Int J Colorect Dis (1990) 5:37–40

International Journal of Colorectal Disease



# Rectal compliance: a critical reappraisal

**R. D. Madoff**[1], **W. J. Orrom**[2], **D. A. Rothenberger**[2] **and S. M. Goldberg**[2]

[1] University of Massachusetts Medical School and Worcester Memorial Hospital, Worcester, Massachusetts, USA
[2] Division of Colon and Rectal Surgery University of Minnesota Hospital and Clinic, Minneapolis, Minnesota, USA

Accepted: 15 September 1989

**Abstract.** Compliance is a widely measured parameter of rectal function. Its value is determined clinically by recording pressure changes associated with volume infusion into a rectal balloon. This paper examines the inherent assumptions of the rectal balloon technique and discusses several of its shortcomings. A stricter definition of rectal compliance is needed, and in vivo compliance should be correlated with the directly measured mechanical properties of the rectal wall.

## Introduction

To maintain continence, the rectum must serve as a faecal reservoir. This storage function requires the rectum to be distensible to accommodate the incoming faecal load. In the surgical literature, distensibility is most commonly measured as rectal compliance, which is defined as the change in rectal volume per unit change in rectal pressure.

In most laboratories, rectal compliance is determined with a rectal balloon technique in which serial volumes of fluid are infused to generate a pressure-volume curve. The proctometrogram, a technical refinement of this method, is based on the same principles [1]. Using these techniques, decreased rectal compliance has been demonstrated in such pathological states as active ulcerative colitis [2] and radiation proctitis [3].

Despite the apparent simplicity of determining rectal compliance, different investigators report a wide range of normal values (Table 1) [2, 4–7]. We believe these discrepancies reflect fundamental theoretical defects inherent in the rectal balloon technique that call its accuracy and relevance into question.

The hypothesis underlying the techniques of determining rectal compliance suggests that: the mechanical properties of the rectal wall are altered by pathologic processes, and that, these alterations adversely affect faecal continence, and can be measured with reasonable accuracy in vivo.

The balloon technique for measuring rectal distensibility rests on these assumptions:

1. The rectum can be modelled as a closed cylinder.
2. Rectal size does not influence measured rectal compliance.
3. Extrarectal tissues do not contribute to measured rectal compliance.
4. The rectum is mechanically passive.

Each assumption is discussed in greater detail below.

### Is it legitimate to model the rectum as a closed cylinder?

It is obvious that no anatomical barrier exists between the lumina of the rectum and sigmoid colon, nor indeed has any functional barrier been described in this location. To measure rectal "compliance," a balloon is necessary to prevent reflux of the infused fluid into the colon. It is unknown whether such reflux plays a physiological role in faecal storage between evacuations. With the balloon technique, an arbitrary proximal limit to the rectum is assigned where none, in fact, exists. Furthermore, because the balloon technique is "blind," the proximal limit of the balloon's axial expansion during volume infusion is not legitimate. This point becomes the newly assigned "top" of the rectum.

Consider two rectums with mechanically identical walls. Should axial expansion of the rectal balloon be

**Table 1.** Normal rectal compliance

| Author, year | Compliance (ml/cm $H_2O$) |
|---|---|
| Suzuki, 1982 [4] | 15.7 |
| Varma, 1985 [3] | 9.0 |
| Roe, 1986 [5] | 5.1 |
| Womack, 1986 [6] | 6.6[a] |
| Rao, 1987 [2] | 11.5 |
| Allan, 1987 [7] | 5.9 |

[a] Calculated from published graph

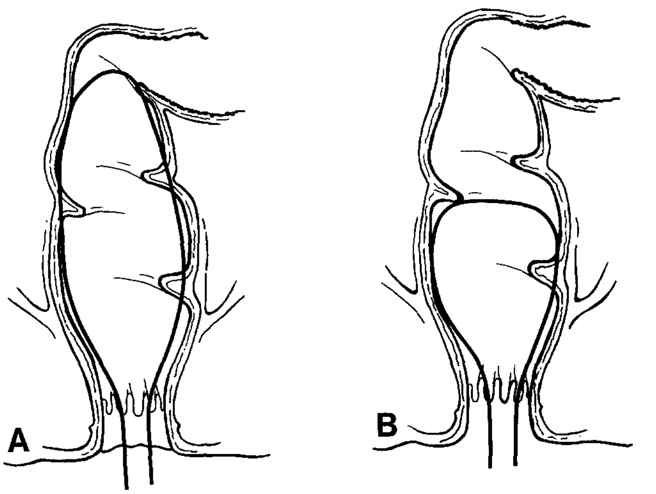

**Fig. 1 A, B.** Effect of rectal balloon axial distension on measured rectal compliance. Even if rectums **A** and **B** are mechanically identical, measured compliance in **A** will be greater

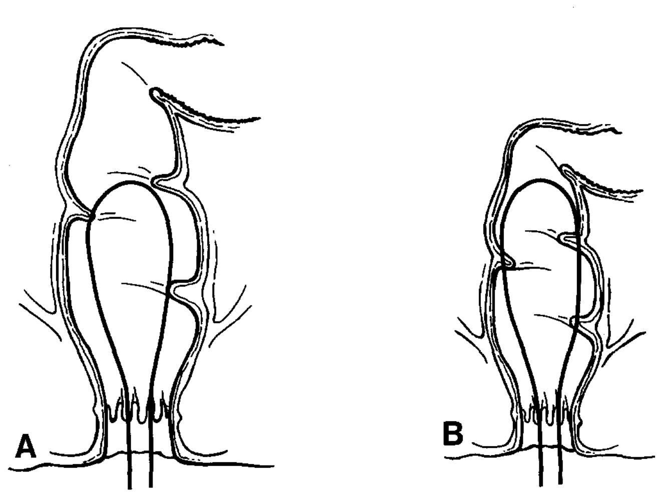

**Fig. 2 A, B.** Effect of rectal size on measured rectal compliance. Regardless of its wall stiffness, rectum **A** will have a higher measured compliance than **B**

limited in midrectum (e.g. by a kink or stricture), radial rectal distension will begin at low volumes and measured compliance will be low. Conversely, if an obtuse rectosigmoid junction permits expansion of the balloon into the distal sigmoid, radial distension of the rectum will occur only after a large volume has been infused and the measured compliance will appear to be high (Fig. 1). Indeed, the balloon infusion technique rests squarely on the assumption that the balloon's axial expansion will stop precisely at the rectosigmoid junction. This supposition has never been tested. It is worth considering that, given an adequately compliant balloon, even a lead pipe would appear to be compliant by this technique; the infused volume could be accommodated without a corresponding rise in pressure by simple axial expansion of the balloon.

## Does rectal size influence measured compliance?

Patients with acquired megacolon have been found to have high rectal compliance [1]. This stands in contrast to the operative observation that acquired megarectum frequently appears to be thick walled and, if anything, stiffer than normal rectum. The discrepancy is explained by the different resting volumes of normal rectum and megarectum and by the confusion that exists between the concepts of capacity and compliance.

Given a very large rectum, a very large volume of fluid must be infused to initiate rectal distension. The volume of fluid adequate to distend a normal sized rectum would not even begin to stretch the walls of a megarectum (Fig. 2).

Conversely, the volume of fluid needed to distend a megarectum would, at a minimum, stretch a normal rectum beyond its usual physiological range, even to the point of rupture. Once again, given a large enough size, a totally rigid rectum would appear to be highly compliant with the balloon technique.

A related problem of size discrepancy has been addressed by pulmonary physiologists. The in vivo compliance of the pediatric lung is less than that of the adult lung, even though the distensibility of the lung tissue itself is identical [8]. This disparity is due to the differences in lung size, and is reconciled by normalizing the measured compliance to lung volume:

$$\text{Specific compliance} = \frac{\text{measured compliance}}{\text{resting volume}} \qquad (1)$$

In the lung, the resting volume is easily determined and is known as the "functional residual capacity". The specific compliance of normal lungs is similar irrespective of lung size [8]. Unfortunately, because the rectum has no functional proximal limit, there is no such thing as a resting rectal volume, and specific rectal compliance therefore can not be calculated.

## Do extrarectal tissues influence measured rectal compliance?

The rectum is surrounded by extrarectal fat, vascular and nervous tissues, genitourinary structures, and the bony pelvis. Determining rectal compliance with the balloon technique actually measures several compliances in series: the compliance of the balloon, the rectum, and the extrarectal tissues. The relationship of these serial compliances is described by this equation:

$$\frac{1}{C_{\text{measured}}} = \frac{1}{C_{\text{balloon}}} + \frac{1}{C_{\text{rectum}}} + \frac{1}{C_{\text{extrarectal tissue}}} \qquad (2)$$

where C = compliance

It is widely accepted that balloon compliance must not significantly alter the measurement of rectal compliance, and to prevent such alteration all investigators use highly compliant rectal balloons. As can be seen from equation (2), a very large $C_{\text{balloon}}$ term causes its reciprocal to be-

**Table 2.** Compliance and tissue elastic properties: a comparison of active inflammatory bowel

| | Active inflammatory bowel disease ($n=5$) mean (range) | Controls ($n=5$) mean (range) | $p$ |
|---|---|---|---|
| Compliance (mls/mm Hg) | 3.11 (0.84 – 6.24) | 7.00 (6.03 – 9.38) | 0.043 |
| Initial modulus (kg/cm$^2$) | 0.016 (0.006– 0.440) | 0.014 (0.005– 0.034) | N.S. |
| Stiff modulus (kg/cm$^2$) | 3.600 (1.20 –25.10) | 6.600 (1.920–15.700) | N.S. |

come negligibly small. One is then left with this equation:

$$\frac{1}{C_{\text{measured}}} = \frac{1}{C_{\text{rectum}}} + \frac{1}{C_{\text{extrarectal tissue}}} \quad (3)$$

The relative values of $C_{\text{rectum}}$ and $C_{\text{extrarectal tissue}}$ are unknown. Nonetheless, in all probability, it is not legitimate simply to ignore the term $1/C_{\text{extrarectal tissue}}$. Indeed, it is entirely possible that, given the anatomy of the bony pelvis surrounding the rectum, the $1/C_{\text{rectum}}$ term is negligibly small in equation (3) and that the measured compliance actually reflects the size, anatomy, and composition of the extrarectal pelvic structures.

## Is the rectum mechanically passive?

It has long been known that the rectum passively accommodates a volume load [9]. Thus, if a balloon is inserted into the rectum and inflated, the initially recorded rise in rectal pressure gradually returns to baseline over the course of one to two minutes (Fig. 3). Current measurement techniques for rectal compliance do not take this phenomenon into account.

A measured decrease in rectal compliance may be due to structural changes in the bowel wall, or simply to increased smooth muscle tone in the rectum. Rao demonstrated that the diminished rectal compliance seen in patients with active ulcerative colitis returns to near normal levels when the disease is quiescent [2]. Rao also found that rectal reactivity, defined as the peak minus steady state rectal pressure in response to rectal balloon inflation, was significantly greater in active ulcerative colitis than in normal controls or in patients with quiescent disease. These findings strongly suggest a role of increased muscle tone or muscle spasm in the genesis of diminished rectal compliance in ulcerative colitis.

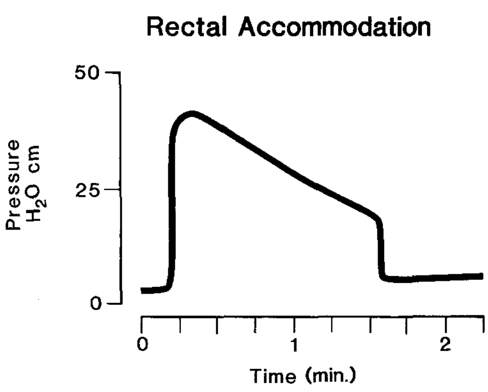


**Fig. 3.** Pressure response to inflation of a rectal balloon. Intrarectal pressure decreases with time

The implication of Rao's findings is clear: a "stiff" rectum in a patient with active ulcerative colitis is insufficient grounds for the rectum's removal, as the stiffness may well be reversible. Rao's findings also underline the confusion inherent in current usage of the term "compliance" with reference to the rectum. To some, compliance is a mechanical property of the rectal wall. To others, it simply implies the results of a functional measurement made on the rectum, usually with the balloon technique. We are unaware of any studies that correlate rectal compliance determined in vivo with the mechanical properties of the rectal wall determined in vitro.

In some preliminary work, we have compared rectal compliance measured in vivo (using a standard balloon proctogram technique as described by Preston and Lennard-Jones [10]), with tissue elasticity measured with an Instron tensiometer. This ex vivo method measures the "modulus of elasticity," i.e., the relationship between stress and strain for a particular material. Stress is the amount of force applied to a material and strain is a measure of the change in length of a material following an applied stress. The larger the number, the stiffer the material. The initial modulus refers to this relationship when measured during the initiation of stress (stretch), and the stiff modulus refers to measurements made just prior to breakage of the material. While in vivo measurement of compliance demonstrated low values in active inflammatory bowel disease when compared with controls, no such differences were seen comparing these two groups using ex vivo measurements of elasticity (Table 2).

## Conclusion

We do not believe that the balloon infusion technique accurately measures physical alterations in the rectal wall. At the same time, we do not believe that such changes are necessarily immeasurable, nor that they lack functional importance.

In order to improve on the current techniques of determining rectal compliance, in vivo measurement must be based on a method that ensures and accurately determines radial rectal distension alone. Measured rectal distensibility must be normalized to the rectum's resting dimensions. Distensibility measured in vivo must be correlated with distensibility measured in vitro. Once these studies have been performed, the true meaning of rectal compliance can be ascertained.

*Acknowledgement.* The authors would like to thank O. Douglas Wangensteen, Ph.D., for his helpful comments and suggestions.

## References

1. Varma JS, Smith AN (1986) Reproducibility of the proctometrogram. Gut 27:288–292
2. Rao SSC, Read NW, Davison PA, Bannister JJ, Holdsworth CD (1987) Anorectal sensitivity and responses to rectal distention in patients with ulcerative colitis. Gastroenterology 93:1270–1275
3. Varma JS, Smith AN, Busuttil A (1985) Correlation of clinical and manometric abnormalities of rectal function following chronic radiation injury. Br J Surg 72:875–878
4. Suzuki H, Matsumoto K, Amano S, Fujioka M, Hozumi M (1980) Anorectal pressure and rectal compliance after low anterior resection. Br J Surg 67:655–657
5. Roe AM, Bartolo DCC, Mortensen NJM (1986) Diagnosis and surgical management of intractable constipation. Br J Surg 73:854–861
6. Womack NR, Morrison JFB, Wiliams NS (1986) The role of pelvic floor denervation in the aetiology of idiopathic faecal incontinence. Br J Surg 73:404–407
7. Allan A, Ambrose NS, Silverman S, Keighley MRB (1987) Physiology study of pruritus ani. Br J Surg 74:576–579
8. Comroe JH, JR (1974) Physiology of Respiration: An Introductory Text. Year Book Medical Publishers, Chicago
9. Duthie HL (1975) Dynamics of the rectum and anus. Clin Gastroenterol 4:467–477
10. Preston DM, Barnes PRH, Lennard-Jones JE (1983). Proctometrogram: does it have a role in the evaluation of adults with constipation? Gut 24:86

David A. Rothenberger, M.D.
Division of Colon and Rectal Surgery
Box 450
University of Minnesota Hospital and Clinic
420 Delaware Street SE
Minneapolis, MN 55455
USA