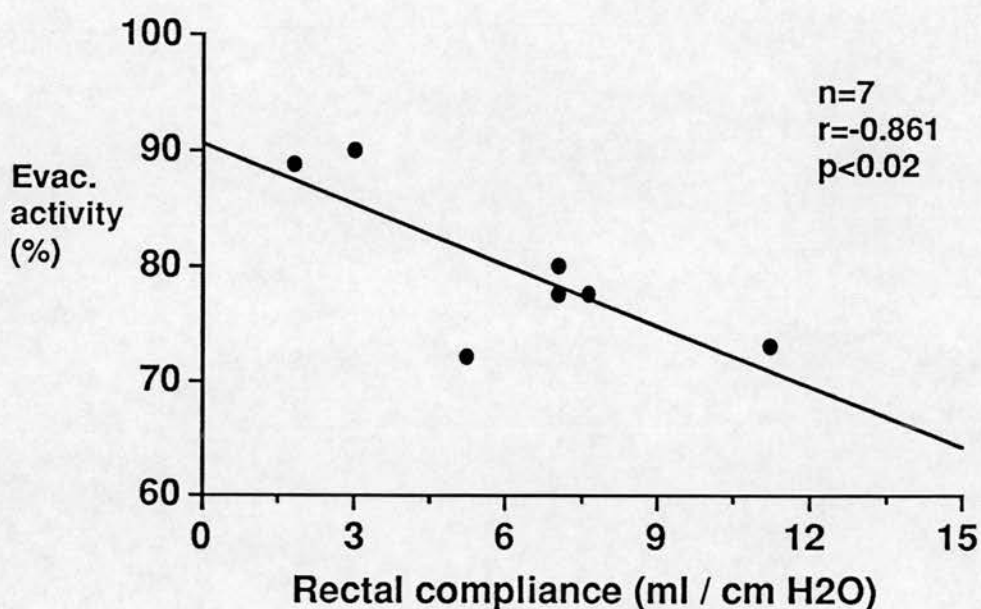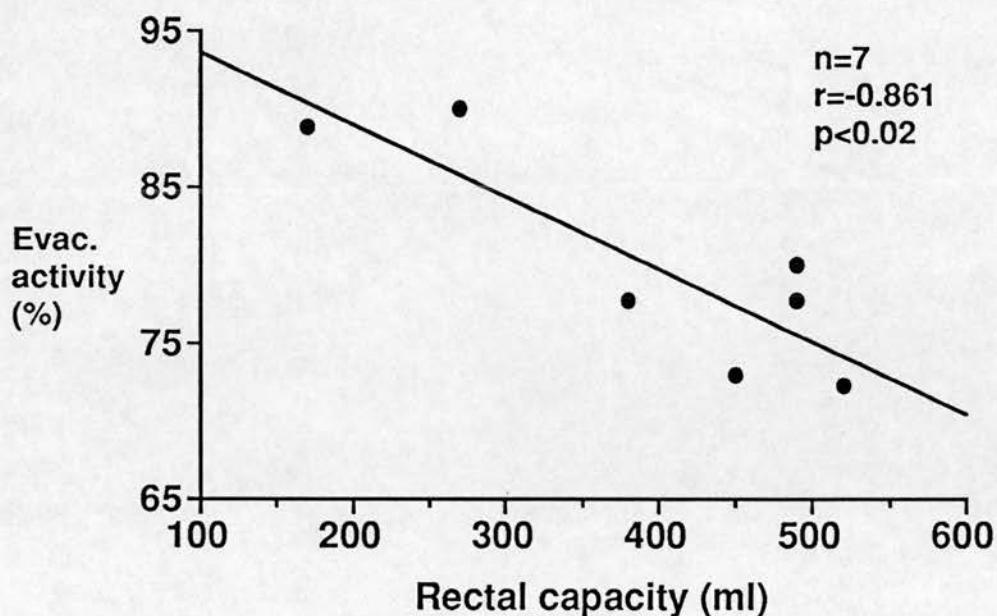
Figure 8.10 The relationship between the percentage
of the activity evacuated and the rectal capacity
(upper diagram) and compliance (lower diagram); in the
7 patients with features of obstructive defaecation who
achieved a more 'satisfactory' rectal emptying during
isotope proctography. Patients with reduced rectal
capacity and compliance achieved more adequate rectal
emptying. Thus, the so presented 'satisfactory'
evacuation may be artificial and attributed to the
reduced rectal capacity. (Spearmans correlation
coefficients and their p values are illustrated).
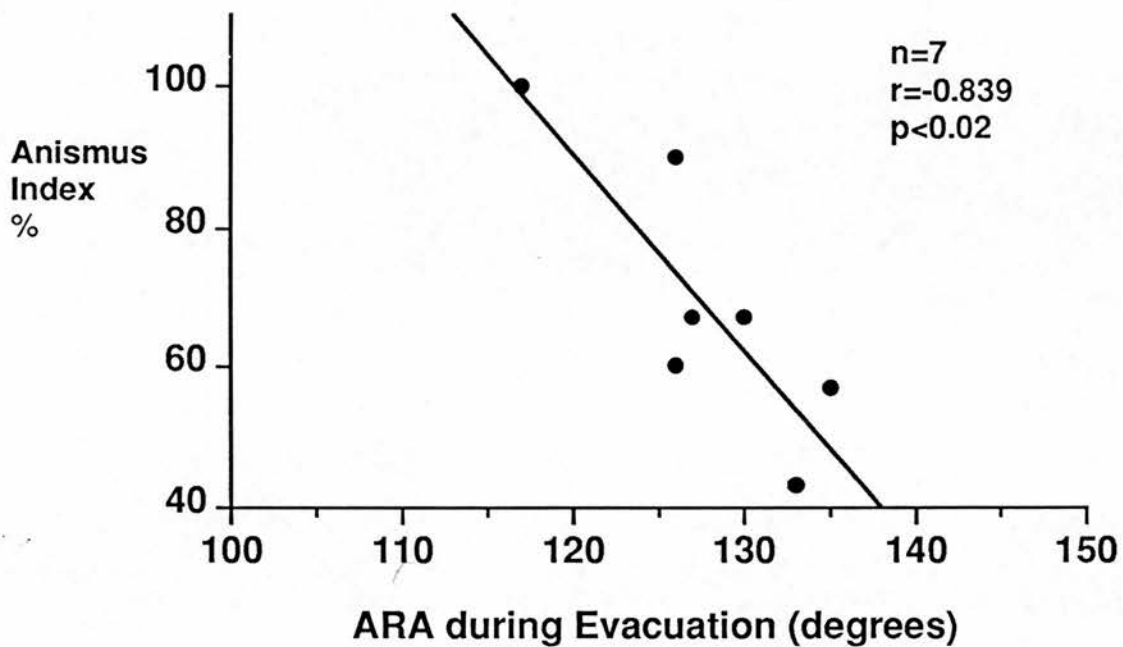
Figure 8.11 The relationship between the anismus index and the anorectal angle (ARA) during evacuation, in the 7 constipated subjects with features of obstructive defaecation and a 'satisfactory' rectal emptying. Patients with high anismus index achieved a less obtuse anorectal angle during evacuation. Thus, this subgroup is characterised by obstructive proctographic features despite the more satisfactory rectal emptying achieved. Figure 8.10 demonstrated the dependence of the rectal evacuation in this subgroup on the rectal capacity and compliance. (Spearmans correlation coefficient and p value are illustrated).
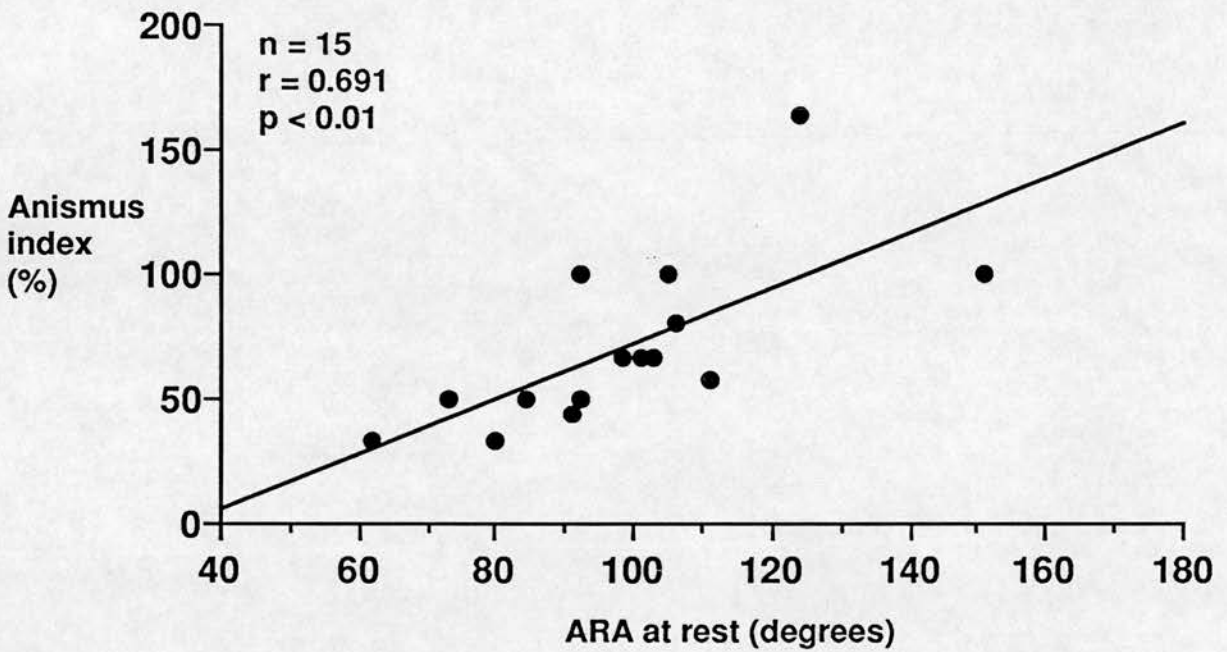
Figure 8.12 The relationship between the anismus index and the anorectal angle (ARA) at rest, in the 15 constipated subjects with obstructive defaecation features and incomplete rectal emptying. Patients with a high anismus index have more obtuse anorectal angles at rest. This may be attributed to the weakness of the pelvic floor musculature due to longstanding straining at defaecation. (Spearmans correlation coefficient and its p value are illustrated).

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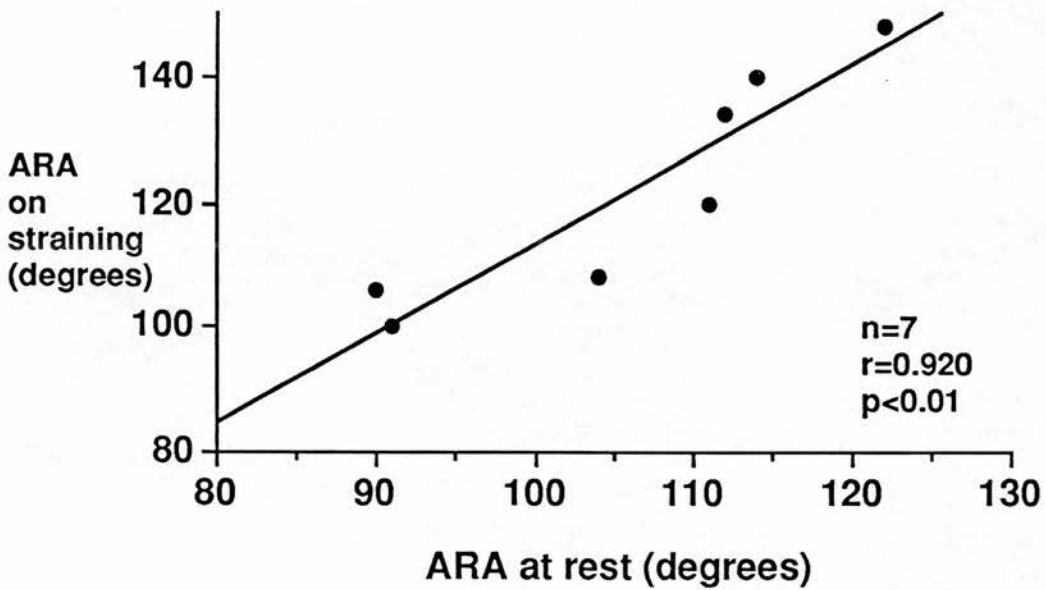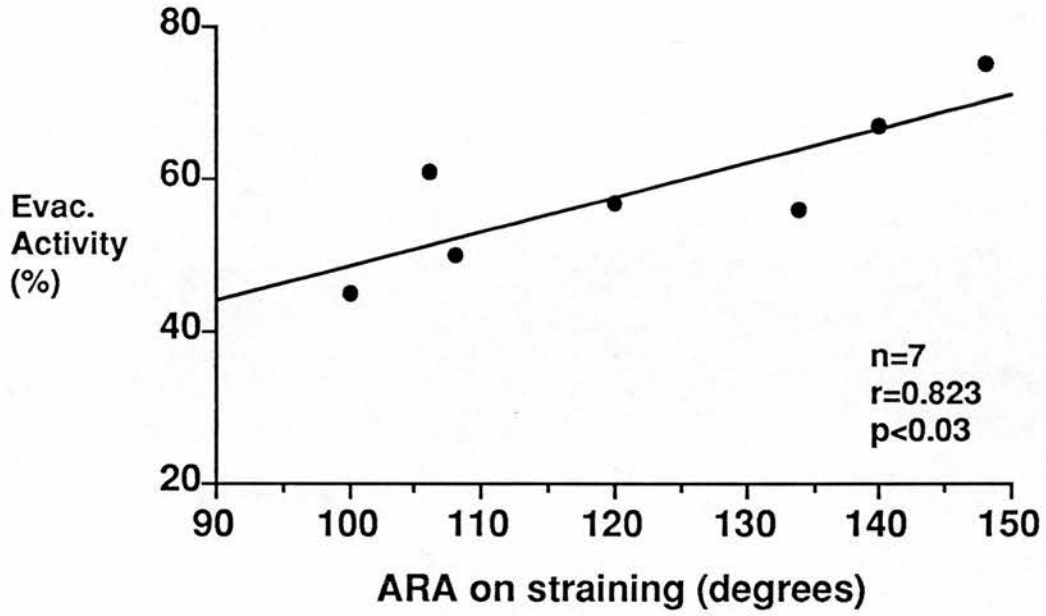
Figure 8.13 The relationship between the anorectal angle (ARA) on straining and the percentage of the activity evacuated (upper diagram) and the anorectal angle at rest (lower diagram); in the seven constipated subjects with no features of obstructive defaecation. Patients with more obtuse anorectal angle on straining achieved more satisfactory evacuation and this depended upon the anorectal angle status at rest. (Spearmans correlation coefficient and p value are illustrated).
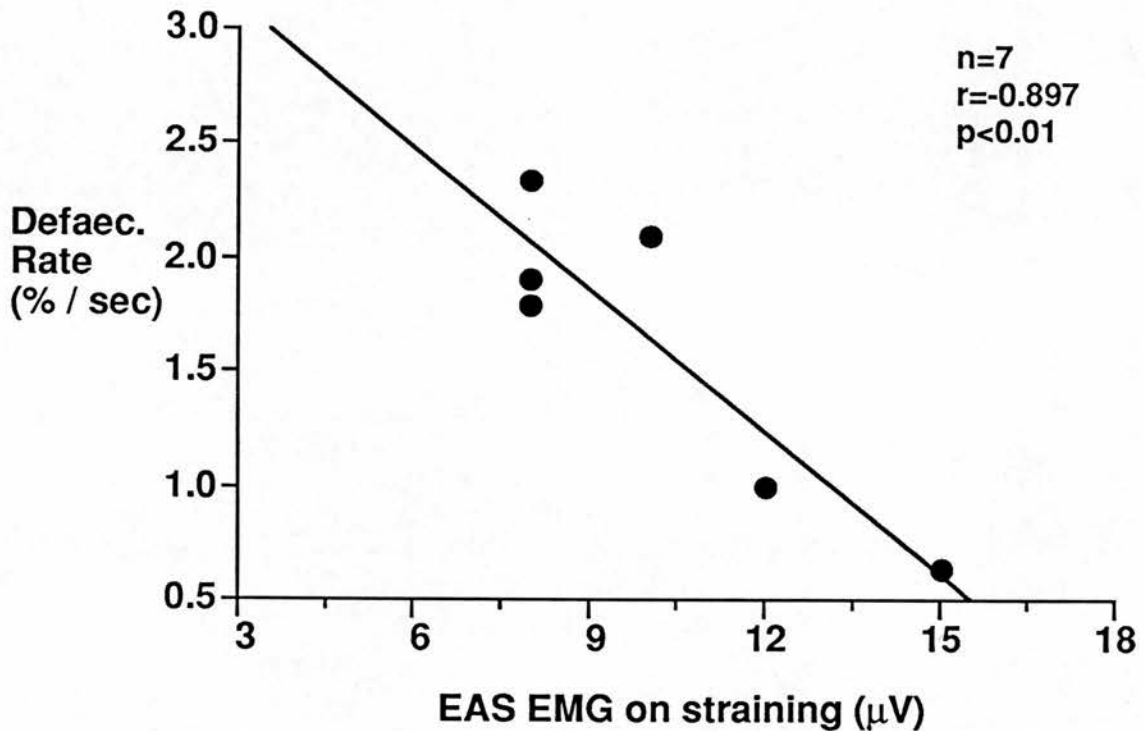
Figure 8.14 The relationship between the defaecation rate and the EMG voltage of the external anal sphincter (EAS) on straining, in the 7 constipated subjects with no features of obstructive defaecation. Patients with low external anal sphincter EMG voltage on straining achieved an enhanced defaecation rate. (Spearmans correlation coefficient and p value are illustrated).

The number of patients illustrated in this diagram is 7. The black dots are shown to be six because two patients presented with the same values. Thus, one of the black dots represents two patients in this instance.

8.5   DISCUSSION

The study described here, was performed in a group of patients with intractable constipation. The main group under examination was composed of patients in whom the primary abnormality was an inability to empty the rectum with accompanying obstructive symptoms such as chronic straining at stool, a feeling of occlusion on defaecation and commonly the necessity for self digitation. All were unable to expel a rectal balloon, just as most of them had difficulty in expelling a soft formed stool. This simple observation may explain why this severe type of constipation presents as such an intractable problem. Why do these patients have difficulty in emptying the rectum? All had normal recto-sphincteric inhibitory reflexes, showing that the smooth muscle of the internal anal sphincter relaxes on rectal distention. Therefore, it appears that the difficulty in evacuating does not originate in the internal anal sphincter.

Pelvic floor electromyography and proctography demonstrated in all these patients a persistent increased pelvic floor activity indicative to a contraction that may cause functional colonic outlet obstruction. It may be easy to understand how a patient who is asked to evacuate unwillingly in the presence of his or her investigators may feel uncomfortable, during such tests and may contract the pelvic floor, thus mimicking the obstructive defaecation syndrome. Furthermore, the precise pattern of pelvic floor function during straining in normals is not known exactly.

The normal group (Group III), however, did not show any increased activity of the pelvic floor muscles on straining and all the controls were able to expel the rectal balloon. The conclusion derived from this evidence was

that the increased activity of the pelvic floor muscles on attempted defaecation is a non-physiological event. To lessen the patients upset at evacuating in the presence of other people, a small separate room in the Department of Nuclear Medicine was kept for proctography alone and the investigations done were kept to the minimum (additional tests during proctography were only an insertion of a wire electrode into the EAS to record its activity and intrarectally of a telemetering capsule for the simultaneous recording of intrarectal pressures), so as to avoid the feeling of tension and stress from the patients point of view, and allow more 'relaxation'. Thus, the necessary tests during proctography were thought to be the EAS EMG and the measurement of intrarectal pressure. The activity of the puborectalis muscle, which may play an important role in the mechanism of obstructive defaecation, was observed through the resultant changes in the ARA (see Chapter 7).

Is the defaecation reflex disturbed in the constipated OD patients and if it is, at what level? Assuming the defaecatory action to be a reflex of an acquired controlled sort, the three parts requiring assessment in this disorder, are the rectal sensation, the local motor neurones and their control by higher centres and the striated muscles of the pelvic floor. The tonic contraction, of the EAS, ensuring continence, is maintained by spinal reflexes, further controlled by supraspinal centres which increase tone to maintain continence and inhibit tone, thus to allow defaecation. An area in the pons has control over distal colonic, and anorectal motility (Weber et al, 1985). Achievement of socially acceptable continence is a learned phenomenon which varies from about 2 years of age (Fritz and Ambrust, 1982).

The patients investigated did not have any evidence of neurological disease or deficit, and any other organic causes of constipation were excluded

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prior to the study. Therefore, two parts of the reflex needed further investigation: the rectal sensation and the coordination of the striated muscles of the pelvic floor. All of the patients experienced the urge to defaecate as the proctometrogram balloon was distended in the rectum, thus lack of rectal sensation did not appear to be the factor in the failure of defaecation. Is however, impairment of rectal sensation important in the process of defaecation? Patients with impairment of sensation may find it difficult to proceed to defaecation, resulting in infrequent evacuation. It was shown that the sensation in the OD constipated patients was significantly impaired ($p<0.01$) in comparison to the normal controls. This was not so in Group II, thus the impairment in rectal sensation was explicit to the OD group. Furthermore, the delayed pudendal nerve conduction in the OD group which is associated with lower SQP may well be the result of the inappropriate straining on defaecation. No difference in the pudendal nerve conduction was observed in Group II.

Although the %EVAC was not significantly different in the two constipated groups, the OD group had significantly longer defaecation time associated with a lower defaecation rate. The ARA changes were significant in that the attempted straining failed to achieve an adequate opening out of the ARA in the OD group. There was a significant PF descent on straining and evacuation with a number of patients having abnormal perineum descent, in the OD group.

The IRP are important in initiating the evacuating process. There was an increase in the IRP on straining in the two, I and II, Groups. However, this persisted on evacuation only in the OD group, most likely because of their unsuccessful straining attempt and as an expression of their 'wish to defaecate'. On the other hand, the greater IRP on evacuation may imply the

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patient's response to the increased EAS EMG that was observed in the OD group compared with the second group. Therefore, higher IRP may be needed to overcome the 'anal barrier' and proceed to defaecation. Moreover, the defaecation rate was inversely proportional to the anal canal resting pressure. However, the Anismus index, an index of the severity of the 'outlet obstruction' problem (Kawimbe et al, 1988), was inversely proportional to the IRP during evacuation. This may be contradicting the just above mentioned theory and enlightens another aspect; that is OD patients may not increase the IRP sufficiently in order to achieve evacuation. Thus, relatively low IRP can be part of the problem. Similar observations were reported by other investigators who described a number of OD patients unable to increase the IRP on attempted defaecation (Roberts et al, 1991).

The OD group was in other respects a heterogenious group. Some patients had abnormal perineal descent on evacuation, some had a 'normal descent' and some were unable to move the pelvic floor on defaecation. This may be the result of the chronicity of the problem. A theory about it, is that patients in an early stage may be unable to move the PF on defaecation and present with an 'immobile perineum'. At a later stage, with prolonged chronic straining, pudendal neuropathy develops leading to relative weakness of the PF muscles and ultimately to abnormal perineal descent. Correlations of the ARAs and PF descent both on straining and evacuation show the relation between the two: the lesser the PF descent the less obtuse the ARA. This explains the achieving of a greater ARA on evacuation in the abnormal perineum descent subgroup.

In an attempt to study the proctographic features of the OD phenomenon, the dynamic isotope proctography test was employed. This test, as has been mentioned in Chapter 7, adds the measurement of the

%EVAC, the defaecation time and rate. Seven patients performed a 'satisfactory' rectal evacuation. In these patients however, the %EVAC was inversely related to the maximum rectal capacity. Therefore, their ability to evacuate depended on their bowel capacity; the higher the %EVAC the lower the rectal capacity. The Anismus index in this subgroup correlated inversely to the ARA on evacuation; the higher the Anismus index the more 'acute'[1] the ARA. Thus, the EMG obstructive features were associated with the proctographic ones, despite the evacuation achieved which depended on the patient's rectal capacity.

Fifteen patients, the majority in the OD group, had incomplete evacuation. The defaecation rate in this subgroup, correlated to the change in the ARA on straining; the less the increase in the ARA on straining the 'poorer' the evacuation achieved. The Anismus index related to the ARA at rest. This may be a consequence of the OD problem rather than the cause. Continuing the former theme - where a later stage of development in OD was characterised by abnormal perineum descent, associated with a more obtuse ARA at rest - the relation of the Anismus index to the ARA at rest dependent upon the chronicity of the problem. Thus, the consideration of the OD problem is made more complex by some factors being exposed as resultants rather than causal ones.

A number of patients with intractable constipation, Group II, with no clinical or electrophysiological evidence of outlet obstruction were recruited to the study to allow comparisons of the proctographic features with those from patients with OD features. No isotope proctographic test was

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1.'acute' angle is used to suggest 'a less obtuse angle' and not an acute angle in the absolute meaning, less than 90°

performed in the normal volunteers, Group III, to avoid radiation exposure to normal controls. In the Group II with no evidence of OD features, the %EVAC was related to the ARA on straining. Thus a more obtuse straining ARA may allow a better evacuation. The defaecation time, which was significantly shorter in this group compared with the OD, correlated with the straining EMG voltage; a lower EMG voltage of the EAS on straining may ensure a shorter evacuation time. The defaecation rate, on similar grounds, was inversely related to the straining EMG voltage, which supports the argument of 'the lower the straining activity of the EAS the more efficient evacuation may be achieved'.

The OD syndrome is a complicated multifactorial syndrome involving rectal sensation, incoordinated function of the pelvic floor and abdominal musculature. Other relevant points to consider are the duration of the process predisposing to impairment of the pelvic floor muscles and therefore of their function. A long standing problem, may induce pelvic floor muscle weakness and then a vicious circle may be created. The parameters derived from the isotope proctography, such as %EVAC and defaecation time and rate, provided worthwhile characteristics of the OD problem and showed correlations with the ARA, the EMG voltage of the pelvic floor muscles on straining and rectal capacity. The Anismus index (Chapter 2) can be a reliable means in evaluating facets of OD state and has shown correlations between the intrarectal pressures, the PF descent and the ARAs both at rest and evacuation. It is easily derived, using the anal plug electrode (Chapter 2), which can be used routinely without causing any discomfort, and may help to evaluate the constipated patients with or without symptoms of Obstructive Defaecation.

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CHAPTER 9

EMG BIOFEEDBACK
IN
OBSTRUCTIVE DEFAECATION

9.1   SUMMARY

Twenty-two patients with symptoms of obstructive defaecation were recruited for relaxation training by domiciliary self-regulatory biofeedback. Each patient served as his or her own control for anorectal and proctographic assessments.

Biofeedback training improved the obstructive symptoms of the patients and showed significant change in various parameters related to the obstructive defaecation syndrome. The defaecation rate (% of evacuation / defaecation time) was significantly increased ($p < 0.05$), the anorectal angles (ARAs) at rest and during attempted defaecation were made more obtuse ($p < 0.05$) and the pelvic floor (PF) movements were made more dynamic on voluntary contraction of the anal sphincter ($p < 0.03$), as examined by isotope dynamic proctography. The external anal sphincter (EAS) wire EMG voltage recorded during defaecation was significantly reduced ($p < 0.0005$) as was the surface anal plug EMG electrode voltage ($p < 0.0001$) which was associated with a greatly reduced anismus index ($p < 0.0001$). The rectal sensation was improved ($p < 0.05$), concomitantly.

Biofeedback thus improves the defaecation act in patients suffering from inappropriate contraction of the pelvic floor and sphincter musculature, and it appears from studies such as this, that the defaecation reflex can be influenced by self-regulatory means leading to an improved quality of higher control.

9.2 INTRODUCTION

Experience with biofeedback and other learning procedures in the management of a variety of medical problems encourages the application of these methods to the digestive tract. Learning sessions with biofeedback were reported to have achieved a method of treatment in faecal incontinence (Cerulli et al, 1979) and in particular in patients with meningomyelocele (Wald, 1981). For more than a decade now, investigators, clinicians and researchers, have been attempting to answer questions such as 'could patients with a degree of denervation possibly respond to this instrumental learning procedure?' Van Baal and colleagues (1984) reported successful treatment of a disturbed defaecation reflex caused by viral encephalopolyradiculoneuritis with a form of relaxation biofeedback conditioning. It would therefore, appear that by substituting missing afferent stimuli, the effector side of the defaecation reflex could be reestablished.

In analogous way, the blind were enabled to 'see' through patterned electronic stimulation of the occipital cortex driven by a miniature television system (Almy and Corson, 1979). This has become possible with the advances in electronics and bioengineering. The applicability of instrumental learning to the relief of gastrointestinal disorders is now almost unquestionable. It has been used successfully to achieve strengthening of the contractions of the lower oesophageal sphincter in patients with reflux oesophagitis, through instrumental learning which was promoted by displaying lower oesophageal sphincter pressure and similarly has been used in patients with faecal incontinence, aiming at strengthening the contraction of the anal sphincters (Engel et al, 1974; Cerulli et al, 1979; Constantinides et al, 1983; Schuster, 1985; Coremans and Vantrappen, 1987).

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The studies of the psychological as well as physiological characteristics of patients with severe idiopathic constipation (Wald et al, 1989) encouraged the debut of the biofeedback self-regulation technique in constipation. The relief of functional constipation, or dyschezia, has become an obvious goal. This has been thought of as a logical extension of the above, as it would easily meet the necessary requirements. For example, the objective would be to relearn a specific motor response to distinct and familiar sensory signals. For that, access to the effector system is thought to be necessary. This is not a problem for the disorders of the anorectum, as the effector system may be monitored easily, either by anal sphincter pressure measurement or electromyographic recording of the anal sphincter voltage.

Bleijenberg and Kuijpers (1987) have described a method of treatment of the spastic pelvic floor syndrome with biofeedback, after hospitalisation of the subjects for a period of 2 weeks. This treatment though successful has caused concern to doctors and patients for the relatively long stay in hospital. The opportunity arose to advance this method in the treatment of the spastic pelvic floor syndrome, through the development of a small portable device suitable for domiciliary treatment. This 'biofeedback device' (Myotron 120) equipped with an anal plug electrode allowed display of the EMG voltage of the anal sphincters without any discomfort. After a short period of training of the patients as outpatients they were able to take the device at home for a course of 'self-treatment' (see Chapter 2). A pilot study conducted in the Anorectal physiology laboratory in the Western General Hospital, proved the method to be clinically successful (Kawimbe et al, 1991).

This study investigates constipated patients with obstructive features before and after biofeedback treatment. It examines aspects of the

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defaecation reflex in disturbed defaecation using anorectal manometry, electrophysiology and proctography. The study also aims at an exploration of the mechanisms of the biofeedback influences in the neural control of defaecation.

9.3 MATERIALS AND METHODS

9.3.1 Subjects

Twenty-two patients were recruited, median age 42 years (95% CI: 32, 50 years). Seventeen of them were females (77%) and five were males (23%). Seven of the females were nulliparous (41%) and six were multiparous (with 3 children or more). Ethical permission for this work was obtained from the Ethical Committee of the Lothian Health Board, Edinburgh. Informed consent was also obtained from all patients.

Patients suffered from constipation for 3 to 25 years and complained of prolonged straining at stool. The frequency of defaecation varied from thrice per day to once a week, but with sixteen patients complaining of incomplete emptying of the bowels (73%). Fifteen patients complained of perineal pain and discomfort on defaecation (68%), fourteen complained of abdominal pain and distention (64%), nine patients were unable to evacuate without the use of laxatives and/or enemas (41%), seven had a feeling of obstruction on defaecation (32%) and two of them were unable to initiate defaecation without digital evacuation.

9.3.2 Methods

9.3.2.1 Anorectal Manometry And Electrophysiology

Anorectal manometry allowed measurements of the functional anal canal length, the maximum resting pressure (MRP) and the anal canal pressure increment on voluntary (SQP) and cough reflex (CP) anal sphincter contraction. The recto-sphincteric inhibitory reflex was performed in all patients to exclude aganglionosis as the cause of constipation. Proctometrograms were performed eliciting the volumes of the rectal sensory threshold (SEN), the maximum tolerable rectal capacity (CAP) and the rectal compliance (COM). Electrophysiological tests included the latency of the pudendo-anal reflex (PARL) and integrated electromyography of the external anal sphincter (EAS) via a surface EMG anal plug electrode. The Anismus index (AI) was derived as the relation of the EMG voltage of the EAS on straining to the EMG voltage of the EAS at rest in the formula:

$$AI = \frac{\text{EMG voltage on straining - EMG voltage at rest}}{\text{EMG voltage on 'squeezing' - EMG voltage at rest}} \times 100$$

The above tests are described in detail in Chapter 2.

9.3.2.2 Isotope Proctography

Isotope dynamic proctography combined with simultaneous recordings of EAS EMG, with the use of wire electrodes, and intrarectal telemetry (IRP) were performed in all patients as described in earlier

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chapters (see Chapter 8). The parameters recorded were the percentage of the activity evacuated (%EVAC), the defaecation time (seconds) and the defaecation rate (%EVAC/second); anorectal angle (ARA) at rest, on maximal anal sphincter contraction during voluntary 'squeezing', on straining and during evacuation; and the pelvic floor (PF) movements on voluntary contraction of the anal sphincter, on straining and during evacuation.

9.3.2.3 Rectal Balloon Expulsion Test

Prior to isotope proctography rectal balloon expulsion tests were performed in all patients. The proctometrogram balloon was inserted in the rectum and filled with saline upto a level of sensory awareness (approximately 140 mls). The patient was then asked to evacuate this balloon. An unaided expulsion of the rectal balloon would almost exclude at this stage any obstructive phenomena.

9.3.2.4 Biofeedback Training

The patients after a preliminary evaluation of their symptoms and results of the investigations, having consulted the referring consultant were recruited to the biofeedback study. This involved the attendance of the patient to the hospital on an outpatient basis on at least three occasions. During these visits theoretical and practical instructions were given of how to operate the biofeedback Myotron device (see Chapter 2). This was combined with rectal balloon expulsion exercises that aimed in improving rectal sensory awareness and stimulating anal sensation of the inappropriate contraction of the pelvic floor muscles obstructing the expulsion of the filled balloon. When the patient and investigator were satisfied about the competence of the patient in performing the rectal balloon expulsion

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exercises and the ability to operate the Myotron device, the patient was given the device for a domiciliary course of minimum 4 weeks duration. In the end of this period the patient had the anorectal and proctography tests repeated as above.

9.3.3 Statistical Analysis

The statistical analysis of the results used the median values and their 95% confidence intervals (CI) and the non-parametric sign test for paired comparison of observations.

9.4 RESULTS

9.4.1 Pre-biofeedback Assessment

9.4.1.1 Anorectal Manometry And Electrophysiology

Anorectal manometry revealed: the MRP was 120 cm H_2O (95% CI: 110, 140 cm H_2O), the SQP was 80 cm H_2O (95% CI: 50, 130 cm H_2O). The recto-sphincteric reflex was present in all patients, virtually excluding the diagnosis of aganglionosis as a cause of constipation. Proctometrogram studies showed that the volume of the rectal sensory threshold was 138 ml (95% CI: 110, 180 ml), the maximum tolerable rectal capacity was 425 ml (95% CI: 310, 496 ml) and the rectal compliance was 6.4 ml/cm H_2O (95% CI: 4.2, 7.3 ml/cm H_2O).

Electrophysiological tests showed that the pudendo-anal reflex latency was 48 ms (95% CI: 42, 52 ms) and the integrated EMG showed that

the EMG voltage of the EAS elicited via the surface anal plug EMG electrode at rest was 10 μV (95% CI: 10, 20 μV), the EMG voltage of the EAS on straining was 35 μV (95% CI: 20, 50 μV) and revealed an AI of 67% (95% CI: 50, 80%).

9.4.1.2 Isotope Proctography

Isotope dynamic proctography showed: the %EVAC was 56% (95% CI: 46, 72%), the defaecation time was 112 seconds (95% CI: 52, 167) and the defaecation rate was 0.5 %/sec (95% CI: 0.2, 1.0 %/sec). The ARA at rest was 103° (95% CI: 92°, 106°), the ARA on 'squeezing' was 79° (95% CI: 77°, 93°), the ARA on straining was 112° (95% CI: 96°, 117°) and during evacuation was 127° (95% CI: 120°, 133°). The PF descent on straining was -9 mm (95% CI: 0, -4 mm) and on evacuation was -37 mm (95% CI: -47, -23 mm). The IRP was 5 cm H_2O at rest (95% CI: 5, 10 cm H_2O), on straining 30 cm H_2O (95% CI: 20, 40 cm H_2O) and on evacuation 35 cm H_2O (95% CI: 15, 53 cm H_2O). The EMG of the EAS performed simultaneously with wire electrodes showed that the EMG voltage at rest was 20 μV (95% CI: 10, 40μV), on squeezing 100 μV (95% CI: 56, 100 μV), on straining 50 μV (95% CI: 25, 100 μV) and on evacuation 100 μV (95% CI: 53, 100 μV).

9.4.1.3 Rectal Balloon Expulsion Test

All the patients were unable to expell the rectal balloon unaided in the first instance, but achieved successful expulsions in the end of the hospital training program prior to the biofeedback.

9.4.2 Post-biofeedback Assessment

9.4.2.1 Anorectal Manometry And Electrophysiology

Anorectal manometry revealed that the MRP was 120 cm H_2O (95% CI: 92, 128 cm H_2O), the SQP was 90 cm H_2O (95% CI: 72, 108 cm H_2O) and the CP 70 cm H_2O (95% CI: 60, 88 cm H_2O). The volume of rectal sensory threshold was 100 ml (95% CI: 90, 170 ml), the maximum tolerable rectal capacity 415 ml (95% CI: 355, 481 ml) and the rectal compliance was 6.0 ml/cm H_2O (95% CI: 5.0, 8.0 ml/cm H_2O).

Electrophysiological tests revealed the pudendo-anal reflex latency as 40 ms (95% CI: 37, 48 ms) and the integrated EMG elicited via the surface anal plug EMG electrode, the EMG voltage at rest 10 μV (95% CI: 7, 15 μV) , on straining 10 μV (95% CI: 7, 13 μV), revealing an AI of 0% (95% CI: -2, 0 %).

9.4.2.2 Isotope Proctography

The isotope dynamic proctography showed that the %EVAC was 61% (95% CI: 42, 71%), the defaecation time was 64 seconds (95% CI: 40, 117 sec) and the defaecation rate was 0.8 %/sec (95% CI: 0.5, 1.5 %/sec). The ARA at rest was 110° (95% CI: 104°, 114°), on 'squeezing' was 88° (95% CI: 79°, 92°), on straining was 119° (95% CI: 108°, 131°) and on evacuation was 137° (95% CI: 129°, 139°). The PF descent on straining was -6 mm (95% CI: -13, -3 mm) and on evacuation was -32 mm (95 % CI: -43, -27 mm). The IRP at rest was 10 cm H_2O (95% CI: 5, 20 cm H_2O), on straining was 20 cm H_2O (95% CI: 10, 40 cm H_2O) and on evacuation was 40 cm H_2O (95% CI: 15, 60 cm H_2O). The integrated EMG performed during proctography showed that the resting EMG voltage was 23 μV (95% CI: 10, 42 μV), on

'squeezing' 100 μV (95% CI: 60, 100 μV), on straining 25 μV (95% CI: 10, 43 μV) and on evacuation 15 μV (95% CI: 7, 43 μV).

Analysis of the results obtained from the tests performed before and after the treatment with self-regulatory biofeedback training is given in Table 9.1.

9.4.3 Pre-biofeedback VS Post-biofeedback

9.4.3.1 Anorectal Manometry And Electrophysiology

The anorectal manometry revealed no significant change in the intra-anal canal pressures, MRP or SQP. The proctometrogram however, showed that the volume of the rectal sensory threshold was reduced ($p < 0.05$; Figure 9.1) after the biofeedback, with no noticeable change in the rectal capacity and compliance. Furthermore, the integrated EMG recorded via the surface anal plug EMG electrode showed a significant reduction in the EMG voltage of the EAS on straining ($p < 0.0001$), with the EMG voltage at rest remaining virtually the same. Thus, the AI was greatly reduced ($p < 0.0001$; Figure 9.2) after the biofeedback treatment.

9.4.3.2 Isotope Proctography

The defaecation rate, as the relation of the %EVAC to the defaecation time, was significantly increased after the biofeedback ($p < 0.05$; Figure 9.3). The ARAs at rest, on straining and during evacuation became more obtuse ($p < 0.05$; Figure 9.4) after the biofeedback.

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Table 9.1 The effect of biofeedback on :
anal canal pressures at rest and on maximal contraction
of the anal sphincter during voluntary 'squeeze';
rectal sensory threshold, rectal capacity and
compliance; anismus index, pudendo-anal reflex latency,
and external anal sphincter EMG at rest, on straining
and during evacuation; anorectal angles at rest, on
straining and during evacuation; pelvic floor descent
on straining and during evacuation; percentage of the
activity evacuated, defaecation time and rate;
intrarectal pressures at rest, on straining and during
evacuation.

	PRE-BIOFEEDBACK	POST-BIOFEEDBACK

Anorectal Manometry

MRP cm H2O	120	(110	,140	)	120	(92	,128	)
SQP cm H2O	80	(50	,130	)	90	(72	,108	)
SEN ml	138	(110	,180	)	100	(90	,170	)
CAP ml	425	(310	,496	)	415	(355	,481	)
COM ml/cmH2O	6.4(	4.2,	7.3)		6.0(	5.0,	8.0)	

Electrophysiology

AI %	67	(50	, 80	)	0	(-2	, 0	)
PARL ms	48	(42	, 52	)	40	(37	, 48	)
EAS EMG rest μV	20	(10	, 40	)	23	(10	, 42	)
EAS EMG str. μV	50	(25	,100	)	25	(10	, 43	)
EAS EMG evac.μV	100	(53	,100	)	15	(7	, 43	)

Isotope Proctography

EVAC %	56	(46	, 72	)	61	(42	, 71	)
DTIME sec	112	(52	,167	)	64	(40	,117	)
DRATE %/sec	0.5(	0.2,	1.0)		0.8(	0.5,	1.5)	
ARA rest	103°	(92°	,106°	)	110°	(104°	,114°	)
ARA strain.	112°	(96°	,117°	)	119°	(108°	,131°	)
ARA evac.	127°	(20°	,133°	)	137°	(129°	,139°	)
PFD strain.	-9	(0	, -4	)	-6	(-13	, -3	)
PFD evac.	-37	(-47	,-23	)	-32	(-43	,-27	)

Radiotelemetry

IRP rest	5	(5	, 10	)	10	(5	, 20	)
IRP strain.	30	(20	, 40	)	20	(10	, 40	)
IRP evac.	35	(15	, 53	)	40	(15	, 60	)

MRP= maximum anal canal resting pressure; SQP= anal canal pressure increment on voluntary
contraction of the anal sphincter; SEN= rectal sensory threshold; CAP= rectal capacity;
COM= rectal compliance; PARL= pudendo-anal reflex latency; EAS EMG = external anal
sphincter EMG recorded at rest, on straining and evacuation; AI= anismus index; EVAC %=
percentage of the activity evacuated; DTIME= defaecation time; DRATE= defaecation rate;
ARA= anorectal angles recorded at rest, on straining and evacuation; PFD; pelvic floor
descent on straining and evacuation; IRP= intrarectal pressure recorded at rest, on
straining and evacuation. (The results are expressed: median (95% confidence intervals).
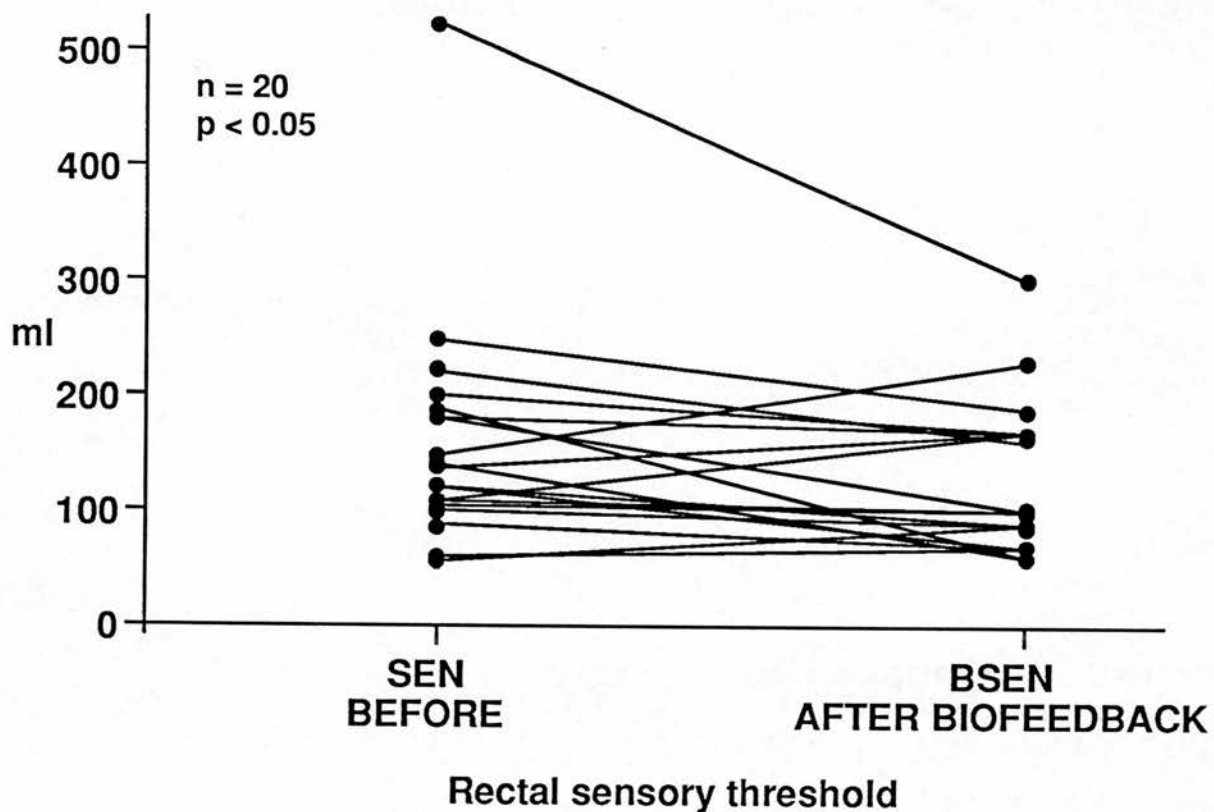
Figure 9.1 Rectal sensory threshold (in millilitres) recorded in 20 patients during anorectal manometry, before (SEN) and after (BSEN) treatment with EMG biofeedback. (The results were compared with the use of the sign test for paired samples, p value is illustrated).
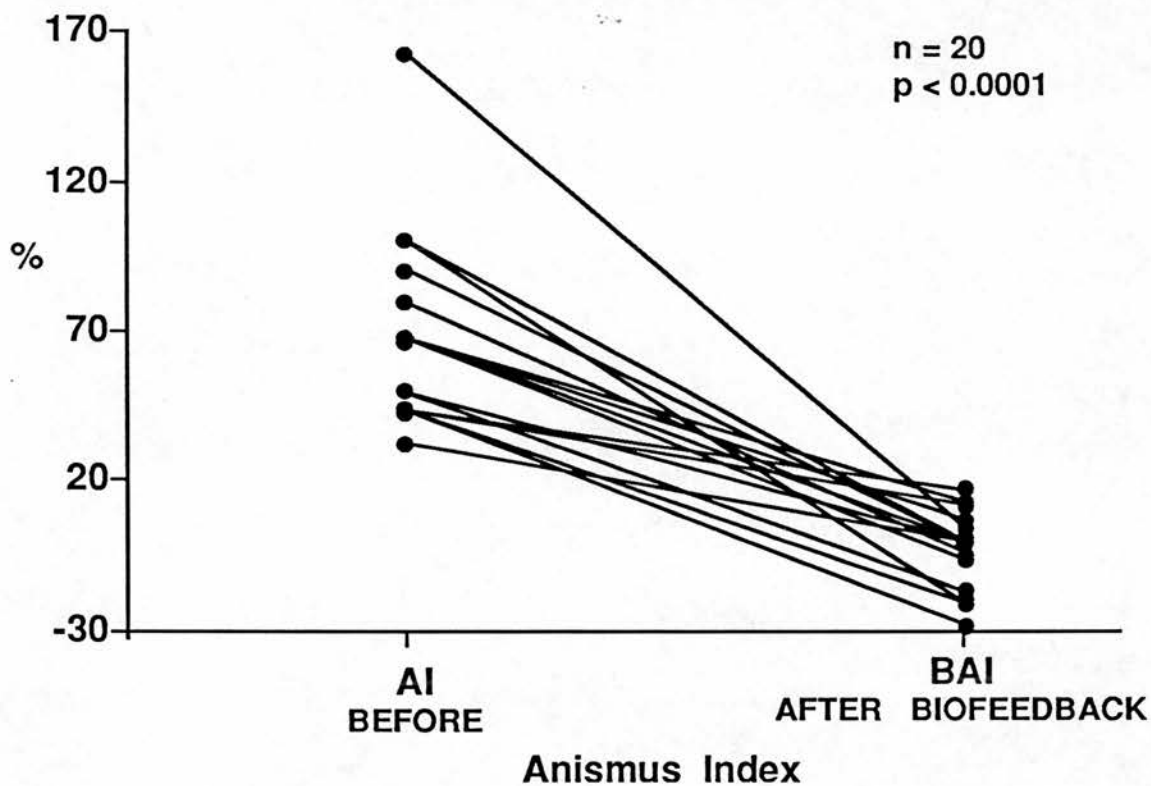
Figure 9.2 Anismus Index (measured in percentage) recorded in 20 patients, during integrated electromyography of the external anal sphincter, before (AI) and after (BAI) EMG biofeedback. (The results were compared with the use of the sign test for paired samples, p value is illustrated).
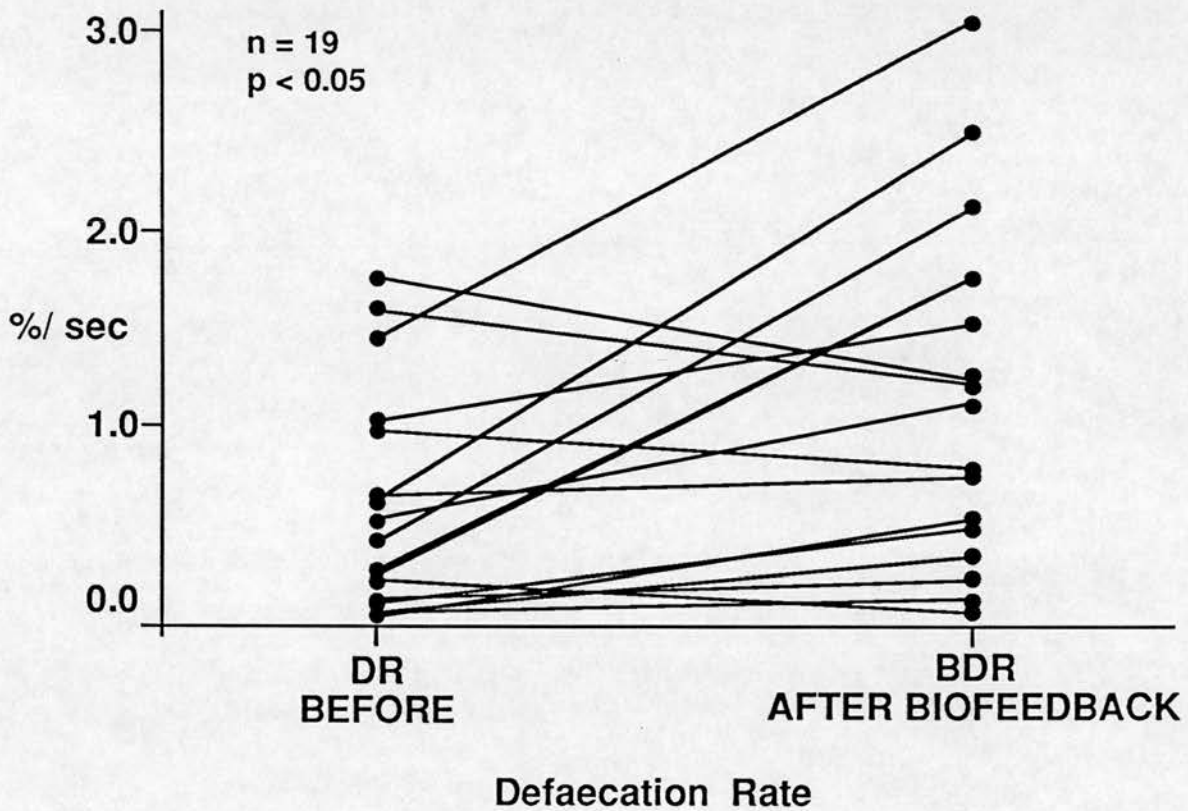
Figure 9.3 Defaecation rate recorded in 19 patients, during isotope proctography, before (DR) and after (BDR) EMG biofeedback. (The results were compared with the use of the sign test for paired samples, p value is illustrated).
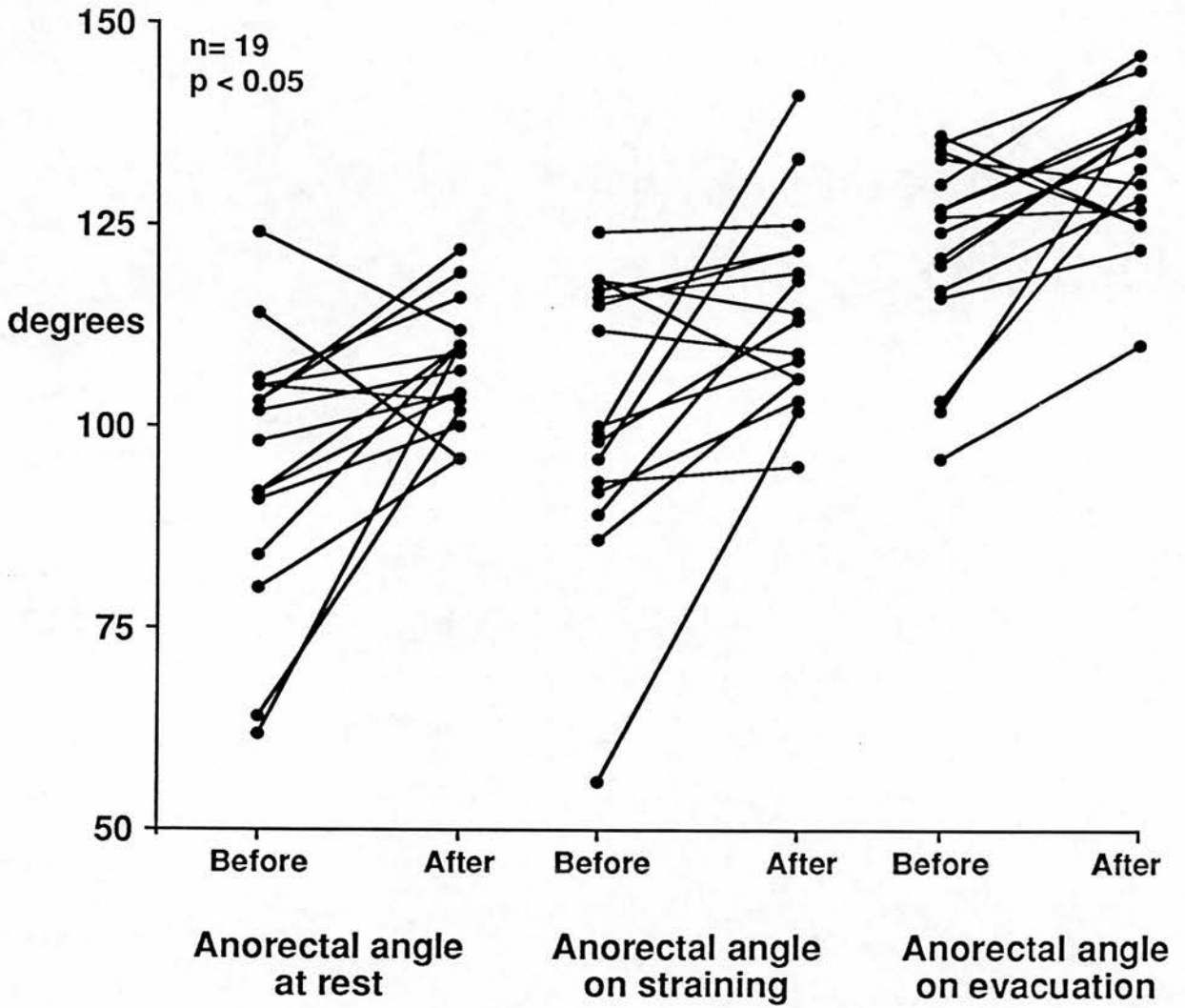
Figure 9.4 Anorectal angles at rest, on straining and during evacuation recorded in 19 patients, during isotope proctography, before and after EMG biofeedback. (The results were compared with the use of the sign test for paired samples, p value is illustrated).

significant increase in the upward-ascent movement of the PF on 'squeezing' (p<0.03), but no difference was observed in the PF descent. The IRP did not show any significant response to the biofeedback, however, the EAS EMG wire electrode recorded a significant drop in the EMG voltage on straining (p<0.02) and on evacuation (p<0.001; Figure 9.5) whereas the EMG voltage at rest was virtually unchanged.

9.5   DISCUSSION

Biofeedback is a simple, safe and effective technique which has been used successfully in the treatment of faecal incontinence due to neurogenic anal sphincter dysfunction (Wald, 1981), in the treatment of obstipation with a disturbed defaecation reflex (Van Baal et al, 1984) and in spastic pelvic floor syndrome causing obstructive defaecation (Bleijenberg and Kuijpers, 1987).   The advantages of biofeedback conditioning (Cerulli et al, 1979) and deconditioning (Van Baal et al, 1984) have been stated in previous studies. A pilot study, performed in patients with EMG evidence of obstructive defaecation, gave promising results altering evacuation parameters such as frequency of defaecation, evacuation time and the need for straining at stool (Kawimbe et al, 1991).

In this study the patients were assessed by anorectal manometry, electrophysiology and proctography prior to biofeedback, thus to elicit the assumed 'defects' in the defaecation problem. A repeat of the tests, after the biofeedback training, elicited objective changes which supported the

External anal sphincter EMG on evacuation
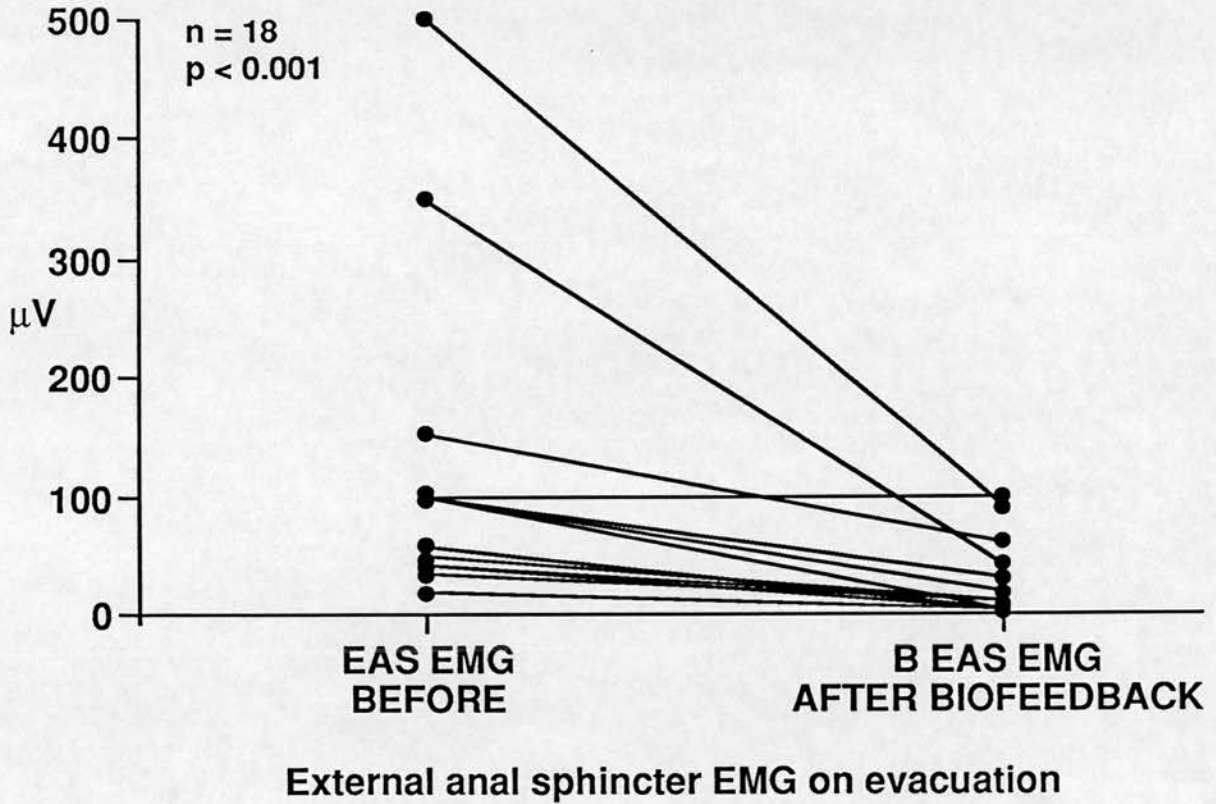
Figure 9.5   External anal sphincter EMG on evacuation
recorded in 18 patients, during isotope proctography,
before (EAS EMG) and after (B EAS EMG) EMG biofeedback.
(The results were compared with the use of the sign
test for paired samples, p value is illustrated).

subjective relief and the improvement in the symptoms. These changes were first of all, an increase in the defaecation rate (%EVAC/D.TIME). This was associated with an improvement in the patient's rectal sensation. More obtuse anorectal angles at rest and during expulsive manoeuvres were observed which were associated with a drop of the EAS EMG voltage during attempted evacuation. Thus, the biofeedback has influenced the defaecation act at different levels. What are the factors therefore that may influnce this act and how does the biofeedback work?

The factors that are considered to be necessary for defaecation are colorectal activity promoted via intrinsic nervous pathways in the intestinal wall and defaecation reflex. The defaecation reflex is a spinal reflex and it has been thought to have its afferent limb in the rectal ampulla (Kock et al, 1972). It is present from intrauterine life in humans, but its voluntary control is acquired through developing the higher cortical activity by training, depending upon environmental circumstances. It is a well recognised fact that a change of circumstances like a vacation, hospitalisation, anxiety and stress may affect defaecation one way or another. It may be assumed that these patients have inhibited their defaecation reflex at some stage, presumably because of 'strong' environmental stimuli registering as a life event. As a result the voluntary control of the reflex by higher cortical centres may be lost which can result in inappropriate use of the pelvic floor and sphincter muscles on attempted defaecation.

The external anal sphincter and the pelvic floor muscles have a continuous level of 'spiking' electrical activity at rest. The EAS reflex contraction in response to transient rises in intra-abdominal pressure (Parks, 1962) may be observed during the recto-sphincteric reflex (Arhan et al, 1977) and proctometrogram (Varma and Smith, 1986). This is again a spinal

reflex that appears to be modulated by conscious mechanisms (Swash, 1982). By steadily increasing the volumes in the rectal balloon at a certain level the EAS and puborectalis are inhibited (Parks et al, 1962). On defaecation, the sphincters relax to permit the passage of the faecal bolus (Kerremans, 1969) via either the cerebral inhibition of the sphincter contraction and/or mechanical stimulation in the anal canal (Duthie, 1975). Once defaecation has commenced, it can continue with no conscious effort, which suggests that the passage of the faecal bolus through the anus may stimulate colonic contraction resulting in the effortless expulsion of a large volume of stool. Once the rectum and anal canal is empty the pelvic floor and sphincter muscles regain their previous resting activity and the anal canal closes.

The patients studied had difficulties in initiating defaecation as well as completing evacuation. This implies a disordered anorectal sensation and of mechanical stimulation within the rectum and anal canal. The incomplete emptying of the rectum implies in turn a failure to stimulate colonic contraction. The simultaneous EMG wire electrode recording of the EAS activity in these patients showed an increase EMG voltage on attempted defaecation thus revealing inappropriate contraction. The cerebral inhibition of the sphincter contraction at defaecation is presumably disturbed. Biofeedback has improved the defaecation rate in these patients by altering the anorectal angles, improving rectal sensation and diminishing the EMG voltage of the EAS. Therefore, although the act of defaecation is a complex phenomenon dependent upon many concatenating factors in the anorectum and higher centres, it can be influenced by a self-regulatory mechanism which depends on the patients' will and effort.

On the other hand, there is the operation of a psychological influence. Patients learn that they are not relaxed during defaecation and then they are

taught how to become so and how to keep their pelvic floor muscles in turn relaxed. They become aware of the fact that they lack relaxation and focus on it. A more relaxed pelvic floor musculature may induce more obtuse anorectal angles; thus the rectal contents can get in touch with the upper part of the anal canal and this improves anorectal sensation. An improved sensation may recruit the conscious effort to provoke defaecation. Then provided the higher centres in control inhibit the contraction of the anal sphincters rectal evacuation may be achieved.

The patients recruited in the study had a variability in their features, some performing a more 'satisfactory' rectal emptying than others and some had hardly any at all. A number of them had an abnormal perineal descent, excessive straining at stool, and some were unable to move their pelvic floor on attempted defaecation. In Chapter 8, it was implied that the chronicity of the constipation problem may alter the appearance and function of the pelvic floor and sphincter muscles; thus the 'young constipated changes to become the old faecally incontinent'. This is also implied by the relation between the PF descent and the obtuseness in the ARA (see Chapter 8). The evacuation process depended upon the rectal capacity and compliance. Biofeedback treatment improved the rate of expulsion, simply by altering the anorectal angles, improving the rectal sensation and diminishing the abnormal EMG voltage of the sphincter muscle.

Biofeedback therefore influenced positively the defaecation reflex, reinforcing its afferent limb via improved anorectal sensation, recruiting the higher centres in the concsious control of the act and through the efferent limb provided increased relaxation of the pelvic floor and sphincter musculature.

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CHAPTER 10

CONCLUSIONS

PROLOGUE

« [Prognostics XI]... Elimination is considered in various ways ... quantity, quality, time of day, number of evacuations, thinness or thickness of the stool, and mode of exit... normal evacuation should occur without noise or wind... if the bowels do not move at a regular time this is a bad sign... feces are retained and constipation occurs with tympanites, and all this with distress because the stool is small and hard... changes the feces into scyballa and this may bring mania...»

(Hippocrates, 5th C. BC)

Anorectal disorders in the form of inappropriate 'elimination' of the bowels have been of interest since ancient times. Hippocrates goes on to define what is normal and abnormal defaecation in almost every aspect, concerned to describe the pattern of what a normal evacuation should be. He stresses the fact that 'scyballous feces' is a 'bad sign' and may even lead to 'mania'. This shows how serious abnormal defaecation was considered and moreover the relation between the psychological condition of the patient to bowel motility and vice versa (Jones, 1924; Saffron, 1972).

Equally in the 20th century AD, anorectal disorders are of ever increasing interest to the clinician and researcher as the population shifts demographically towards an elderly age group, with a longer life expectancy, and who are in general more likely to suffer from defaecation problems than the young. The latest technological developments allow more detailed and sophisticated study of anorectal function.

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10.1   ANORECTAL INVESTIGATIONS

10.1.1   Anorectal Manometry

Anorectal manometry may be carried out via either an analogue system or a digital one, using various microtransducers. The ones described in this thesis, i.e. the water filled microballoon, the 5 mm microtransducer catheter and the 2 mm microtransducer catheter showed a good agreement in the in vitro experiment. In vivo, the variations observed were dependent upon the size of the probes. The water filled microballoon was free of orientational 'fallacies', could have been made disposable if needed, and was used throughout the studies without the fear of 'systems' failure forcing a change of equipment in the middle of the study. It also has enabled a series of repeatable tests to be performed in controlled studies with minimal variability. Carefull preparation of the water filled system avoids the introduction of any air bubbles in the tubes and calibration of the microballoon at the anal verge to eliminate any measurement error may provide as good and accurate results as the microtransducer of a sophisticated digital system.

10.1.2   Electrophysiology

Routine somatosensory tests were performed with the use of a surface anal plug EMG electrode (Pinho et al, 1991) which had been devised with the metal electrodes placed in a parallel manner to the anal canal in conformity with the muscle fibre orientation for a better conduction of the voltage effect (Binnie et al, 1991). Another recent study (Sorensen et al, 1991)

shows that the conventional anal plug electrode, with circular electrode orientation, did not correlate with manometric results, but a disposable sponge electrode with a parallel longitudinal orientation of the plates to the anal canal correlated well with the manometry. It thus once more proves the importance of the plates orientation to the muscle fibre for a more accurate EMG recording.

10.1.3 Anal Endosonography

Using anal endosonography it is now possible to visualise directly the morphology of the anal sphincters. This was done using a 1 cm tip-diameter endoprobe so to cause minimal disturbance to the anal sphincters, thus avoiding misleading measurements. The internal sphincter was significantly thinner when measurements were made via the conventional 2 cm tip-diameter endoprobe (Papachrysostomou et al, 1991). This is therefore a more desirable method for routine investigation as it is more accurate in recording the thickness of the internal sphincter and because of its size it is better tolerated by patients.

10.1.4 Isotope Proctography

Isotope dynamic proctography is also a novel technique explored in this thesis and is making a claim to replace conventional radiological videoproctography in the study of the functional disorders of defaecation. It can be used to record the changes in proctographic parameters, such as the anorectal angles and pelvic floor movements, and also estimates in a more precise way the percentage of rectal evacuation, the

defaecation time and rate. It involves less radiation exposure and is considered safe even for the most protracted defaecation.

10.1.5 Radiological Videoproctography

Radiological videoproctography has been used for the diagnosis of structural defects (Poon et al, 1991), i.e. rectocoeles, rectal intussusception or prolapse, and in evaluation of the electrical stimulator effect on the pelvic floor muscles in patients with faecal incontinence. The radiation exposure in these patients from the radiological videoproctography is therefore much less than the one in patients with constipation and prolonged defaecation.

10.2 ANORECTAL STUDIES IN NORMAL CONTROLS

Anorectal manometry in young people confirmed higher anal canal pressures in males compared with females, for the striated component of the anal sphincter i.e. during its voluntary contraction. This is in agreement with other studies from other researchers (Sun and Read, 1989). This gender difference may be due to the fact that the striated musculature is generally more developed in the male than in the female, as part of secondary sexual characteristics. This is further supported by the fact that anal ultrasonography in normal volunteers revealed a significantly thicker external anal sphincter in males compared with females, irrespective of their body configuration. Thus, the difference in the striated anal sphincter in appearance and function may be hormone dependent.

It would be of interest to study the anal sphincter appearance at a pre-pubertal age to examine whether such a difference exists. This could lead to a better understanding of anorectal function in children and may enlighten aspects of the normal development and function of the anal sphincters in adults. Animal work suggested that in rats the external sphincter increases in size in older animals compared to younger ones (Knudsen et al, 1991). But this did not apply to humans: endosonography of the sphincters revealed a thinner external sphincter in the old compared with the young which may follow the 'normal' ageing process with wasting of the striated musculature.

The internal anal sphincter did not differ in size or function in young males and females. However, older subjects presented with a thicker internal sphincter compared with the young. This is again in agreement with reports from other investigators who reported no gender or other constitutional factor affecting the size of this muscle other than age (Burnett and Bartram, 1991). This may be explained by the provoked increase in the thickness of the internal sphincter, to compensate for a thinner external sphincter and protect from any dysfunction in the control of continence.

Is the increased thickness then compensatory? The internal sphincter thickness corresponded to the thickness of the external one in a reciprocal relationship. There may be two mechanisms by which this is arranged: a first in which the internal sphincter increases its thickness to compensate for thinning with age of the external one and thus maintain an adequate function; or a second mechanism which implies that the increased thickness in the internal sphincter is purely the result of changes in the sphincter architecture with age (Klosterhalfen et al, 1990) which extends outwards to occupy a bigger space, as the surrounding external sphincter is not in sufficiently high tonus any more to hold it so meticulously in its place. The former view is

supported by the fact that the control of continence is not disturbed in the elderly unless the sphincters are subjected to damage because of trauma, parity etc; or other factors coexist such as constipation with overflow diarrhoea and incontinence, or impaired sensation and the like (McKay et al, 1983).

The second mechanism has been explored in young controls by performing a continuous video-recording of the ultrasound scan of the anal sphincters. During the command 'squeeze' the external sphincter increased its activity by voluntarily contracting and thus becoming brighter in appearance. It was then seen to be 'compressing' the internal sphincter with the latter 'diminishing' in size, returning to the status quo on relaxation. In support of this is the fact that the combined sphincter thicknesses had a direct relationship to the maximum resting pressure in the anal canal.

It is well known that both sphincters contribute to the high resting tone in the anal canal, responsible for the pressure barrier in the anorectum thus preventing incontinence (Duthie and Watts, 1965). What is not so well known though, is the contribution of each sphincter to high resting tone and what is the significance of each. The studies in this thesis showed that there was reciprocity and a correlation of the thicknesses of both sphincters with their tonic activity at rest, elicited via the maximum resting pressure. This implies a close structural relationship and a functional collaboration between the two sphincters which equally allows for individual variation. The main deduction made by us is that both sphincters are important in the control of continence but are subject to variation: the external sphincter may play a supportive role, protecting the internal sphincter, but when it is damaged and weak the internal sphincter may come to play its role in continence control.

10.3   ANORECTAL STUDIES IN FAECAL INCONTINENCE

Anorectal manometry in idiopathic faecal incontinence revealed four groups of patients according to the functional deficit of the anal sphincters: the three were related to a deficit of one or other or both sphincters, and the forth remaining independent, apparently, of a sphincter problem. The majority of patients in all the groups were women. This may be because of the predisposition resulting from a weaker external sphincter that is present in women compared with men. The external sphincter pressures, elicited via the voluntary contraction and the cough reflex contraction, are lower in 'normal' young women compared with 'normal' young men. But, apart from that, women are more likely to experience damage to the sphincters through prolonged labour and various obstetric procedures such as a forceps delivery. Both sphincters seem to be equally important in the control of continence. Thus, while in some patients incontinence was the consequence of weakness of the external sphincter, in others incontinence was present in the absence of any apparent weakness of the external sphincter. The same applied to the internal sphincter.

A group of patients had both sphincters weakened, which indicates that in some patients the process of incontinence may involve either both sphincters or deterioration of the one may provoke decline of the other. It is important to stress that in these groups described, the deterioration in sphincter function was also associated with impaired rectal sensation. In the fourth group, patients with incontinence had no apparent weakness of either sphincter, nor was any sensory impairment present. This suggests the

importance of other factors in continence control, apart from the integrity of sphincters and rectal sensation. This group had an abnormally high rectal compliance, which was presumably enough to cause disturbance in the mechanism of continence. The conclusion is therefore made that continence control may depend equally on various aspects of rectal function, such as compliance, sensation, and the competency of the anal sphincters.

It may prove rewarding to study patients with incontinence without a sphincter deficit using ambulatory techniques. This may help to establish data about their sampling reflex and evaluate objectively relevant information of the actual time and circumstances under which their incontinence develops. An objective assessment of patients with different forms of neurogenic incontinence with the use of laboratory anorectal studies as well as ambulatory 24 hour recordings may lead to a better understanding of the means of continence control and in turn to a more precise form of management.

The pudendo-anal reflex electrical stimulator trial in incontinent patients showed that the external anal sphincter responds to repetitive stimulation of the pudendal nerve. The evidence for this in the patient group selected for this treatment was their increase in the anal pressures, the resting as well as the squeeze and cough ones. The functional anal canal was longer after the electrical stimulator treatment presumably because of the increased sphincter tone. This is a finding that has been observed after the surgical correction of incontinence in procedures like sphincteroplasty (Wexner et al, 1991). In the case of the operation the lengthening of the anal canal seems to correspond best to the mechanical correction achieved in the process of the repair. The electrical stimulator, however, provokes a longer area of the high pressure zone as a result in the increase of the electrical

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activity in the anal canal.

The electrical stimulator influenced the pelvic floor movement on voluntary contraction. This finding was observed during radiological video-proctography. It follows from this, that the increase of the pelvic floor ascent on squeezing may also be due to an improvement in the external sphincter tonus. However, there was no significant change in the anorectal angles either at rest or during voluntary contraction. This implies no significant change in the electrical activity of the puborectalis muscle that would have been expected to promote a less obtuse anorectal angle in an enhanced control of continence. The puborectalis muscle was thus not affected by the electrical stimulator.

This may reflect the fact that the anorectal angles in the videoproctograms were originally not much disturbed, in the patients studied by the electrical stimulator. Therefore, either the puborectalis was not sufficiently damaged to be influenced by the stimulator or another explanation could be that the pudendal nerve is not involved in the major innervation of the puborectalis (Percy et al, 1981), unlike the case for its role in the external sphincter. Another possibility is the reinnervation which may be realised by the overlap in the innervation of the external anal sphincter by the pudendal nerve from the contralateral side (Wunderlich and Swash, 1983). This may be another reason why there is a greater response of the external anal sphincter to electrical stimulation than happens in the case of the puborectalis.

In addition to the electrical stimulation of the external sphincter via a reflex arc, direct stimulation has been reported to affect the external sphincter type of fibre in an attempt to achieve transformation of the fibre Type 2 which is increased in neurogenic faecal incontinence to Type 1 (George et al, 1991). This requires a continuous direct electrical stimulation

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(Williams et al, 1989) and has been used also by physiotherapists (Dynamic Medical Instruments, 1989). The outcome and the success of such a form of stimulation needs to be thoroughly studied and evaluated.

Another form of activation of the anal sphincters, is by biofeedback training. Biofeedback is used for the recording of the resting activity and evoking the attempted voluntary contractions by demonstrating the increase and decrease in the EMG voltage during the alternating exercises. This involves active recruitment of the muscle and various centres in the USA claim excellent results. A variation of this, is the method that involves filling the rectum with fluid before the actual contractions of the muscles are evoked, in this way helping to restore rectal sensation in particular. It has thus proved beneficial mainly in patients with faecal incontinence associated with impairment in rectal sensation (Cerulli et al, 1979).

The internal anal sphincter was thicker in the incontinent group compared with the normal control one. No such difference was observed in the external anal sphincter thickness. The anal sphincters in faecal incontinence appeared to have no reciprocity in their thicknesses. It may be apparent that a thicker external sphincter is associated with a thicker internal sphincter and vice versa. This may be explained by the fact that some patients with faecal incontinence had physiotherapy and pelvic floor exercises which may have provoked a thicker external sphincter without the appropriate functional response in the electrical activity that would prevent these patients from having faecal incontinence.

The internal sphincter in the faecally incontinent had similar structural changes with the elderly (Lubowski et al, 1987). The sum of the thicknesses did not correlate with the maximum resting pressure in the incontinent patients as was the case in the normal control group. This may

be because whatever the cause of the changes in the sphincter thicknesses it may not be an adequate muscle for accomplishing the task of preventing incontinence.

The faecal incontinence group was composed of older people and therefore any changes in the sphincter thickness may be explained by age changes as much as inherent structural changes due to incontinence. Hence, it may be concluded that the reciprocity in the sphincter appearance, present in the normal controls but disturbed in the incontinent, may be important for the preservation of a congruent relation between the two sphincters. This integral relationship resulting in the maintenance of a successful pressure barrier may be critical in the prevention of incontinence as it is absent in this phenomenon.

10.4 ANORECTAL FUNCTION IN CONSTIPATION

Isotope dynamic proctography with simultaneous external sphincter EMG and intrarectal radiotelemetry have enabled quantitative assessment in patients with constipation with and without obstructive defaecation features. In patients with obstructive defaecation there was increased EMG activity of the external sphincter on attempted defaecation, impaired rectal sensation, incomplete evacuation with a rather prolonged defaecation time and a lower defaecation rate.

The defaecation rate was a more precise way of quantitatively characterising the anorectal function on defaecation as it equally involved the ability of a patient to proceed to rectal evacuation along with the time required. The anorectal angle on straining did not appear to achieve a more

obtuse state and the pelvic floor movement on attempted defaecation seem to have been variable from an 'immobile perineum' to an abnormally descending one. However, the pelvic floor descent correlated with the anorectal angles on attempted rectal evacuation. This may be related to the fact that prolonged, chronic straining at stool may cause damage to the anal sphincters; thus the obtuse anorectal angles may come to be associated with an abnormally descending perineum.

The quantitative assessment of the anorectal function on defaecation that the isotope proctography provided enabled comparisons to be made between the two main methods of proctography. In some patients the capability of rectal evacuation may depend on the rectal function itself rather than the anorectal angle and the activity of the anal sphincters.

The anal plug surface EMG electrode has been used in patients with obstructive defaecation for deriving the anismus index. This index, characterising the electrical voltage of the external sphincter on straining compared with the muscle's resting activity, has proved to be in agreement with the severity of the clinical symptoms of obstructive defaecation (Kawimbe et al, 1988).

In the studies described in this thesis the anismus index has also proved reliable in characterising facets of the obstructive defaecation problem. The correlations that have been derived between the anorectal angles, the intrarectal pressures and the anismus index show the associations between the obstructive characteristics of the abdominal, pelvic and anal sphincter musculature.

The constipated subjects with no obstructive features had relatively no abnormal increase in the EMG voltage of the external sphincter on attempted defaecation with the anismus index as zero percent. On isotope

dynamic proctography they had a shorter defaecation time and a higher defaecation rate, while the anorectal angles were made more obtuse on attempted defaecation, but they had also an incomplete rectal emptying.

The incomplete rectal emptying that was observed in this group reflects the fact that although the isotope proctogram is closer to 'natural' rectal evacuation than is the radiological proctogram because of the characteristics of the simulated 'faecal' bolus; the method however still involves unnatural 'retrograde' filling of the bowel in a comparatively short time upwards through the rectum. Therefore the rectum may not be behaving in its usual way and thus recordings obtained may not reflect the reality of the abnormal situation.

Biofeedback (Schwartz, 1988) revealed another approach to the study of the defaecation reflex. The improvement in the features of defaecation was most reliably demonstrated by the improvement in rectal evacuation in relation to the time involved, or the defaecation rate. In association with a higher defaecation rate the anorectal angles were increased and the abnormal EMG voltage of the external sphincter on attempted straining was decreased. The impaired rectal sensation was also improved. It thus appears, that for the achievement of a better rectal evacuation other parameters may be important in restoring disturbed defaecation. Biofeedback, as a self-regulatory treatment may be successful in conditioning the defaecation reflex, acting at different levels of nervous control through the pathways involved in such a process, the higher cortical centres and the afferent and efferent limbs.

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EPILOGUE

As was stated in the prologue to this chapter, anorectal disorders constitute a subject of increasing importance in Medicine at the present time. They have grown to be so because of the ever advancing age of the population in most western countries. Aspects in the lifestyle of the same elderly patients favour functional diseases of the lower bowel. It is an age in which therapy is sought for an ever-increasing range of bowel conditions often of progressive complexity and this in turn provokes the need for greater technology as an aid to diagnosis. The physiopathology of two of the commonest proctological conditions discussed herein is as yet poorly elucidated. However, their clarification is aided by an intensifying interest in this area of research.

As in other areas of endeavor, our insights into problems are advanced by measurements of the characteristics of the disease phenomena that we study. More exact measurement leads to more refined knowledge. By Lord Kelvin's dictum, the more we measure something the more we understand it. This has been the theme of our approach to a better understanding of the derangements of the physiological mechanisms inherent in anorectal disorders.

And as Hippocrates, too, reminds us...

«... There is no authority except facts. These are obtained by accurate observation. Deductions are to be made only from facts...»   (Moon, 1923)

If we have managed to uncover any things of factual significance in our studies, we trust that they have been treated according to such timeless principles.

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POST SCRIPTUM

«They say man has succeeded where the animals fail because of the clever use of his hands, yet when compared to the hands, the sphincter ani is far superior. If you place into your cupped hands a mixture of fluid, solid and gas and then through an opening at the bottom, try to let only the gas escape, you will fail. Yet the sphincter ani can do it. The sphincter apparently can differentiate between solid, fluid and gas. It apparently can tell whether its owner is alone or with someone, whether standing up or sitting down, whether its owner has his pants on or off. No other muscle in the body is such a protector of the dignity of man, yet so ready to come to his relief.»

BORNEMEIER 1960

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Use of the pudendo-anal reflex in the treatment of neurogenic faecal incontinence

N R Binnie, B M Kawimbe, M Papachrysostomou, A N Smith

Use of the pudendo-anal reflex in the treatment of neurogenic faecal incontinence

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Abstract
An electrical stimulator has been devised to treat neurogenic faecal incontinence caused by pudendal nerve neuropathy and works on the basis of repeated stimulation of the pudendo-anal reflex arc. Although conduction in the pudendo-anal reflex arc may be prolonged, and is so in neurogenic faecal incontinence, it must be shown to be present before the method can be used. This stimulation results in an immediate rise in the pressure in the anal canal and a significant increase in the electromyographic activity of the external anal sphincter. Maintenance of the stimulus over a two month period raised the mean resting pressure significantly in the anal canal and increased the reflex and voluntary responses of the external anal sphincter to coughing and squeezing actions respectively. The length of the sphincter was not affected. There was widening of the mean motor unit potential duration, though this was not significant. The resting electromyogram was enhanced after the course of treatment, indicating greater spontaneous activity in the external sphincter. The changes led to seven of the eight patients studied becoming continent at the end of the treatment.

Neurogenic faecal incontinence is an increasing problem in an ageing population. Not all patients are suitable for a post-anal repair, which is the mainstay of surgical treatment.[1] Various electrical stimulators have been designed in the past with the aim of returning function to the external sphincter and pelvic floor. These make use of a surface anal plug electrode[2] or are implanted with a radiofrequency link outside the body.[3] Although some have been successful at first, they have not found continued use, mainly because of wire breakages in the implants and anal pain or mucosal ulceration with the anal plugs.[4]

The pudendo-anal reflex latency[5] is a useful measurement in the electromyographic investigation of neurogenic faecal incontinence. A prolonged latency from the stimulus artefact to the sphincter response indicates, inter alia, the degree of neuropathy. A portable stimulator has been designed to provide repetitive stimulation of the pudendo-anal reflex which elicits contraction of both the external anal sphincter and the pelvic floor. The method attempts to restore continence by provoking contraction of these muscles selectively through the reflex. Manometric and electrophysiological responses in patients with neurogenic faecal incontinence were studied before and after pudendo-anal reflex stimulation treatment and any clinical change was noted.

Neurophysiological tests performed before and after treatment by the stimulator

	Pre-stimulation (mean (SEM))	Post-stimulation (mean (SEM))	p Value
PARL	55·9 (6·9) ms	65·9 (6·8) ms	p>0·05
PAR amp	37·5 (10·5) µV	49·5 (9·2) µV	p<0·01
MUPD	12·7 (3·3) ms	12·8 (3·4) ms	p>0·05
Electromyogram	11·6 (4·9) µV	26·9 (7·3) µV	p<0·01

PARL=pudendo-anal reflex latency; PAR amp=pudendo-anal response amplitude; MUPD=motor unit potential duration.

Patients
Eight women with a mean age of 47·5 (range 32–65) years took part in the study, for which ethical permission had been obtained from Lothian Health Board. Parity ranged from 1–5, with a mean of 3·1. All presented with faecal incontinence, were incapacitated socially, and had to wear incontinence pads. During the study each patient acted as her own control. All had an intact pudendo-anal reflex arc with a mean latency of 55·9 ms and a range of 47·2–69·4 ms (Table). The normal latency was mean (SD) of 39 (5·8) ms.[6]

Methods
All measurements were performed at the initial presentation and were repeated after completing an eight week trial of electrical stimulation.

MANOMETRY
A standard water filled microballoon system with external transducer measured the anal canal pressure by a 1 cm station pull through technique. The anal sphincter high pressure zone reflected the functional length of the anal sphincter, whose maximum resting pressure was recorded. The reflex contraction pressure of the external sphincter during a maximum cough was recorded at the point of maximum resting pressure, as was the maximum voluntary squeeze pressure of the sphincter.

Manometric recordings were also made of the inhibitory fall, as the recto-sphincteric reflex, in the resting pressure within the anal canal on rapidly distending the rectal ampulla with a balloon containing 50 ml of air. The anal sphincter pressure was also measured in response to dorso-genital nerve stimulation at the parameters to be used in the subsequent treatment.

ELECTROPHYSIOLOGY
An anal plug electrode was used with an electromyographic integrator to obtain amplitude measurements of the external anal sphincter resting electromyogram and the electromyo

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gram was also recorded during dorsal nerve stimulation. The pudendo-anal reflex latency and the response amplitude were recorded after applying over one hundred consecutive synchronised impulses to the dorso-genital nerve using an electromyographic multi-function apparatus (Medelec MS 92a, Woking, Surrey, England). The mean motor unit potential duration of the external anal sphincter was calculated from the mean of 20 motor unit potential durations taken at four sites around the anal sphincter circumference.[7] These were obtained with a concentric needle electrode, using the signal trigger and delay function of the recording equipment. The number of phases in each motor unit potential were counted and the fraction or overall percentage of polyphasic units was calculated for each subject. Each part of a motor unit which lay between two crossings of the base line, including the part of the potential between the onset and the first crossing, was termed a phase.[8] A polyphasic unit has greater than four phases. Anal sphincter mapping was performed at the time of motor unit potential duration acquisition using a concentric needle electrode to show that the external anal sphincter ring was intact in all cases.

ELECTRICAL STIMULATOR

The portable stimulator, which has a rechargeable nickel cadmium battery power source, provided a train of square wave stimuli to the dorso-genital nerve with fixed frequency of 1 Hz and a duration of 0·1 ms (Fig 1). Saline-soaked felt electrodes were used to apply the skin stimulus in the mid-line at the base of the clitoris identical to that used for the pudendal reflex test. A sub-maximal tolerable stimulation voltage of mean (SD) 135 (15) v was used, which was two
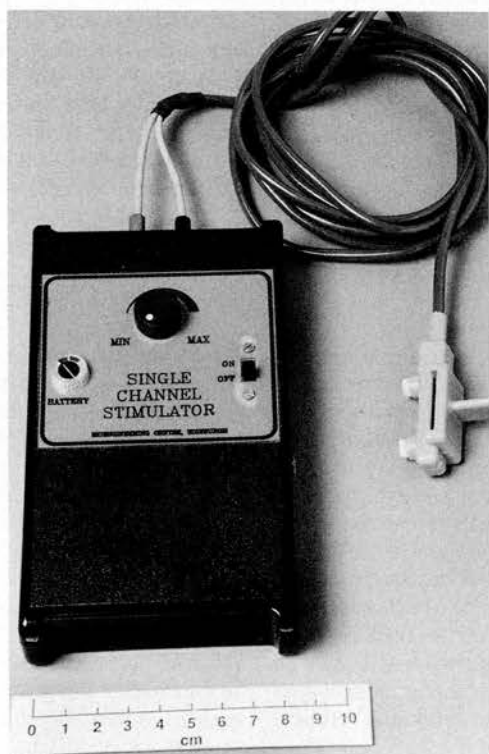
Figure 1: The portable dorsal genital nerve stimulator with the felt stimulating electrodes in an insulating handpiece.
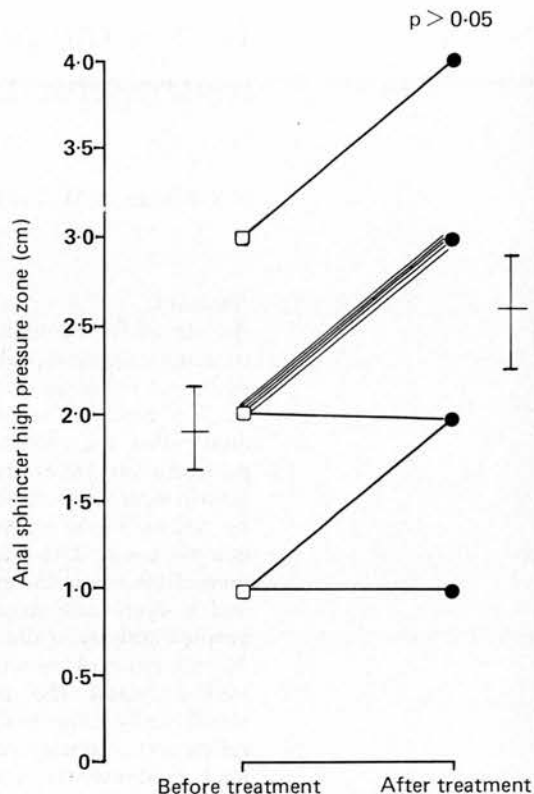
Figure 2: The length of the anal canal (in cm) before and after dorsal genital nerve stimulation, showing p value and SEM.

or three times the sensory threshold. The immediate effect of activating the stimulator was to cause a significant rise (n=8) in the external anal sphincter electromyographic activity from mean (SEM) 11·6 (1·7) μV to 44·9 (1·9) μV (p<0·01), with a corresponding significant rise in the anal canal pressure from mean (SEM) 49·1 (4·0) cm H_2O to 89 cm (10·4) cm H_2O (p<0·01). Treatment lasted for five minutes on three occasions per day for an eight week course and was self-administered.

STATISTICS

The statistical evaluation for the measurements of the high pressure zone, maximum resting pressure, maximum voluntary squeeze contraction, and cough reflex contraction pressure was done by a Student's t test using logarithmic conversion of the data of the paired observations before and after treatment. The remaining data were analysed by the Wilcoxon signed rank test for paired data.

Results

MANOMETRY

The anal canal high pressure zone, representing functional anal sphincter length (Fig 2), was increased from mean (SEM) 1·9 (0·2) cm to 2·6 (0·3) cm after the period of stimulation, but not significantly (p>0·05).

The patients with faecal incontinence had individual resting pressures below 60 cm H_2O, which represented their 'continence threshold.' In the anal canal this pressure was significantly increased from mean (SEM) 49·1 (4·0) cm H_2O

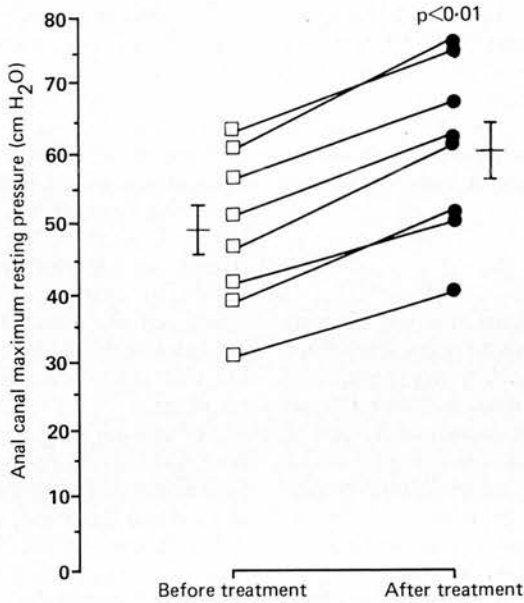Figure 3: The maximum resting pressure recorded in the anal canal before and after the course of dorsal genital nerve stimulation, showing p value and SEM.

Figure 5: Maximum pressure recorded in the anal canal during a maximal voluntary squeeze contraction of the sphincter before and after the course of dorsal genital nerve stimulation, showing p value and SEM.

to $61 \cdot 2 (4 \cdot 5)$ cm H_2O ($p < 0 \cdot 01$) after the course of electrical stimulation (Fig 3).

The pressure elicited by the reflex contraction of the external anal sphincter in response to coughing, the cough reflex contraction pressure (Fig 4), was significantly increased from mean (SEM) $80 \cdot 6$ ($8 \cdot 2$) cm H_2O to $106 \cdot 1$ ($11 \cdot 2$) cm H_2O after the period of stimulation ($p < 0 \cdot 01$).

The maximum voluntary squeeze contraction of the external anal sphincter (Fig 5) was also increased significantly from mean (SEM) 112 ($12 \cdot 1$) cm H_2O to 150 ($17 \cdot 3$) cm H_2O after the period of stimulation ($p < 0 \cdot 01$) (Table). The anal canal pressure reduction which followed provoking an internal sphincter recto-sphincteric reflex was not significantly altered by the course of dorsal nerve stimulation (from mean (SEM) $43 \cdot 8$ ($3 \cdot 5$) cm H_2O to $45 \cdot 4$ ($3 \cdot 2$) cm H_2O ($p > 0 \cdot 05$)).

The recto-sphincteric reflex showed that the sphincter could be reflexly inhibited in these patients but this was not changed by treatment (mean (SEM) $43 \cdot 8$ ($9 \cdot 9$) cm H_2O to $45 \cdot 4$ ($9 \cdot 1$) cm H_2O after treatment).

ELECTROPHYSIOLOGY

The pudendo-anal reflex latencies with a mean (SEM) of $52 \cdot 9$ ($2 \cdot 4$) ms were prolonged when compared with the normal range of 39 ($0 \cdot 94$) ms,[6] and were indicative of neurogenic injury (Table). The pudendo-anal reflex response amplitude (Table) was significantly increased from mean (SEM) $37 \cdot 5$ ($3 \cdot 7$) μV to $49 \cdot 5$ ($3 \cdot 3$) μV ($p < 0 \cdot 1$) after the period of stimulation.

The motor unit potential duration of the external anal sphincter was prolonged or widened with a mean (SEM) of $12 \cdot 7$ ($1 \cdot 2$) ms when compared with the accepted normal range of $6 \cdot 9$ ($0 \cdot 2$) ms (Table). There was also a high mean number of polyphasic motor unit potentials recorded from the external anal sphincter in the treated subjects with a mean (SEM) of $25 \cdot 9$ ($9 \cdot 4$)%, the normal being 12%, both of which results are in keeping with reinnervation of the muscle after a previous neurogenic insult.[7] The motor unit potential duration values were not affected by the course of electrical stimulation with a mean (SEM) of $12 \cdot 7$ ($1 \cdot 2$) ms before and $12 \cdot 8$ ($1 \cdot 2$) ms after stimulation ($p > 0 \cdot 05$) (Table).

The resting or basal integrated electromyogram of the external anal sphincter was increased significantly from mean (SEM) $11 \cdot 6$ ($1 \cdot 7$) μV to $26 \cdot 9$ ($2 \cdot 6$) μV after the course of stimulation. The external anal sphincter electromyographic response and the pressure responses to activation of the stimulator were also retested. There was a significant increase in the electromyographic response ($n = 8$) from mean (SEM) $44 \cdot 9$ ($4 \cdot 9$) μV to $72 \cdot 3$ ($5 \cdot 4$) μV ($p < 0 \cdot 01$) with a concomitant significant increase in the pressure response from
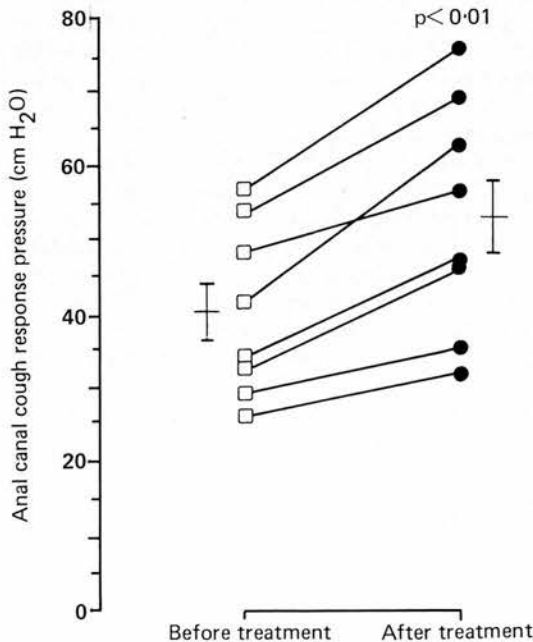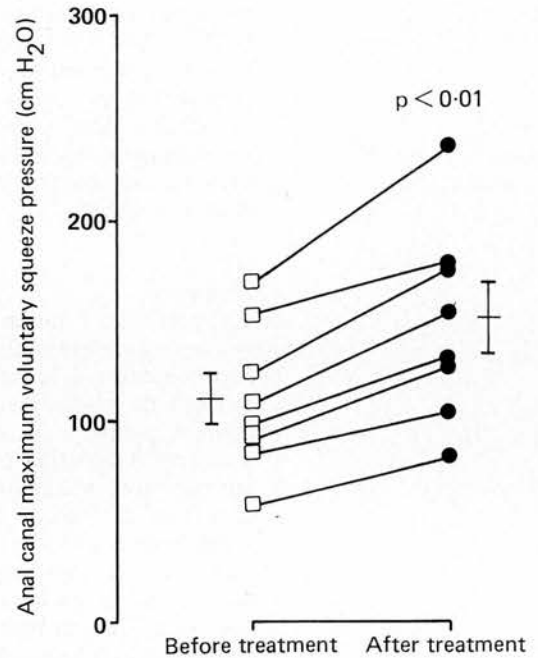
Figure 4: Maximum pressure recorded in the anal canal during the reflex response to a cough before and after the course of dorsal genital nerve stimulation, showing p value and SEM.

mean (SEM) 89 (10·4) cm H_2O to 128 (13·3) cm H_2O (p<0·01). Seven of the eight subjects had marked clinical improvement and became continent of both faeces and flatus after the course of stimulation. One patient was able to control faeces imperfectly, but not flatus. This patient is the one with the lowest values in Fig 3 before and after stimulation.

Discussion

The pelvic floor and external anal sphincter at rest are in a state of continuous tonic contraction, dependent on a spinal reflex arc completed through the conus medullaris by afferent and efferent pathways in the sacral 2, 3, and 4 segments of the spinal cord. The integrity of the arc can be tested by the pudendo-anal reflex, elicitation of which, in patients with faecal incontinence, produces a measurable contraction of pelvic floor and external sphincter but with an increased latency from stimulation to response. This has been used as an indicator of neurogenic damage. Traction injury to the pudendal and pelvic nerves is associated with dysfunction of the pelvic floor and external anal sphincter which can result in faecal incontinence.[9] Injury to these nerves also occurs during excessive straining with perineal descent such as occurs during labour.[10] Both types of injury tend to be incomplete, with preservation of the anatomical pathway sufficient for elicitation of the reflex and for using it for treatment. When there is a partial denervation the remaining nerve fibres attempt to reinnervate the muscle fibres by sprouting. Reinnervation of the pelvic floor can take up to two years to be complete depending on the site and degree of the nerve injury.

The women in this study all had reduced spontaneous activity in the external anal sphincter at rest, as was reflected in the low spontaneous integrated electromyographic activity. There was also a weak reflex pressure response to coughing and a reduced voluntary squeeze contraction of the external anal sphincter. This manometric picture coupled with the electromyographic evidence of prolonged pudendo-anal reflex latency, prolonged mean motor unit potential duration, and increased polyphasic potentials confirm the neurogenic nature of the external anal sphincter dysfunction. Where there is a normal recto-sphincteric reflex, rectal filling relaxes the internal anal sphincter. There is then little compensatory action of the external sphincter, which is demonstrably weaker in its barrier action as shown by the poor pressure responses to voluntary and stress reflex contractions of the striated muscle.

Treatments for neurogenic faecal incontinence reflect the spectrum of the condition, which ranges from occasional soiling to frank incontinence. Dietary changes and medication have been advocated to give some predictability of bowel habit.[11 12] Pelvic floor exercises with physiotherapy are used for urinary stress incontinence but the results are variable.[13 14] Voluntary sphincter responses can be improved by training devices, and biofeedback has been claimed to be effective.[15-17]

The surgical procedure of post-anal repair was devised by Parks,[1] who reported results of 72% fully continent and 12% continent for solid stool,[18] although Keighley[19] reported a lower figure for full continence of 63% with a further 21% continent for solid stool. The use of electrical stimulation for diagnosis in patients with denervated muscle has been practised for over a hundred years.[20] The application of Faradic stimulation for the therapy of the anal sphincter has been regarded as unpleasant and without much effect,[3] and Caldwell[21] designed an implantable device for anal sphincter stimulation but with the serious technical problem of cable breakage.

The present method of stimulating the pelvic floor and external anal sphincter makes use of the pudendo-anal reflex and has followed from the observation that the external sphincter contracts during the recording of the reflex. The reflex shows no signs of habituation[22] over several minutes of stimulation. A stimulator was therefore designed to produce trains of stimuli similar to those used in the test situation.

All the women in the study were shown to have neurogenic faecal incontinence due to pudendal nerve neuropathy and had a prolonged but intact pudendo-anal reflex before the period of electrical stimulation of the pudendo-anal reflex. After eight weeks of treatment seven out of eight subjects became fully continent of faeces and flatus while one remained incontinent of flatus only. There was no change in the pudendal reflex latency or in the length of the sphincter. The maximum resting anal canal pressure was measured above the 60 cm H_2O pressure which was the 'continence threshold' for the eight patients and the 'protective' cough and squeeze pressures associated with the external sphincter activity were significantly improved.

The improvement in sphincter function is reflected in the enhanced resting electromyogram, which should help raise the spontaneous activity to that in a normal external anal sphincter. The effectiveness of the return of sphincter function needs explanation. It may have resulted from hypertrophy of the remaining innervated muscle fibres giving the sphincter an enhanced activity and thus perhaps making the subjects more aware of its contraction. There was widening of the motor unit potential duration in some patients but this was not significant, indicating that further or reinnervation of the sphincter is an unlikely mechanism. Loss of tone in the pelvic floor could perpetuate the lack of spontaneous activity in the spinal reflex arc since afferent input to the sacral cord is essential for its activity to persist. Simple tightening of the pubo-rectalis portion of the pelvic floor in a post-anal repair, for example, would not persist unless the muscle could actively maintain this position afterwards and electromyographic studies show increased resting activity after the repair in keeping with a reactivation of the pudendo-anal reflex arc. The raised electromyographic and pressure levels during the activation of the stimulator at the end of treatment showed how far a two months' course of treatment can build up these related effects.

In neurogenic faecal incontinence, the

pudendo-anal reflex is almost always present though prolonged, and its presence must be confirmed before an electrical sphincter stimulator dependent on it is used. The evidence suggests that this reflex can be harnessed by repetitive electrical stimulation to aid the restoration of the control of defaecation. The action is likely to be due to stimulation of the external anal sphincter rather than the internal sphincter. The mean basal pressure in the anal canal, which measures both sphincters, had risen but the contribution from the internal anal sphincter to the increased pressure readings had probably not changed because the values obtained on inhibiting it in the recto-sphincteric reflex were not increased. Therefore, it can be deduced that the pressure effect is predominantly on the external sphincter, perhaps accompanied by one on the pelvic floor.

This type of stimulation differs from Faradism, which has been abandoned because it is short-lived and its effects were achieved through the stimulation of local nerve endings only. Studies are proceeding to ascertain the contribution of the present method of pelvic floor stimulation in promoting clinical effects such as the duration of continence and its associated pressure changes, including whether reflex stimulation can be applied to pudendal neuropathy of varying degrees of severity.

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The importance of the orientation of the electrode plates in recording the external anal sphincter EMG by non-invasive anal plug electrodes

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Abstract. Two non-invasive anal plug electrodes of similar size have been compared, one with the electrode plates orientated circularly in the anal canal and the other with the plates in the long axis of the anal canal. There was a significant increase in the amplitude in the EMG signals recorded at rest and during squeeze from the external anal sphincter with a longitudinally placed electrode in 117 patients. Inappropriate contraction of the external anal sphincter when straining at stool was more readily detected using the longitudinal electrode in 52 patients investigated for intractable constipation. The longitudinal electrode detected the amplitude of the response to the elicitation of a pudeno-anal reflex more readily than the circular electrode. When in 12 of the 117 the pudeno-anal reflex EMG signal was either absent or not detected with the circumferential plug electrode, the longitudinal electrode detected the presence of a low amplitude response in 11 of these. When the non-invasive longitudinal electrode was compared to invasive fine wire stainless steel electrodes, a correlation was found for external anal sphincter resting EMG ($r = 0.99$, $p < 0.01$), voluntary squeeze EMG ($r = 0.99$, $p < 0.001$) and strain EMG ($r = 0.91$, $p < 0.01$). The longitudinal anal plug electrode thus facilitates surface acquisition of EMG activity.

Résumé. Deux électrodes anales non invasives de contact d'un diamètre similaire ont été comparées, l'une avec les plaques d'électrode orientées circulairement dans le canal anal et l'autre avec les plaques suivant le grand axe du canal anal. Il existait une augmentation significative de l'amplitude des signaux électriques enregistrés au repos et durant la contraction du sphincter anal externe pour les électrodes placées lonitudinalement chez 117 patients. Une contraction inappropriée du sphincter anal externe durant la défécation était plus facilement détectée en utilisant des électrodes longitudinales chez 52 patients explorés pour constipation irréductible. L'électrode longitudinale détectait l'amplitude de réponse au déclenchement du réflexe pudendo-anal plus facilement que l'électrode circulaire, mais chez 12 des 117 malades le signal électrique du réflexe pudendo-anal était soit absent, soit

n'était pas détecté avec une électrode circonférentielle tandis que l'électrode longitudinale détectait la présence d'une réponse de basse amplitude chez 11 d'entre eux. La comparaison entre l'électrode longitudinale non invasive et l'électrode invasive par fil d'acier inoxydable fin montrait une corrélation pour l'EMG de base du sphincter anal externe ($r = 0.91$, $p < 0.01$), le tracé de contraction volontaire ($r = 0.99$, $p < 0.001$) et le tracé de défécation ($r = 0.91$, $p < 0.01$). Ainsi l'électrode longitudinale par plaque améliore l'enregistrement de l'activité électromyographique.

Introduction

Anal plug electrodes usually have two circular electrode plates circumferential to the anal plug which thus lie parallel to the external anal sphincter muscle fibres. Due to the increased longitudinal conductivity of muscle, it is accepted that bipolar surface electrodes for recording striated muscle EMG are usually placed in the direction of the muscle fibres [1]. Each electrode is connected to either side of a balanced amplifier while a third electrode connects the patient to ground [2]. Because of this theoretical implication, an anal plug electrode was constructed with two electrode plates placed along the long axis of the anal plug, the electrodes being equally separated on the circumference. The electrode plates were thus separated along the length of the external anal sphincter muscle fibres. A series of anorectal electrophysiological investigations was done to compare the two types of anal plug electrodes which differed with their circular and longitudinal arrangements. These included recording the integrated EMG activity of the external anal sphincter at rest, during voluntary squeeze and during straining, and while eliciting the pudendo-anal reflex latency response. Patients with anismus [3] who have an inappropriate contraction of the external anal sphincter can be recognised by detecting a rise in the external anal sphincter EMG activity when straining at stool. The nor-

mal response to straining at stool should be relaxation of the pelvic floor and external anal sphincter with a reduction in the EMG activity. The pudendo-anal reflex latency assesses the integrity of the reflex arc from the dorsal genital nerve to the S234 component of the sacral cord and the efferent pudendal nerve conduction time to the external anal sphincter [4].

A further aim of the study was to compare the more sensitive of the two types of non-invasive anal plug electrode with invasive fine wire stainless steel electrodes.

Patients

One hundred and seventeen patients participated in the comparison of the orientation of the plates of the two anal plug electrodes and had studies done at rest and during squeeze and strain manoeuvres. These 117 patients were 94 females (mean age 55.4 ± 9.3 years) and 23 males of mean age 31 ± 6.2 years. These patients, in addition, all had a pudendo-anal reflex study. Of the 117 patients, 52 patients showed, during straining, possible anismus effects. The patients who were being investigated for obstructive defaecation were represented by 38 females of mean age 48.2 ± 11.5 years and 14 males (mean age 32.4 ± 5.7 years).

Eight consecutive subjects attending the ano-rectal laboratory participated in a comparison of the more sensitive of the two plug electrodes with the fine-wire method. All patients gave informed consent for the procedures involved.

Materials

Electrodes

The electrode referred to as the circumferential electrode is the Disa 13k 78/79 (Disa Electronics, Bristol) (Fig. 1 a).

The longitudinal anal plug electrode has two $0.25\,\text{cm} \times 2\,\text{cm}$ stainless steel electrode plates placed in parallel on the longitudinal axis of the neck of the plastic anal plug, separated equally on the circumference [5]. The electrode plates are thus separated in the direction of the external anal sphincter musle fibres (Fig. 1 b). The

plastic plug is machined to the appropriate shape with an overall length of 7 cm, a bulbous distal end 1.5 cm diameter and the neck of the plug being 2 cm in length and 0.5 cm in diameter.

The fine wire stainless steel electrodes [6, 7] were placed in a hypodermic needle with the ends protruding. The wires were insulated with a teflon coating and approximately 0.25 cm of the tips were bared and hooked over to allow the position to be maintained in the muscle on withdrawal of the needle.

Methods

Integrated EMG

All the subjects had investigation of rest, squeeze and strain EMG performed using either the circumferential electrode first and then the longitudinal one or else this was done in the reverse order, the order being varied but not formally randomised.

For the wire electrode study the subjects were placed in the left lateral position and the fine wire stainless steel electrodes introduced into the external anal sphincter in the mid-line posteriorly with a hypodermic needle to a depth of 1.5 cm. The needle was then withdrawn leaving the hooked electrodes in place in the external
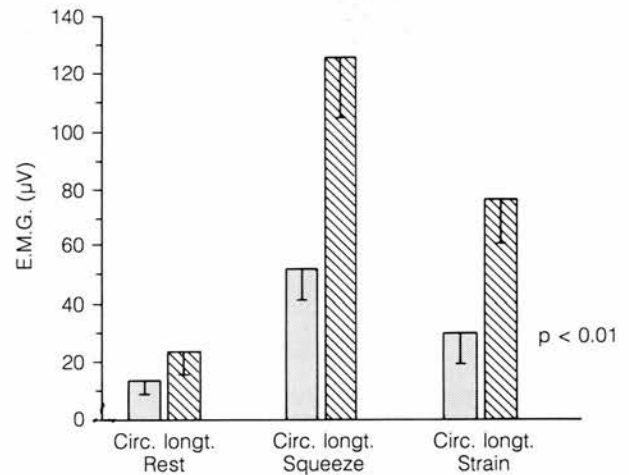
Fig. 2. One hundred and seventeen patients had a comparison of both forms of anal plug electrode and the figure shows (for rest and squeeze) mean rectified EMG amplitude (μV) recorded during rest and squeeze with circular and longitudinal anal plug electrodes. It also shows the inappropriate contraction and EMG responses for strain manoeuvres in 52 subjects who had obstructive defaecation
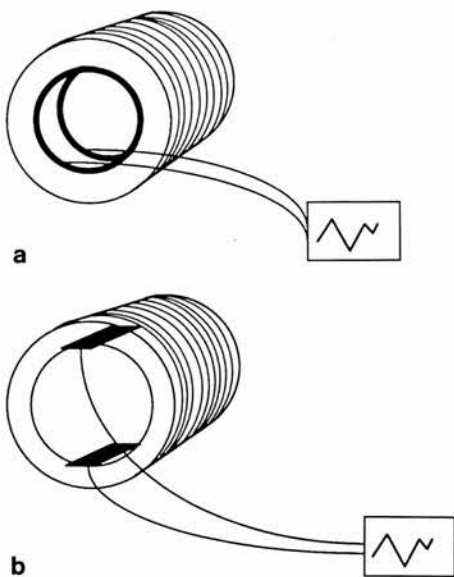

Fig. 1 a, b. The alignment of the electrode plates (a circular electrode, b longitudinal electrode) in relation to the external anal sphincter in the two forms of anal plug electrode

Fig. 3. Mean pudendo-anal reflex response amplitude (μV) with circular vs longitudinal anal plug electrodes
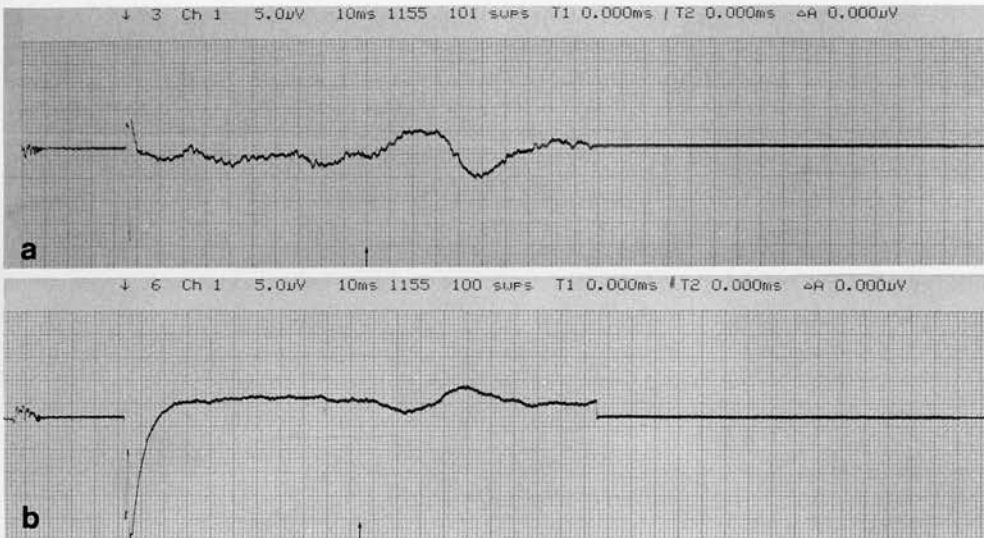
Fig. 4 a, b. Mean pudendo-anal reflex EMG response amplitude (μV) showing an augmented response with longitudinal anal plug electrodes but a barely detectable response with the circular anal plug electrode
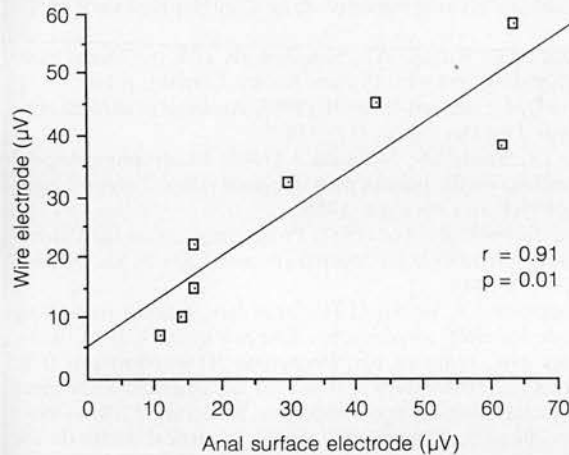
Fig. 5. Correlation of external anal sphincter rectified EMG (μV) during straining, recorded with invasive wire electrodes and non-invasive longitudinal anal plug electrode

anal sphincter muscle. The wires were connected to an isolated EMG integrator (Ormed 4880, MX216) and the recorder calibrated to read the required EMG range (0–50 μV). After insertional EMG activity ceased the resting EMG activity in the external anal sphincter was recorded. The subject was then asked to contract the external anal sphincter and the squeeze EMG was recorded. The subject was finally asked to strain as if at stool and the strain EMG was recorded. This procedure was repeated twice to confirm the recordings. The wire electrodes were now withdrawn and the anal plug electrode to be compared was inserted into the anal canal for the same investigations to be repeated.

Pudendo-anal reflex

The pudendo-anal polysynaptic reflex arc incorporates the sensory dorsal genital nerve, the S234 spinal cord and the efferent pudendal nerve to the external anal sphincter. The Medelec MS92a stimulus triggered response unit records the time delay from skin stimulus to the EMG response in the external anal sphincter. The time to onset of the digitally averaged response to at least 100 stimulus impulses is 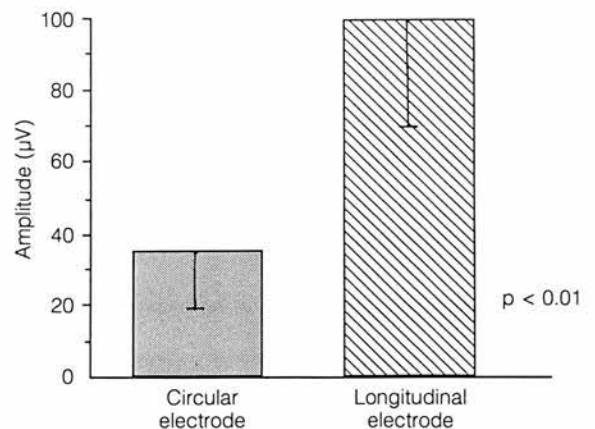taken as the pudendo-anal reflex latency. The sensitivity of the incoming signal amplifier is selected to the most appropriate sensitivity for the amplitude of the incoming EMG signal from the muscle. If the amplifier sensitivity is set too high the display store

will be overloaded and the signal peaks will be flattened. The amplitude of the pudendo-anal signal response in microvolts (μV) is therefore equal to the volts per division times the screen divisions, and this can be measured electronically within the apparatus. Finally, a paper copy of the pudendo-anal reflex response can be printed out with all that information included.

Statistical analysis

The anal plug electrode and fine wire electrode tests were compared by deriving p values and a correlation coefficient [8].

Results

Orientation of electrodes

The rectified EMG amplitudes recorded from the external anal sphincter with the longitudinal electrode were significantly higher than those recorded with the circumferential electrode during rest and squeeze activity (Fig. 2). In 52 patients with obstructive defaecation there was an inappropriate contraction rectified EMG voltage when straining. The inappropriate EMG change was detected more readily by the longitudinal electrode than by the circular one ($p < 0.01$) (Fig. 2). In the 117 patients who had the pudendo-anal reflex response studied, the signal latency obtained from the external anal sphincter was identical with the circular and longitudinal electrodes (45.3 ± 2.3 ms). There was, however, a significantly higher response amplitude when the responses were recorded with the longitudinal electrode ($p < 0.01$) (Fig. 3). In keeping with this, the sensitivity of the incoming signal amplifier of the EMG apparatus could be significantly reduced by a factor of 10. Figures 4a and b show the enhancement of the EMG voltage obtained with the longitudinal electrode compared to the circular one during the elicitation of the pudendo-anal reflex. There were 14 females (age 66.7 ± 8.6 years) in whom no pudendo-anal reflex could be detected using the circumferential electrode although the response was present with the longitudinal one.

Invasive versus non-invasive

There was a significant correlation between the rectified EMG voltage recorded with the longitudinal anal plug electrode and the fine wire electrode for the external anal sphincter resting EMG (r=0.99, p<0.01), the squeeze EMG (r=0.99, p<0.001) and the strain EMG (r=0.91, p<0.01) (Fig. 5). The direct correlation persisted between the two techniques in both the normal situation with reduction of EMG on straining, and in the abnormal state of anismus when there was inappropriate contraction of the external anal sphincter on straining at stool.

Discussion

The familiar hour-glass-shaped anal plug electrode was originally made by Hopkinson for anal muscle stimulation with two parallel circumferential electrode plates 1 cm apart placed at either end of the neck of the electrode at the presumed site for stimulation of the "recto-pubalis" muscle [9]. However, the circular external anal sphincter and loop of pubo-rectalis muscle at the ano-rectal junction are arranged such that their muscle fibres lie in the same circle or loop shape, respectively. The longitudinal conductivity of muscle tissue is 5 to 15 times larger than in the transverse direction [1]. Recording electrodes should therefore be placed longitudinally with respect to muscle [10]. This is at variance with the design of the Hopkinson electrode used in the treatment of female urinary incontinence [11] and the currently available anal plug electrodes used for surface recording of the EMG activity of the external anal sphincter (Disa 13k78/79).

Electrophysiological investigation of the pelvic floor can provide detailed information on the pelvic floor muscle motor unit potential duration and single fibre density [12]. The pudendo-anal reflex latency investigation is well tolerated, is much less invasive and is a useful ano-rectal EMG screening test in patients with neurogenic faecal incontinence [4]. This study shows that an anal plug electrode with longitudinal electrode plates significantly improves the detection of the external anal sphincter EMG signal response on eliciting the pudendo-anal reflex.

When healthy skeletal muscle is completely relaxed it has no detectable EMG activity [2]. The pelvic floor, external anal sphincter and external urethral sphincter are unusual in that they have continuous tonic EMG activity at rest [13], provided that the reflex arc is intact [14, 15]. The detection of changes in EMG activity in the pelvic floor can be recorded with a concentric needle electrode [16]. The longitudinal electrodes detected these responses better than the circular ones and may be used to measure the reduction in EMG activity during normal defaecation straining, and to detect failure of this in obstructive defaecation or anismus [3]. The use of artefact-free fine wire electrodes is to be regarded as the "gold standard" for diagnosing inappropriate contraction of the external anal sphincter during dynamic studies while straining as if at stool [7]. The presence of an anal plug within the anal canal might also induce non-physiological responses in the external anal sphincter. However, the

significant direct correlation with the invasive fine wire electrode at rest (p<0.01), during squeeze (p<0.001) and straining (p<0.01) shows that this is not so. The inappropriate increases in the rectified EMG during straining in obstructive defaecation or anismus were detected as readily with the longitudinal anal plug electrode as they were with the fine wire electrodes.

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Outlet obstruction constipation (anismus) managed by biofeedback

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Abstract
Fifteen subjects presenting with intractable constipation due to obstructive defecation, mean (SEM) duration 8·8 (1·8) years, had the inappropriate contraction and electromyographic changes in the pelvic floor muscles and external anal sphincter typical of this condition. An electromyographically derived index was used to grade its severity. A self applied biofeedback device was used to allow electromyographic recording of the abnormal external anal sphincter. The subjects were encouraged to reduce the abnormal electromyographic activity on straining after instruction and training. The procedure was intended as a relearning process in which the non-relaxing activity of the pelvic floor was gradually suppressed. Biofeedback training was maintained on a domiciliary basis for a mean time of 3·1 weeks and resulted in a significant reduction in the anismus index (mean (SEM) 69·9 (7·8)% before biofeedback, mean 14 (3·9)% after biofeedback, p<0·01). There was an associated reduction in the time spent straining at stool and in the difficulty of defecation and an increased frequency of defecation. Defecatory video proctograms in six subjects showed improvements in the anorectal angle during straining and evacuation. The clinical benefit to the patients persisted after a mean follow up of 6·2 months.

Inappropriate contraction of the posterior portion of the pelvic floor musculature when straining to defecate can produce a form of constipation which is caused by the anorectal 'outlet' obstruction which ensues. This implies failure of the inhibition of the pelvic floor muscle which occurs in normal defecation together with a spasm of the pelvic floor which creates the conditions for the severe constipation of this state known as anismus.[1-3] The affected subjects strain excessively at stool with the higher centres unaware of the incoordination of the pelvic floor. The inappropriate external anal sphincter contraction can be detected by modern non-invasive electromyographic techniques.[4] The claim has been made that biofeedback training can promote defecation by restoring the capability of inhibiting the anomalous contraction of the pelvic floor. This is done by learning to suppress the activity of the non-relaxing part of it.[1]

A self applied electromyographic device, Myotron 120 (Physiological Feedback Systems, Vijftig Bunderweg 1, Dorst (NB), The Netherlands) allows the subject to see or hear the electromyographic response of the external anal sphincter muscle during straining, and the feedback of biological information is the basis of the

training technique.[5] The aim of the study was to assess the effect of using such self applied recording as a biofeedback means of domiciliary treatment in a group of subjects with anismus using subjective improvement and objective evidence as measures of the outcome.

Patients

Fifteen subjects, 12 women and three men, median age 45 years, range 22–76 years, presented with intractable constipation and excessive straining at stool due to difficulty in evacuating the rectum. The mean (SEM) duration of the presenting complaint was 8·8 (7·1) years. All subjects had some perineal discomfort at defecation and one had an anterior rectal mucosal prolapse. Each underwent proctoscopy and rigid sigmoidoscopy to exclude other associated pathology such as rectal prolapse or solitary rectal ulceration. All were asked to stop taking their medication at the start of treatment.

Methods

ANORECTAL MANOMETRY
Standard manometric methods were used to measure the length of the anal sphincter high pressure zone, the maximum resting pressure, and the rectosphincteric reflex relaxation of the internal sphincter.[6] A continuous infusion proctometrogram technique was used to assess sensory awareness, maximal rectal capacity, and the rectal compliance.[7] In a further test the proctometrogram balloon was filled to the level of sensory awareness and the subject invited to attempt to expel the balloon voluntarily. This was repeated as a training exercise up to 10 times in each subject with the object of increasing the subject's rectal sensory awareness.

ELECTROPHYSIOLOGY
The pudendoanal reflex latency[8] and the external anal sphincter motor unit potential duration was measured using a standard concentric needle electrode technique.[9]

DETECTION OF ANISMUS
The subject lay in the left lateral position with a ground electrode wrapped round the right thigh. An anal plug electrode[4] connected to an isolated electromyographic integrator was placed in the anal canal. The resting electromyography was recorded from the external anal sphincter before the squeeze recording and the strain recording after bearing down as if at stool. An anismus

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TABLE I   *Anorectal manometry and electromyographic results before and after biofeedback and at later follow up in 15 subjects (mean (SEM))*

Test	Before biofeedback	After biofeedback	Follow up (months)
High pressure zone in anal canal (cm)	3·1 (0·2)	3·0 (0·2)	3·1 (0·2)
Maximum resting pressure in the anal canal (cm H₂O)	92·3 (5·1)	9·14 (5·6)	92·9 (5·5)
Rectosphincteric reflex (cm H₂O)	66·4 (4·6)	66·2 (4·5)	66·1 (3·8)
Maximum rectal volume of capacity (ml)	448 (21)	443 (22)	445 (23)
Rectal compliance ratio of volume/intraluminal pressure (ml/cm H₂O)	7·6 (0·4)	7·6 (0·5)	7·7 (0·5)
Pudendo anal reflex latency (ms)	42·3 (1·7)	42·4 (1·7)	42·5 (1·8)
Motor unit potential duration of the external anal sphincter (ms)	8·8 (0·6)	8·7 (0·7)	8·9 (0·8)

index was calculated from strain electromyographic voltage−rest electromyographic voltage ×squeeze recording−rest electromyographic voltage×100. [10]

ELECTROMYOGRAPHIC BIOFEEDBACK

The subjects came to the anorectal motility laboratory for training and met the doctor and the technician carrying out the study. They were shown a diagrammatic representation of their problem and the objectives of the biofeedback treatment were explained. The anal plug electrode was placed in the anal canal and connected to the biofeedback device. The Myotron was calibrated and the resting electromyographic recording was noted. The subjects now contracted the external sphincter and recorded the squeeze, which was displayed as μV in excess of the original resting recording. Then, bearing down as if at stool, the subjects took particular note of the straining recording. The electromyographic activity could also be monitored continuously by means of a built in loud speaker in which the frequency of the sound waves varied proportionately with the electromyographic level. At successive straining attempts and by altering the method of straining as required to become purposeful, the subject tried to relax the pelvic floor and to reduce the straining recording down to or below the resting recording and thus correct the anismus dysfunction by restoring the normal defecation inhibition of the pelvic floor.

Subjects then took the device home with the aim of using it for two sessions per day. They were to attempt defecation only on the morning occasion, the second session being a reinforcement exercise. The Myotron had a simple set of instructions attached to it since some subjects were uncertain of some of the steps and details of the procedure or became confused by the sequence of events.

The duration of domiciliary biofeedback treatment was in multiples of two weeks, depending on the subjects' symptoms and whether they thought they would benefit from continuing biofeedback. The group was, on the whole, highly motivated and all went through the learning exercise and period of training. They particularly appreciated the availability at all times of the female technician in the team. Eight subjects used the device for two weeks, six for four weeks, and one for six weeks. They also kept a diary record of the number of stools passed per week, the time spent straining at stool, the degree of difficulty in passing stools, and noted any perineal pain or discomfort. The last two symptoms were scored as indices on an analogue scale of 0, 1=mild, 2=moderate, 3=severe. The subjects who had begun to keep a diary of these events before starting biofeedback continued to do so throughout the treatment and continued for two weeks afterwards before attending the laboratory for review.

RADIOLOGY

Video-proctograms were performed using a mixture of barium potato mash mixture for six subjects. The anorectal angle was measured at rest, on squeezing to contract the sphincters, and on straining (bearing down) to simulate evacuation.

FOLLOW UP

All subjects were reviewed between three and six months after the assessment at the end of biofeedback treatment when the anorectal function tests were repeated. Two subjects were seen again at one year and a further two were reviewed at over 15 months, giving an overall mean (SEM) follow up time of 6·2 (4·6) months.

STATISTICS

Statistical analysis was performed on the data using the non-parametric Wilcoxon signed rank test for paired data.

Results

ANORECTAL MANOMETRY

There were no significant differences in the results of the standard anorectal manometric investigations before and after biofeedback or between biofeedback and follow up tests (Table I).

ANORECTAL NEUROPHYSIOLOGY

The pudendoanal reflex was present in all subjects with a mean (SEM) latency of 42·3 (1·7) ms (Table I). The mean motor unit potential

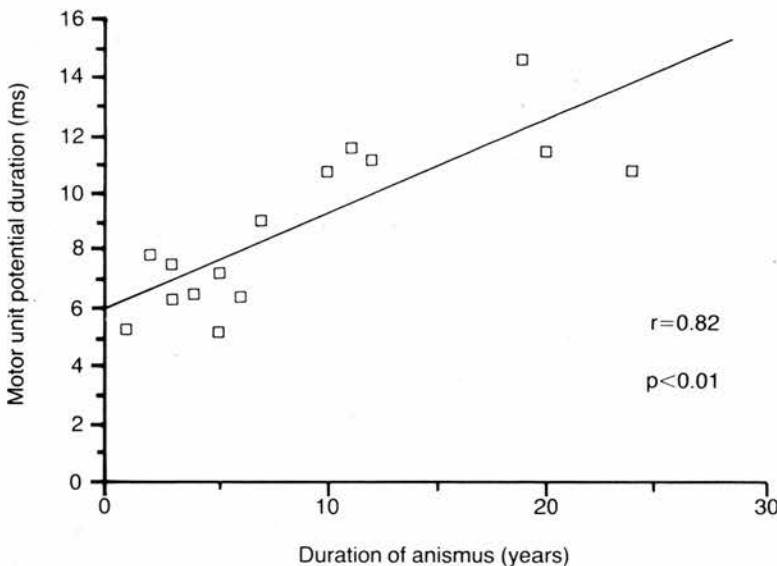*Figure 1: Correlation of external anal sphincter mean motor unit potential duration and duration of symptoms of anismus.*

TABLE II   *Results of anismus index plus records from diaries of 15 subjects before and after biofeedback and at later follow up (mean (SEM))*

Test	Before biofeedback	After biofeedback	Follow up (months)
Anismus index	69·9 (7·8)	14·0 (3·9)	14·6 (3·7)
Perineal pain at defecation	2·3 (0·2)	0·5 (0·2)	0·4 (0·2)
Difficulty at defecation	2·8 (0·1)	1·1 (0·2)	0·6 (0·1)
Time spent straining at stool	12·7 (1·2)	5·6 (0·8)	4·5 (0·5)
No of bowel motions per week	5·2 (0·8)	8·8 (1·0)	7·4 (0·7)
Ability to expel rectal balloon or balloon expulsion test	2	13	11

duration of the external anal sphincters was 8·8 (0·6) ms. The widest motor unit potentials were in subjects with the longest history of anismus (Fig 1) (r=0·82, p<0·01).

ANISMUS AND BIOFEEDBACK
The anismus index before and after biofeedback and at the latest follow up is given in Table II,
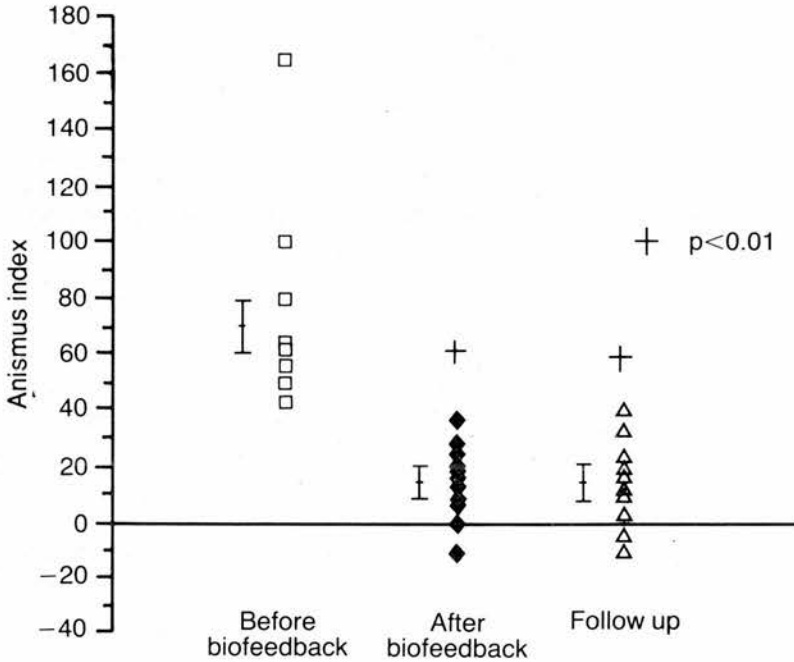

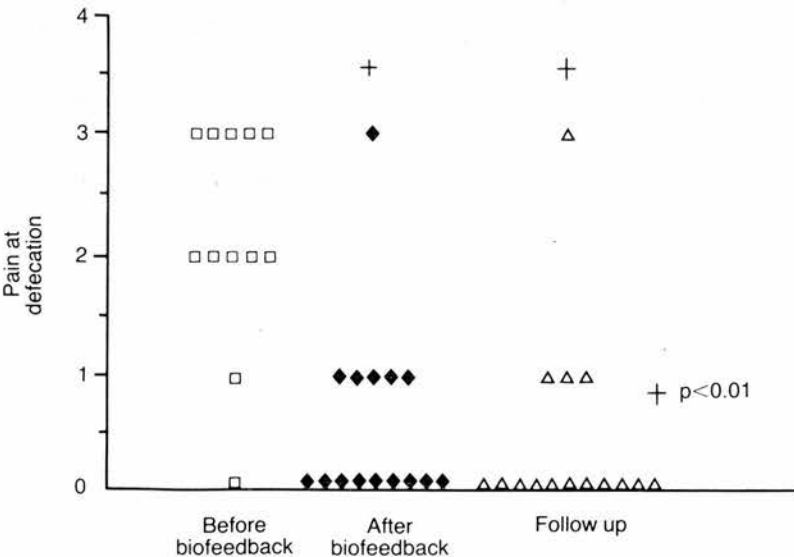*Figure 2: Anismus index before and after biofeedback (mean (SEM)).*

Figure 3: Degree of pain at defecation.

which also gives the data for stool frequency, perineal discomfort at defecation, difficulty with defecation, and time spent straining at stool before and after biofeedback training. The anismus index fell significantly (mean from 69·9 (7·8) to 14·0 (3·9); p<0·01) (Fig 2). The analogue scale value for pain at defecation, the degree of difficulty of defecation, and the time spent straining (Figs 3-5) were all significantly decreased (p<0·01), though the overall time spent at defecation was increased (Fig 6). The increase in the frequency of defecation was significant after biofeedback (p<0·01) (Fig 7) but this change did not persist at follow up. Before biofeedback training only two subjects could expel the rectal balloon, whereas after biofeedback training 13 out of 15 could do so.

RADIOLOGY
In the six subjects examined by radiology the anorectal angle before biofeedback was made more acute by squeezing movements (at rest 82° average, postsqueeze 67·5° average) and obtuse on straining (95° average). After biofeedback the effect of squeezing (88° at rest, 62·5° postsqueeze) still made the anorectal angle acute but the angle on straining became 104·5° on average. Five of the subjects could not expel the barium potato mixture when examined before biofeedback training. Only three could do so when examined by the same method after biofeedback despite the 10° increment caused by the opening out of the anorectal angle which had formerly acted as an obstacle to evacuation. All three subjects who, after biofeedback, failed to expel contrast medium, however, claimed that this was caused by lack of privacy during the examination and that they had no similar problem at home.

Discussion
Anorectal outlet obstruction due to anismus or anismus like activity follows the loss of the normal inhibition of the pelvic floor that occurs while straining to defecate.[11] In addition to their abnormal electromyographic responses the subjects in this series presented with intractable constipation. A sample of these showed typical radiological signs of this condition such as the acute anorectal angle becoming more acute with squeezing actions of the external sphincter and pelvic floor muscle combined with the same angle failing to open out to an obtuse angle with straining or bearing down movements to prepare for the evacuation of the faecal bolus. Radiological verification of these effects and the consistently abnormal electromyographic changes showed that the patients with intractable constipation had anismus or were in an animus like state. We know that the electromyographic changes alone may not be consistent and are also found in other conditions such as severe constipation, perineal pain, and the solitary rectal ulcer syndrome.[12]

The failure of the pelvic floor and external anal sphincter to relax is compounded by their inappropriate contraction.[13] The descriptive term 'anismus' has been applied to this part of the phenomenon[3] and is suspected if the history
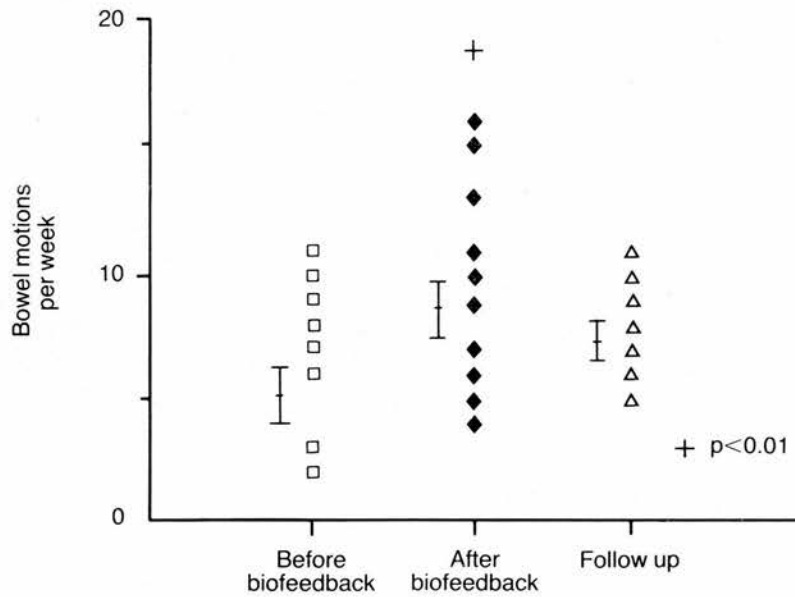
Figure 4: Degree of difficulty at defecation.

Figure 5: Time spent straining at stool (mean (SEM)).

Figure 6: Time spent on the toilet (mean (SEM)).

includes excessive straining during defecation with difficulty in evacuating the rectum, often requiring self digitation of the rectum.[14] The condition is confirmed objectively by anorectal manometry which initially shows a rise in sphincter pressure with straining[2] and the electromyographic studies showing increased activity with straining.[11] Defecography shows an accentuation of the puborectalis indentation at the anorectal angle with straining.[15]

Electromyographic changes suggesting anismus were detected in all subjects using a surface anal plug electrode to record the abnormal electromyographic changes indicative of the inappropriate contraction of the pelvic floor muscle when straining. There was a significant correlation between the duration of the presenting complaint of excessive straining and the mean motor potential duration of the external sphincter. This implies that straining caused a traction injury to the pudendal nerve[15] and that some reinnervation was occurring, which in turn prolonged the mean motor potential duration of the affected muscle.[9 16]

Attempts to overcome the obstructive effects of the non-relaxing puborectalis muscle at defecation in true anismus have been varied. Pharmacological blockade of the sympathetic innervation has been tried when pelvic floor spasm affects the bladder. Puborectalis relaxation by local injection of botulinus toxin has been shown to be effective in correcting anismus,[17] but the effect is relatively short lived and needs to be repeated. Various surgical methods such as partial division of the puborectalis muscle have been advocated[18 19] to allow obstructed defecation to proceed, but against this approach is the overriding importance of maintaining continence.

As anismus subjects are unaware of the incoordination of the pelvic floor, biofeedback offers a simple and minimally invasive technique for relearning how to suppress the non-relaxation of the pelvic floor.[5] The Myotron 120 device is ideally suited for retraining anismus subjects.[4] It is small, compact, easily operated, and relatively inexpensive. An experienced tutor needs to instruct the subjects on what they are required to do and aiming to achieve with the device. The clinical aim is trouble free defecation, which is not always accompanied by complete resolution of the anismus muscle abnormality.

In our series a minor degree of electromyographic anismus remained and was acceptable as it was asymptomatic. The subjects maintained a reduction in the anismus index over a two year period. When tested after the biofeedback training period the fall in the anismus index was accompanied by less time spent in straining, more bowel movements per week, and less perineal pain and discomfort. They more readily expelled a balloon bolus from the rectum and generally spent more time over defecation, feeling that there was clinical improvement in their defecation capability.

Our radiological studies confirm that the anorectal angle is acute in anismus subjects and becomes increasingly so on contraction of the sphincters as in squeezing movements, nor does this angle open out in the mimicked defecation of

Figure 7: Number of bowel motions per week (mean (SEM)).

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straining or bearing down. After biofeedback treatment the anorectal angle significantly 'opened out' on straining. Some subjects found it difficult to expel the barium mixture, unlike the balloon in the laboratory experiments, whether due to embarrassment or some element of the anismus like state continuing. In patients with defecation problems defecography may detect anatomical abnormalities and give some insight into the pathophysiology of defecation, but has been thought to lack clinical relevance in establishing the diagnosis and progress.[20]

What remains is to determine the longterm duration of the improvement and to acquire more information about the mechanism of the anismus defect as well as the nature of other anismus like states. It is not known how biofeedback reverses the anismus state or whether biofeedback training abolishes it directly or promotes indirectly a compensatory phenomenon.