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Anorectal function after low anterior resection of the rectum

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Abstract. Impaired neorectal function or sphincter incompetence have been respectively implicated as causative factors of increased frequency of defaecation or incontinence after low anterior resection of the rectum (LARR) for rectal carcinoma, although individual mechanisms of anorectal function have not been fully studied. Functional and laboratory results were evaluated in 19 subjects, who had a LARR for rectal carcinoma before and after the procedure, and were compared to those of normal subjects. LARR worsened anorectal function, mostly by significantly increasing the daily number of defaecations ($p<0.001$), while major incontinence was reported in three cases. Patients with rectal carcinoma have a decreased resting anal pressure on manometry, as compared to controls ($p<0.001$). LARR further reduces anal resting pressure ($p<0.001$) as well as all parameters that express internal sphincter activity, such as presence and amplitude of either slow ($p<0.05$ and $p<0.01$) or ultraslow waves. LARR also impaired external anal sphincter activity, as expressed by the reduction in anal squeeze pressure ($p<0.001$). Anorectal sampling was found reduced in incidence and frequency in LARR patients as compared to controls ($p<0.01$ and $p<0.001$), and was impaired even further postoperatively ($p<0.001$). Rectoanal inhibitory reflex was present in all but three patients postoperative, but significantly impaired as compared to controls. Rectal volumes to elicit transient or permanent desire to defecate, maximal tolerable rectal volume and rectal compliance were also significantly reduced after LARR ($p<0.001$, $p<0.001$, $p<0.01$ and $p<0.001$ respectively). Large bowel transit was significantly enhanced after LARR ($p<0.001$). On defaecography, the anorectal angle was found to be more obtuse but in higher position postoperatively as compared to controls ($p<0.001$). Bowel motion frequency was inversely related to rectal compliance ($p<0.001$) and length of remaining distal rectal stump, while patients with incontinence exhibited the lowest anal pressures. It is concluded that reduced neorectal capacity after removal of the rectum and impaired anal sphincter function because of stretching and damaged innervation, as well as impaired rectoanal coordination are all responsible for the functional problems after LARR.

Résumé. On attribue à une dysfonction du néorectum ou à une insuffisance sphinctérienne l'augmentation de fréquence des défécations et l'incontinence observée après des résection antérieures basses du rectum pour cancer rectal bien que les différents mécanismes de la fonction anorectale n'aient pas été totalement étudiés. Les résultats fonctionnels et les valeurs de laboratoire ont été déterminés chez 19 patients avant et après résection antérieure basse pour cancer du rectum; ces données ont été comparées à des sujets témoins. La résection antérieure basse du rectum péjore la fonction anale en augmentant essentiellement le nombre d'exonérations quotidiennes ($P<0.001$) alors que des incontinences majeures sont observées chez 3 patients. Les patients avec un cancer du rectum ont une diminution de la pression anale de repos à la manométrie en comparaison au témoin ($P<0.001$). La résection antérieure basse, par ailleurs, diminue la pression de repos ($P<0.001$) de même que tous les paramètres témoignant de l'activité du sphincter interne telles que la présence et l'amplitude d'ondes de contractions lentes ($P<0.05$ et $P<0.01$) ou de contractions ultra-lentes. La résection antérieure basse interfère avec l'activité du sphincter externe ainsi qu'en témoigne la réduction de la pression de contraction volontaire ($P<0.001$). L'échantillonage anorectal était réduit en incidence et fréquence chez des patients opérés comparativement au contrôle ($P<0.01$ et $P<0.001$) et était altéré en post-opératoire également ($P<0.001$). Le réflexe inhibiteur recto-anal était présent chez tous les patients à l'exception de 3 en post-opératoire mais était significativement altéré comparativement au contrôle. Le volume rectal entraînant le besoin transitoire ou permanent d'exonérer de méme que le volume maximal tolérable et la compliance rectale était significativement réduite après résection antérieure basse ($P<0.001$, $P<0.001$, $P<0.01$ et $P<0.001$ respective-

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ment). Le temps de transit colique était significativement accéléré après résection antérieure basse ($P<0.001$). Sur les défécographies, l'angle ano-rectal était plus obtus et en position plus haute en post-opératoire comparativement au sujet témoin ($P<0.001$). La fréquence des exonérations était inversement proportionelle à la compliance rectale ($P<0.001$) et à la longueur du moignon rectal résiduel alors que les patients présentant une incontinence avaient des pressions anales les plus basses. On en conclut que les troubles fonctionnels secondaires à une résection antérieure basse résultent d'une diminution de la capacité du néo-rectum et d'une altération de la fonction sphinctérienne secondaire à la dilatation du néo-rectum et d'une altération de la fonction sphinctérienne secondaire à la dilatation anale et à une atteinte de l'innervation de même qu'à des troubles de la coordination recto-anale.

In oncological terms, low anterior resection of the rectum (LARR) for very low rectal carcinomas is an adequate operation, offering recurrence and survival rates comparable to those of abdominoperineal resection [1–4] and better quality of life, as a result of preserving the anus [3, 5]. The introduction of stapling devices has allowed surgeons to overcome hand-sewing difficulties and to achieve rectal anastomosis very close to the pelvic floor [6–8]. Thus, LARR is nowadays considered as the operation of choice for low rectal lesions [2, 3, 7]. However, there are patients, who experience various functional abnormalities after LARR. The abnormality most commonly seen is the increased frequency of defaecation, while occasional incontinence of liquid, and less frequently, of solid stools are also reported [2, 5, 9, 10]. Controversy still exists concerning the pathophysiology of these functional disturbances. Both pelvic nerve damage during dissection of the rectum [11, 12] and sphincter stretching during fashioning of the anastomosis [12, 13], as well as reduced neorectum capacitance [9, 10] have been implicated. In an effort to add further information to the issue, we prospectively studied the changes in ano-neorectal function after low anterior resection of the rectum by means of clinical assessment, functional tests, anorectal manometry, evacuation proctography and colonic transit studies.

Patients and methods

Twenty-six patients underwent a LARR for rectal carcinoma. Nineteen of them completed all the pre- and postoperative tests, and were included in the study. There were no cases with anastomotic leak or local recurrence among them. Ten patients were men and 9 women, with a mean age of 59 years (range: 39 to 72 years). The operation in all cases involved resection of the lower discending colon, sigmoid colon and rectum with high ligation of the inferior mesenteric vessels, total excision of the mesorectum and lateral pelvic clearance. An end-to-end colorectal anastomosis was fashioned using a circular EEA 31 stapler. No temporary defunctioning colostomy was performed in any case. The maximal tumour diameter and the margin of distal clearance were measured on each fresh specimen. The distance of the anastomosis from the dentate line was assessed postoperatively by proctoscopy. The results of the patients were compared to those of 16 age and sex matched normal subjects, who served as controls.

Clinical assessment

Bowel frequency per day, ability to distinguish flatus from faeces, ability to defer call for stools for at least 15 min and frequency of faecal soiling were assessed 9 to 12 months postoperatively.

After clinical assessment, the patients were classified into six grades, according to McDonald and Heald classification [5] as follows: (a) grade 0: no change in bowel habit and continence, (b) grade I: increased number of stools without affecting normal lifestyle, (c) grade II: increased number of stools that affects daily social habits, (d) grade III: occasional soiling from liquid faeces, (e) grade IV: frequent soiling or occasional incontinence to solid faeces and (f) grade V: frequent incontinence to solid faeces.

Anorectal manometry

All patients had anorectal manometry preoperatively and 9 to 12 months postoperatively. The polyvinyl catheter, used for manometry, had an external diameter of 4.2 mm and consisted of one central (1.5 mm internal diameter) and four radially arranged tubes (1 mm internal diameter). The central tube ended in an inflatable balloon at the tip of the probe. Each of the four peripheral, blindly ended, tubes had a side opening and was continuously perfused with water (0.6 ml/min), by a low compliance perfusion system (Arndorfer Medical Specialties, Greendale, Wisconsin, USA). The four openings were arranged at 0.5 cm intervals along the probe. The distal opening was placed 5 cm central to the tip of the probe. A pressure transducer, incorporated in each perfusion line, was connected to an amplifier and a chart recorder (Beckman Dynograph R-611, Beckman Instruments Inc, California, USA).

During rectoanal manometry, the following parameters were calculated, at first, by the station pull-through technique: (i) the mean maximal resting pressure (MMRP), (ii) the total length of the anal sphincter, (iii) the length of the high pressure zone (the sphincter length with pressures higher than the 50% value of the MMRP) and (iv) the maximal mean squeeze pressure (MMSP). Thereafter, the catheter was again placed into the rectum, with the side holes along the anal canal, for stationary recordings for 1 h. From these recordings, the presence, frequency and amplitude of slow and ultra slow waves and of sampling events were assessed. In postoperative measurements, by inflating the endorectal balloon with air, the minimal volume to elicit transient call for stools, the minimal volume to elicit permanent call for stools and the maximal tolerable volume were assessed. Also postoperatively, the rectoanal inhibitory reflex (RAIR) was tested by inflating the balloon with air in increments of 10 ml for periods of 60 s and up to 150 ml. The following variables of the RAIR were measured: (a) minimal volume to initiate transient internal anal sphincter relaxation, (b) percentage and absolute value of anal pressure drop during inflation of rectal balloon at 100 cc (c) volume of air in the rectal balloon, that caused sustained IAS relaxation. The pressures created in the rectal balloon during inflation were simultaneously measured by connecting the central catheter to an air filled transducer, and the rectal compliance was calculated from the slope of the volume/pressure curve.

Anorectal radiology

Evacuation proctography was performed by transanally inserting into the rectum 150 ml of mashed baritate potato, simulating faeces. While the patients were seated on a radiolucent commode, well penetrated lateral radiographs at rest, during squeezing and during straining were taken. On these radiographs, the anorectal angle and its distance from the pubococcygeus line were measured (positive values for tip of the angle placed below the line).

Colonic transit studies

Subjects swallowed 30 radio-opaque shapes, and x-rays of the daily collected stools were taken, where from the time taken to defecate, at least 80% of the shapes, was assessed.

Statistical analysis

Unless otherwise stated, values are expressed as mean ± SD. Statistical analysis was performed by using Fisher's exact test, Mann-Whitney U-test, Wilcoxon test for paired and unpaired values and regression analysis for "the best fit", as appropriate. *P* values less than 0.05 were considered to be statistically significant.

Results

Tumour diameter was 4.6 ± 1.5 cm (range: 1 to 7.5 cm). The margin of distal clearance was 2.2 ± 0.8 cm (range: 1 to 4 cm) and the distance of anastomotic line to dentate line varied from 0.5 to 5 cm, wich a mean value of 2.85 ± 1.4 cm. There were 1 Duke's A, 11 Duke's B and 7 Duke's C carcinomas. Margins of resection were reported to be free of disease. There was no clinical evidence of anastomotic leak and no recurrence of disease was detected during the follow-up period. Bowel frequency increased postoperatively as compared both to preoperative state and to controls. Furthermore, 7 of the patients could not distinguish flatus from faeces and 6 could not defer call for stools for more than 15 min. Overall quality of bowel habits was significantly worse in postoperative patients as compared to both to preoperative state and that of the controls (Table 1). Both the number of bowel motions and the clinical grading were inversely related to the length of the remaining distal rectum (distance of anastomotic line to dentate line) (Fig. 1 and 2). Resting pressure was lower in patients than in controls, decreasing even further postoperatively. Squeeze pressure also decreased after LARR, as did the anal pressure increment (MMSP minus MMRP) and the length of the HPZ (Table 2). Slow waves, of a lower amplitude, were present for shorter periods of time, and in less patients preoperatively, as compared to controls. The operation further reduced the presence and the amplitude of slow waves. Ultra slow waves were present in 4 patients preoperatively and in one of them postoperatively. The operation reduced the amplitude of ultra slow waves for this patient. Frequency of sampling was lower in patients as compared to controls. Sampling was absent in 4 patients preoperatively and in one control only. Postoperatively, the frequency of sampling events was reduced even further, while less reduction in resting pressure was observed during the sampling events. Seven patients postoperatively did not exhibit any sampling events (Table 2). These patients tended to present the worst functional results.

RAIR was absent in three patients postoperatively. These patients did not exhibit sampling events, and they complained of major (2 cases) or minor (1 case) incontinence. Minimal volume to elicit permanent IAS relaxation was significantly smaller, as compared to controls. At 100 ml of air in the rectal balloon, a smaller percentage of resting pressure drop was observed, although the residual

Table 1. Results of clinical assessment

	Controls	Pre-operatively	Post-operatively
Bowel motions/day	1.1 ± 0.3	1.3 ± 0.7	3.9 ± 3**
Ability to distinguish flatus from feces	16/16	18/19	12/19*
Ability to defer call for stools <15 min	16/16	18/19	13/19**
Major incontinence	0/16	0/19	3/19
Grading	0:15, I:1	0:16, I:2 II:1	0:2, I:5** II:4, III:4 IV:2, V:2

* $p<0.05$; ** $p<0.001$ (postop vs preop and controls)

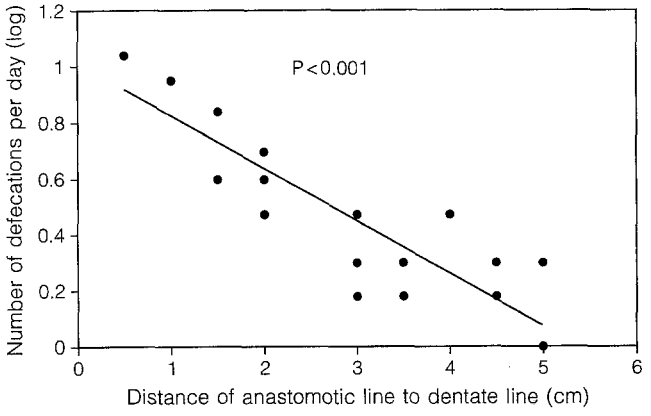

Fig. 1. The number of daily bowel motions in patients after LARR is significantly inversely related to the length of the rectal stump, which is left in situ, distal to the anastomosis. The line of identify fits to a linear model (Log values of the number of daily motions have been plotted)

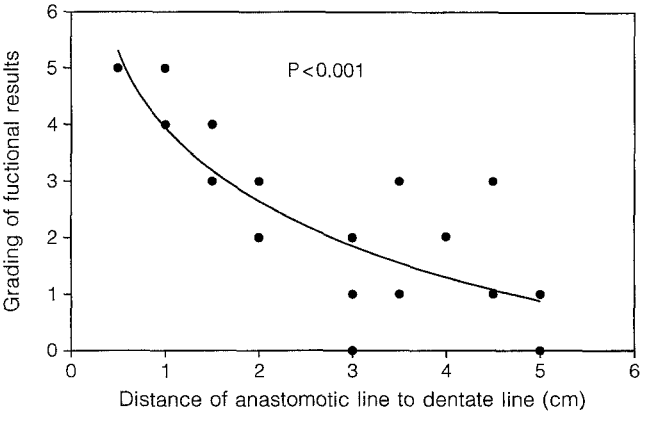

Fig. 2. Functional results after LARR, as defined by the clinical grading according to McDonald and Heald [5], are significantly related to the length of the rectal stump, which is left in situ. The longer the rectal stump the better the functional results are. The line or identify fits to a logarithmic model

Table 2. Variables of anal sphincter activity

	Controls	Preop.	Postop.
MMRP (cmH_2O)	75 ± 11	60 ± 7*[1]	47 ± 10*[2]
MMSR (cmH_2O)	162 ± 38	169 ± 29	104 ± 28*[2]
Pressure increment (cmH_2O)	87 ± 25	108 ± 30	56 ± 22*[2]
HPZ (cm)	3.5 ± 0.5	3.5 ± 0.4	2.4 ± 0.4*[2]
Slow waves			
presence (*n* of subjects)	15/16	9/19*[4]	3/19*[6]
presence (% of time)	68 ± 11	50 ± 11*[5]	37 ± 4*[6]
amplitude (cmH_2O)	21 ± 4	17 ± 3*[3]	12 ± 1*[7]
Ultra slow waves			
presence (*n* of subjects)	4/16	4/19	1/19
presence (% of time)	6 ± 2	5 ± 1	3
amplitude (cmH_2O)	31 ± 8	23 ± 4	17
Sampling			
presence (*n* of subjects)	16/16	15/19	12/19
frequency (events/h)	10 ± 2	5.5 ± 4*[8]	2.3 ± 2*[9]
reduction of resting pressure (%)	54 ± 12	52 ± 9	39 ± 8*[10]

*[1] $p<0.001$ (preop vs controls)
*[2] $p<0.001$ (preop vs postop),
*[3] $p<0.05$, *[4] $p<0.01$, *[5] $p<0.001$ (preop vs controls);
*[6] $p<0.05$, *[7] $p<0.01$ (preop vs postop)
*[8] $p<0.01$ (preop vs controls); *[9] $p<0.001$, *[10] $p=0.002$ (preop vs postop)

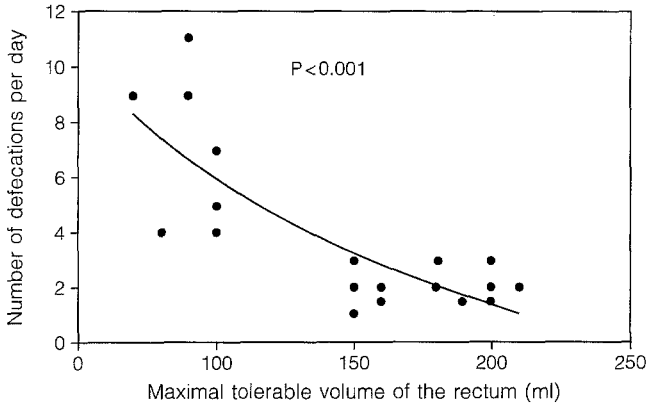

Fig. 3. The number of daily bowel motions after LARR is inversely related the maximal tolerable volume of the neorectum. The line of identify fits to a logarithmic model

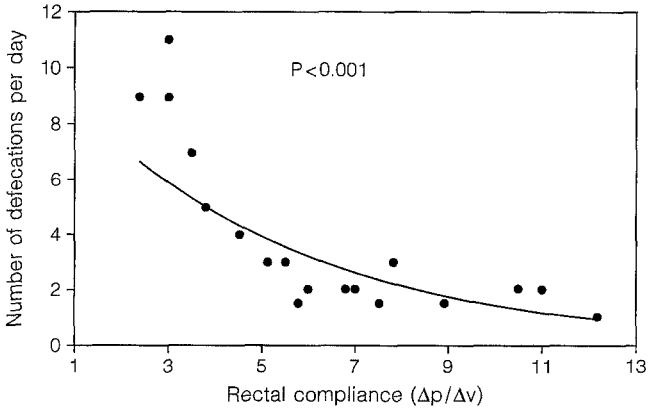

Fig. 4. A significant inverse relationship exists between the compliance of the neorectum after LARR and the number of daily bowel motions. The line of identify fits to an exponential model

Table 3. Rectoanal inhibitory reflex, rectal sentation and rectal compliance in postoperative patients and controls

	Controls	Postop	p<
Rectoanal inhibitory reflex			
minimal rectal vol for transient IAS relaxation (ml)	30 ± 9	26 ± 5	n.s.
minimal rectal vol for sustained IAS relaxation (ml)	113 ± 16	71 ± 23	0.001
IAS residual pressure at 100 ml of rectal air (%)	43 ± 5	55 ± 9	0.001
IAS residual pressure at 100 ml of rectal air (cmH_2O)	35 ± 8	27 ± 5	0.001
Minimal rectal vol for transient desire to defecate (ml)	85 ± 15	20 ± 44	0.001
Minimal rectal vol for sustained desire to defecate (ml)	131 ± 40	83 ± 29	0.001
Maximal tolerable rectal vol (ml)	245 ± 58	145 ± 46	0.001
Rectal compliance (ml/cmH_2O)	11.3 ± 2.1	6.2 ± 2.8	0.001

Table 4. Anorectal angle (degrees) and perineal descent (cm) in postoperative patients and controls

	Controls	Patients	*p*<
ARA at rest	98 ± 6	107 ± 14	0.05
ARA during squeezing	78 ± 4	96 ± 8	0.001
ARA at straining	116 ± 13	136 ± 15	0.001
PD at rest	1.7 ± 0.6	0.6 ± 0.7	0.001
PD during squeezing	0.8 ± 0.5	0 ± 0.8	0.001
PD at straining	5.2 ± 1.2	3.4 ± 1.2	0.01

ARA, anorectal angle (degrees); PD, perineal descent (cm)

pressure of IAS at this rectal volume was significantly less, as compared to controls. Minimal rectal volumes to elicit transient and permanent desire to defecate, as well as maximal rectal tolerable volume were significantly less in postoperative patients than in controls. A significant inverse relationship was found between maximal tolerable volume and number of defaecations (Fig. 3). In addition, compliance of the neorectum of the patients was less compared to the rectal compliance of the controls, while a significant inverse relationship was found between compliance and number of defaecations after LARR (Fig. 4) (Table 3).

In comparison with controls, postoperative patients showed a faster large bowel transit, as they expelled more than 80% of the shapes in a shorter period of time (41 ± 4 h vs 62 ± 8 h of the controls, $p<0.0019$). At defaecography, the anorectal angle for all situations was found to be more obtuse in postoperative cases, as compared to controls. Similarly, perineal descent, again for all situations, was less in patients after surgery, then in controls (Table 4).

Discussion

Several factors are considered to be essential for normal anorectal function. Faecal volume and consistency, colonic motility, rectal distensibility, anorectal angle, integrity of

anorectal sensation and internal and external sphincter activity are all responsible for the maintainance of continence [14–15]. Lack or alteration of one of the above rarely determines bowel frequency or incontinence, which however may develop when more than one factors are affected. LARR is associated with impaired anorectal function, mainly characterized by both increased bowel frequency and minor or major soiling, in percentages varying from study, though significant for most of them [5, 8–10, 16]. The functional results of the present study did not differ from those reported by most authors. The majority of the patients, approximately one year after surgery, experienced functional anorectal problems, interfering with daily social habits.

Although results from anorectal pathophysiological studies after LARR are reported to be at variance, it seems that anal sphincter injury is the predominant cause of incontinence [8, 12, 17, 18], while increased bowel frequency is mainly the result of impaired neorectal function [5, 8–10, 17, 18]. Data on anal sphincter function after LARR is controversial. Most of the studies report an impairment of the internal anal sphincter function [12, 16, 18, 19], while there are fewer reports confirming an impairment of the external sphincter activity as well [8, 17].

The data from the present study showed, at least to some extent, that internal anal sphincter activity is already impaired in patients with a low rectal carcinoma, and this is expressed by the lower anal resting pressure and the reduced presence of slow waves, as compared to controls. The interpretation of these original findings is not clear. We attribute the reduced internal sphincter activity to the presence of the rectal tumour, which might act as an endorectal volume, continuously eliciting inhibition of the internal sphincter. The results of the present study also showed, that LARR further impairs anal function, by affecting the activity of both the internal and the external anal sphincters.

The mechanism, by which anal sphincter injury occurs after LARR, is unclear. Both direct or indirect injury to the innervation have been implicated. Horgan et al. [12] support the view, that impairment of the internal anal sphincter activity is a result of direct injury, due to anal dilatation by the stapling device, during fashioning of the low anastomosis, in a manner similar to Lord's operation [20]. They also found, that the intraabdominal steps of the procedure that might disrupt sympathetic, parasympathetic and transmural innervation of the anal sphincters [11], do not affect intraoperative anal pressure. However, this hypothesis can hardly explain the impairment of external anal sphincter activity after LARR, observed by us and others [8, 17]. This impairment is more likely to occur because of an injury to the nerve supply of the sphincter, as a result of division, stretching or even thermal injury. Hallgren et al. [21] have confirmed this hypothesis. Hence, anal sphincter dysfunction after LARR is the result of either anal dilatation or damage to the nerve supply, or most likely both.

Failure of the neorectum after LARR fully exhibit the reservoir properties of a normal rectal ampulla has been implicated as the main cause of the increased frequency of daily bowel motions [8–10, 16–18]. It has been also shown, that the shorter the rectal stump left in situ is, the worse the functional results [10, 18]. Neorectal function in the present series was also found to be significantly compromised. Considering that maximal tolerable rectal volume is inversely related to the daily frequency of bowel motions, and that the number of defaecations and the functional grading in general are also inversely related to the length of the rectal stump that is left in situ, it can be assumed that as much as possible of the distal rectum must be preserved, whenever the level of the tumour permits without compromising the oncological principles of the operation.

Reports on rectoanal inhibitory reflex after LARR are variant. Some report absence of the reflex in most of the patients [8], some others find the reflex in approximately half of the cases [9], while others report a recovery of the reflex several months postoperatively in the majority of the patients [17, 18]. Discrepancy of the results on the inhibitory reflex might reflect technical differences or differences in interpreting the results. In the present series, the reflex was present in all but 3 patients postoperatively. The 3 patients, with an absent reflex, had resting pressures towards the lowest range of values, a reason for which the reflex might be absent [22], while one of them reported occasional soiling and the other two frank incontinence. However, all the features of the inhibitory reflex were compromised postoperatively in all patients as compared to normals. Although it has been postulated that tension receptors responsible for the inhibitory reflex are positioned on the rectal wall [23], the presence of the reflex after excision of the rectum signifies that similar receptors should be also found abundant in the pelvic musculature, a hypothesis also proposed by others [24].

Transient spontaneous relaxation of the upper part of the internal anal sphincter is defined as sampling, and during this event, a small amount of rectal contents comes into contact with the transitional zone, and sensory information is provided as to the nature of these contents [25]. Sampling is observed regularly in normal subjects, but it is defective in patients with idiopathic incontinence [26]. We found that patients with rectal carcinoma also have a defective anorectal sampling, possibly as a result of an already partially relaxed internal sphincter, thus being unable to show any further relaxation. Sampling becomes more defective after LARR either because of further sphincter relaxation, or even disruption of the neural pathways, mediating this local reflex.

An acute anorectal junction, which is situated very close to the pubococcegeal line at rest, has been considered of great significance in maintaining continence, by composing a flap-valve mechanism [27, 28]. Functional improvement after surgery for incontinence has been associated with an elevation of the anorectal angle, which also becomes more acute [29]. Batignati et al. [18] have reported, that the anorectal angle was found to be more obtuse and in significant lower position in 6 subjects after LARR for rectal carcinoma as compared to controls. They postulate that this abnormal finding contributes, to some extent, to the functional problems observed in patients after LARR. However, the results of the present study showed that, although anorectal angle becomes more obtuse, it is situated in higher position after LARR. These

findings have been also observed after anterior resection of the rectum for rectal prolapse, with improvement of incontinence [30], adding, thus, further evidence to refute the flap-valve theory [31].

Left colon segmental activity is considered essential in impeding the transit of colonic contents. Removal, therefore, of the left colon results in a faster colonic transit [30]. This was the case, in the patients of the present series, who showed a significantly faster colonic transit time as compared to controls. This observation signifies, that larger amounts of faecal contents, in a neorectum with reduced capacity and compliance, may excert a great strain on an already impaired anal sphincter, contributing thus to greater urge for defaecation or even incontinence.

In conclusion, LARR for rectal carcinoma is associated with defaecatory disorders, namely a degree of incontinence and increased number of bowel motions. The former is the result of impaired internal as well as external anal sphincter activity, possibly because of damage to the innervation or/and of anal stretching. The latter one is considered to be the result of reduced neorectal capacity and compliance, and of increased colonic transit. Preoperative manometry should be applied in all patients before a sphincter saving operation, to identify any possible preexcisting impaired sphincter activity, which might turn into severe incontinence postoperatively. Construction of a colonic reservoir might also be considered in a very low anastomosis, as proposed by others [9, 23].

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