NEUROGENIC DISTURBANCES OF THE COLON AND THEIR INVESTIGATION BY THE COLONMETROGRAM*

A PRELIMINARY REPORT

JAMES C. WHITE, M.D.
MAX G. VERLOT, M.D.,
AND
OTTO EHRENTHEIL, M.D.
BOSTON, MASS.

FROM THE NEUROSURGICAL SERVICE OF THE MASSACHUSETTS GENERAL HOSPITAL, BOSTON, MASS.

IN 1927, Rose[1] described a method of observing the reaction of the bladder to filling. Many communications of interest have appeared since, which have been recently reviewed in McLellan's[2] excellent monograph. Cystometry has become a most useful aid in studying the behavior of the bladder. Eight years before Rose's first publication, Joltrain, Baufle, and Coope[3] proposed a method of measuring the filling pressure of the large intestine. They described only a few such attempts and drew no important conclusions. So far as we are aware, nothing more had been done in studying the physiology of the colon by colonmetry until the method was independently rediscovered and put into routine use in the study of neurologic disturbances in defecation at the Massachusetts General Hospital, two years ago.

METHOD.—The apparatus employed is very simple, and consists of a vertical glass tube manometer one meter in height, connected on one side to an intravenous drip apparatus and on the other to a rectal tube (Fig. 1). The reservoir is filled with water at body temperature and the tubing cleared of air. The base line of the manometer is adjusted so that the meniscus of the water column is at the zero mark when the tip of the rectal tube is level with the patient's anus. The tube is then inserted a few inches within the rectum and held in this position by adhesive tape. It is best to have the patient lying on his back with his head comfortably supported on a pillow. When the anal sphincter is paralyzed the connection can be made water-tight by using a Foley bag type of catheter with the balloon inflated to 100 cc. (Fig. 1, insert). The same device is also useful when the test has to be made through a colostomy opening. Once the apparatus is adjusted, water is allowed to flow into the rectum at a constant rate of approximately 100 cc. per minute. The patient is instructed to report any sensation of "gas," "urge to defecate," or cramp-like pain, with its location and intensity. Extreme care must be exercised in any patient with an insensitive colon or with colonic diverticula, lest a perforation be produced by overdistention.

The test is best performed a number of hours after the last meal and when

* Read before the American Surgical Association, St. Louis, Mo., May 3, 1940.

the bowel has been recently evacuated. A correct interpretation cannot be drawn if the patient has been given a cathartic or narcotic drug.

We wish to point out that the colonmetrogram does no more than measure the tone, reflex irritability, and sensitivity of the colon as a whole. It gives a good indication of the competence of the anal sphincter, but fails to give a true

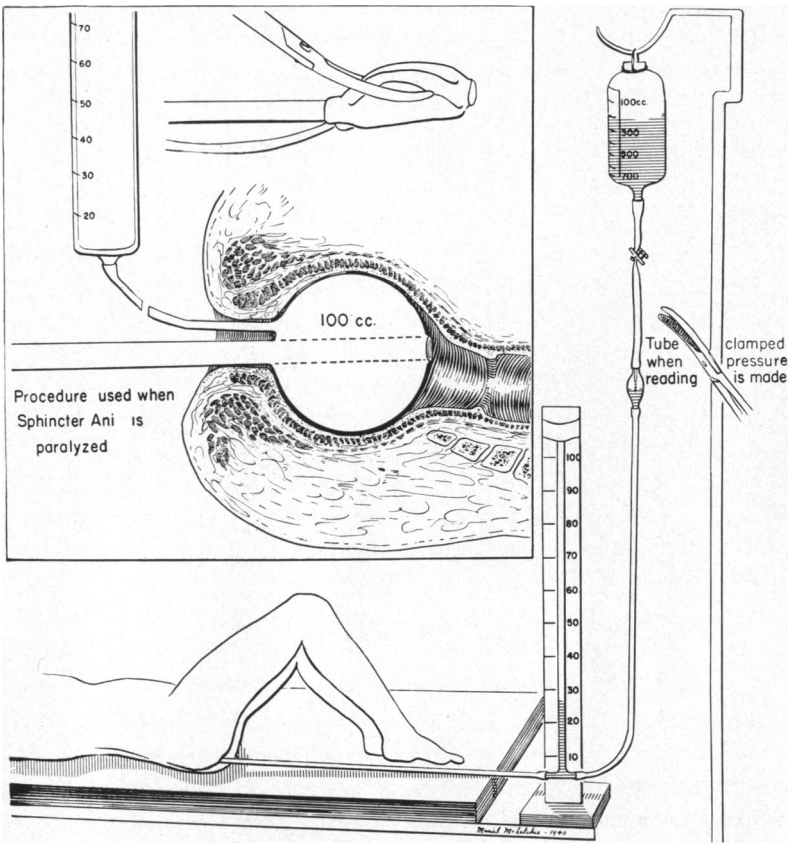

FIG. 1.—Apparatus and technic of colonmetry.

indication of the expulsive power of the rectum, which is dependent to a large degree on the contractile force of the abdominal musculature and the diaphragm. The integrative mechanism of the rectum, sphincter ani, and perineal muscles must be studied by the more elaborate methods which have been described by Denny-Brown and Robertson.[4] Furthermore, localized functional abnormalities in the rectum, sigmoid, or higher portions of the colon cannot be differentiated. It would appear, however, that neurologic disturbances usually affect the colon as a whole, and for this reason we have found the colonmetrogram to be a simple and valuable method of testing the nervous activity of the viscus.

MATERIAL.—This investigation has been focused on patients with disease, injury, or operative lesions of the brain, spinal cord, cauda equina, or pelvic

nerves which may cause an alteration of function or sensation in the large bowel. Sixty-seven colonmetrograms have been performed in a series of 40 patients.

RESULTS.—The normal colonmetrogram closely resembles the cystometrogram, except for the fact that a fourfold larger volume of water is usually required for filling.* Figure 2 illustrates the comparative volume of fluid which is required to fill the normal bladder and colon. Whereas the normal adult bladder holds from 300 to 500 cc. at a maximal comfortable capacity, the colon holds between 1,500 and 2,000 cc. Both hollow viscera have

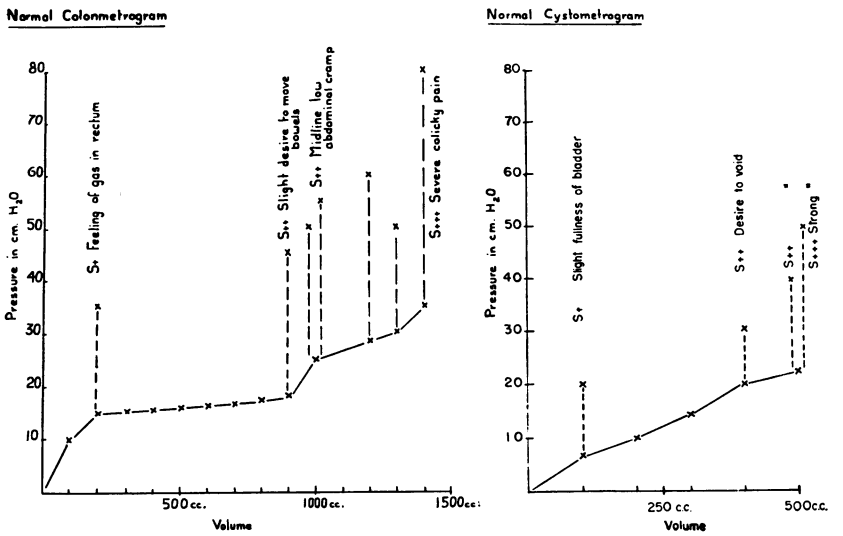

FIG. 2.—The normal colonmetrogram and cystometrogram.

a relatively similar basic tone and react to stretching by intermittent reflex attempts to empty. This is shown by peristaltic contractions which last a few seconds and send the intravesical and intracolonic pressures up to from 30 to 90 cm. A sensation of fulness is produced in the normal colon, as in the bladder, when the pressure reaches 30 cm., whereas a contraction which raises the column above 50 cm. becomes distinctly uncomfortable. The basic tone is seen to rise rather steeply as the normal capacity is approached, and peristaltic waves occur with increasing frequency until a state of tetanic contraction is reached. At this point, fluid usually leaks out around the catheter. The pressure-volume measurements can be combined with barium fluoroscopy if a thin barium mixture is used that will not clog the manometer. The contraction peaks are then seen to correspond to mass waves of peristalsis which sweep the fluid down into the distal colon. Haustral segmentation does not produce any waves visible in the manometer, as no fluid is forced down the canal.

* With slow filling of the colon there is always a possibility of leakage through the ileocecal valve. Short of fluoroscopic examination, this unknown factor cannot be controlled, but we have no evidence that it is of importance.

The smooth muscle in the colon, as in the bladder, reacts to stretch stimuli by reflex contraction (Denny-Brown and Robertson[4]). Colonmetry in patients with various types of neurologic lesions, therefore, brings out changes which are characteristic of the level at which the nervous system is involved. These phenomena are identical with those observed in the bladder (McLellan[2]), and quite similar to alterations in the tendon reflexes.

Typical cases which illustrate the effect of injury to the various segmental levels of the nervous mechanism of defecation are appended. It must be borne in mind that this is a preliminary report and that colonmetry has not been

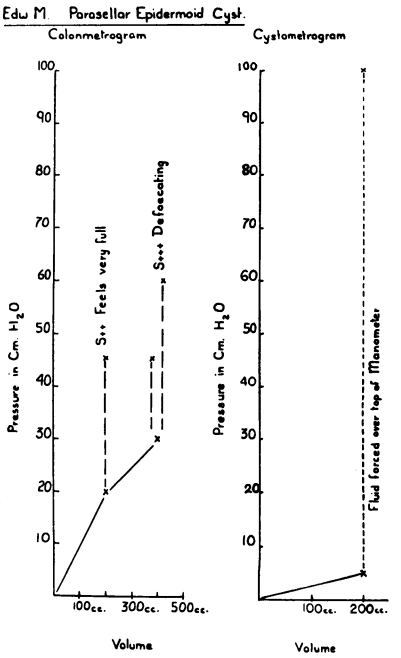

FIG. 3.—Case 1: Hypertonia of colon and bladder seen in the case of a brain tumor which compressed the hypothalamus and cerebral peduncles.

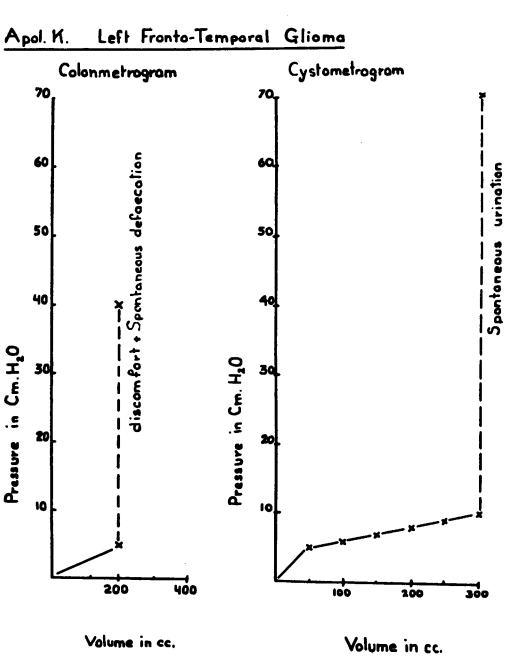

FIG. 4.—Case 2: Hypertonia of colon and bladder observed in an extensive tumor of the left frontal lobe.

undertaken on a large enough series of cases to draw final conclusions. But the evidence at hand is entirely consistent and the findings quite similar to data obtained from the bladder by a great many investigators. Since conclusions can be drawn only from complete and clearly defined lesions of the nervous system, such as can be produced in the experimental animal, this report is necessarily based upon the relatively small proportion of our total cases which fulfill these criteria.

I. LESIONS IN THE BRAIN

Case 1.—Edward M., male, age 15. Epidermoid cyst in floor of left middle fossa, with extension across the midline and compression of hypothalamus and cerebral peduncles (verified at autopsy).

The patient was intelligent and cooperative. There was no clinical evidence of injury to the autonomic centers in the hypothalamus. Both his cystometrogram and colonmetrogram curves are reproduced in Fig. 3, and reveal an extraordinary hypertonicity of both bladder and colon, with entirely normal sensation. On a second occasion, the colonmetrogram was repeated with barium and the filling observed fluoroscopically. On account of the intense muscular activity of the sigmoid, barium could not be forced up beyond the rectosigmoid.

Case 2.—Apol. K., male, age 57. Left frontotemporal glioma. Diagnosis was established only by ventriculography, as the patient subsequently died without operation or postmortem examination.

The patient was aphasic, apraxic, and had undergone a pronounced change in personality, so that his cooperation could not be counted on with certainty. Right hemiparesis and a suggestive homonymous field defect were present. On two separate occasions colonmetry was performed and each time, after 200 cc. of fluid had run in, there was a powerful contraction wave with leakage around the tube. Cystometry showed a similar degree of hyperirritability of the bladder (Fig. 4).

Discussion.—The cerebral cortex inhibits the spinal reflex activity of the bladder[2] and apparently of the colon as well. It thereby increases the storage capacity of these hollow viscera. Lesions situated in the cortex or brain stem frequently remove this inhibitory action and result in hypertonicity. Sensation usually remains unaltered.

II. DESTRUCTION OF SPINAL CORD ABOVE SACRAL LEVEL

Case 3.—Rita H., female, age 21. Spina bifida from twelfth thoracic to fourth lumbar vertebra, with infiltrating lipoma.

The patient had had spastic legs and absence of sensation below her eleventh thoracic segment since infancy. In 1933, Dr. W. J. Mixter removed a mass of fatty tissue which compressed the lower end of her spinal cord from the twelfth thoracic to the fourth lumbar vertebra. Little improvement followed, and the patient had just managed to get about with the aid of leg braces and a pair of crutches, but had had the good fortune to have an adequately functioning automatic bladder.

Her colonmetrogram (Fig. 5) shows an unusual hypertonicity of the colon with frequent peristaltic waves and fluctuating alterations of pressure from 40 to 90 cm. Fluoroscopic observation during a barium enema revealed an abnormally large colon with deep peristaltic waves which swept over its transverse and sigmoid loops. The barium was repeatedly forced down against the Foley bag and leaked around it when the balloon was not drawn tightly against the anal sphincter. The patient's only knowledge of filling was brought to her by the increasing spasticity of her legs. It is surprising that an individual with such an unusually hypertonic colon should be very constipated and only able to move her bowels with difficulty once a week.

Case 4.—Stephen C., male, age 18. Epidural abscess in upper thoracic spine (T4 to T6), drained four weeks previously.

In this case an extradural collection of pus had compressed the spinal cord and resulted in a spastic paraplegia with very feeble movements in the left leg and paralysis of the right. Anesthesia was complete in his right lower leg, but some position and pain sensation remained on the left. Colonmetry revealed an increase of tone nearly as intense as that shown in Figure 5. His sensation of filling, which was not destroyed, was most peculiar. He never felt the usual suprapubic cramp-like discomfort, but at 300 cc. noted discomfort in his penis and rectum and at 700 cc. complained of fulness in his chest. Abnormal subjective localization of sensation is not unusual after incomplete spinal injuries and is often seen on distending the bladder, compression of the testicle, and even on cutaneous stimulation.

Discussion.—Unfortunately, we have not yet been able to obtain a colonmetrogram immediately after a transverse injury to the spinal cord in its cervical or thoracic portions. During the stage of "spinal shock" there is a flaccid paralysis of the limbs with abolition of the tendon reflexes. It is also well established that there is a flaccid paralysis of the bladder, since cystometry shows practically no rise in tone or peristaltic contractions, even when a large amount of fluid is run in. During this stage of general reflex depression, patients have abdominal distention with no audible peristalsis, and usually fail to expel an enema or even gas through a rectal tube. Plain roentgenograms reveal large quantities of gas trapped in the small and large intestines. We have colonmetric and cystometric evidence in two patients, secured between two and three weeks after transverse spinal injuries, that the colon recovers its muscular tone more rapidly than the bladder, since in both of these patients the atonic stage persisted in the bladder, whereas the colon was already developing its chronic hypertonic state.

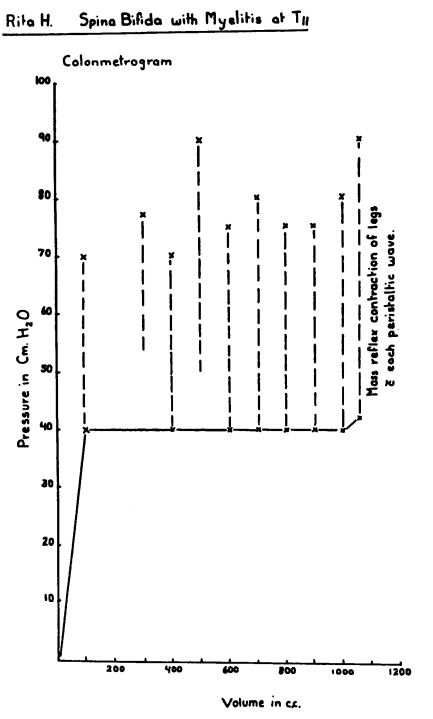

FIG. 5.—Case 3: The "reflex colon" with extreme hypertonia after a transverse spinal lesion at the eleventh thoracic segment.

The remarkable hypertonia which soon develops after high injuries to the spinal cord is well shown in Figure 5. These physiologic changes in the spastic colon have not been adequately described previously, but they closely resemble the condition observed in the bladder by Munro[5] and McLellan[2] after satisfactory treatment and recovery of automatic bladder function. The abnormalities observed in this group of patients are not unlike those in the preceding group with intracranial lesions, except for the fact that patients with spinal injuries have little or no sensation. Both groups may have sudden and imperative necessity to defecate or urinate, or in spite of their hyperactive reflex tone may be definitely constipated, but the patients with spinal injury often do not know when they are soiling themselves.

III. DESTRUCTION OF SACRAL CENTERS IN CORD OR CAUDA EQUINA

Case 5.—Herbert M., male, age 43. Fracture of the twelfth thoracic vertebra one year previously, with compression and injury to cord.

A fall from a scaffolding had resulted in paraplegia, for which a decompressive laminectomy from the eleventh thoracic to the second lumbar vertebra had been performed at another hospital. Thereafter he had recovered to a remarkable degree, so that he could walk without support, although his legs remained somewhat weak and his tendon

reflexes nearly flaccid. He had regained sensation down to the fourth lumbar segment, but remained totally anesthetic over the sacral dermatomes. His bladder, which had been treated by prolonged catheter drainage, was rigid-walled and contracted to 100 cc. maximum capacity. It was totally insensitive and dribbled constantly. His anal sphincter was also paralyzed, but he had not suffered from incontinence.

The colonmetrogram (Fig. 6) shows the characteristic hypotonia and absence of peristaltic waves commonly seen in injury to the sacral centers of the spinal cord or more distal structures. Accurate sensation was gone, although he mentioned a peculiar feeling in his left testicle at a filling of 1,000 cc. and a slight desire to defecate at 2,000 cc. At 2,800 cc. he felt nauseated, but he had no pain or true sense of distention. In spite of these abnormalities the patient did not complain of any difficulty with his bowels.

Case 6.—Emma H., female, age 43. Paralysis of lower sacral nerves after intrathecal alcohol injection.

Two intrathecal injections of 0.8 cc. of absolute alcohol had been performed upon

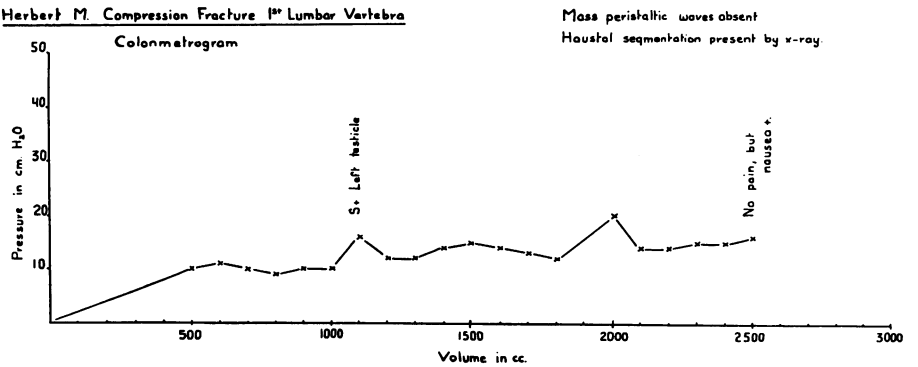

FIG. 6.—Case 5: The atonic colonmetrogram found after injury to the sacral segments of the spinal cord.

this patient six days apart, for the relief of a painful thigh amputation stump. After the second injection she complained of great difficulty in emptying her bladder, with absence of sensation on micturition or defecation. She developed a large urinary residual and had to be placed on tidal drainage. In addition, she noticed that it was difficult to move her bowels without an enema. On neurologic examination, abnormal findings were localized to the structures supplied by the second to fifth sacral nerves. They consisted of a narrow zone of anesthesia around the anus and forward over the perineum to the labia minora, and weakness of her sphincters.

Both her colon and cystometrograms disclosed a state of atonia and flaccid paralysis, with nearly complete loss of sensation (Fig. 7). Peristaltic waves appeared in the colonmetrogram, and the patient noticed an aching sensation above her umbilicus only after distention to 1,700 cc. The bladder was more severely injured and showed no muscular response to stretching.

Discussion.—Destruction of the cauda equina, or of the sacral segments in the spinal cord, produces a severe functional disturbance of the colon as well as the bladder, because the sacral pathways which transmit the contraction reflex are interrupted. Fluoroscopic observations show a loss of peristaltic rush waves, but haustral segmentation remains. Loss of sensation in the lower half of the colon is complete (Fig. 7). It is theoretically possible that the cecum and ascending colon may retain some residual sensation, as this area is supposed to receive its innervation from the splanchnic trunks. Although the

sensation of a full rectum is abolished and the anal sphincter paralyzed, the patient may notice few symptoms beyond mild constipation and soiling when he has diarrhea. Experimental megacolon has been produced in animals by Adamson and Aird[6] by cutting the pelvic nerves, and it would seem as though such a condition were developing in Case 5.

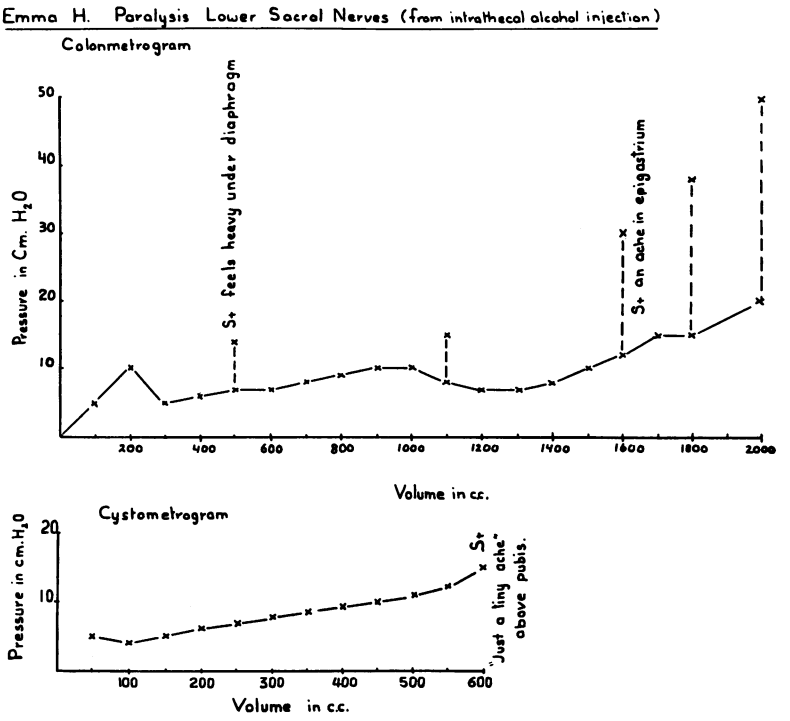

FIG. 7.—Case 6: Hypotonia of colon and atonia of bladder after chemical injury to lower sacral roots in cauda equina.

IV. DESTRUCTION OF LOWER SENSORY NERVE ROOTS AND POSTERIOR COLUMNS

A. In Syphilis of Central Nervous System

A few months before this investigation was begun, a male, age 57, entered the hospital for treatment of long-standing neurosyphilis. He gave a history of increasing constipation and abdominal distention. These symptoms had followed a recent onset of numbness and ataxia in his legs. In a plain abdominal roentgenogram the right half of the colon and lower ileum were seen to be distended with gas. The cecum was huge. In addition, he had an enormously distended bladder. Both the blood Hinton and spinal fluid Wassermann tests were positive. His spinal fluid examination gave normal pressure and dynamics; two lymphocytes; a total protein of 67 mg.; and gold sol. 5555532100. In addition to the typical pupillary findings, ataxia, and loss of deep reflexes, he showed an unusual degree of muscular weakness in his legs with loss of pain and temperature sense. Because the reason for his distention was not recognized and it was felt that rupture of the cecum was imminent, a cecostomy was performed. The cecostomy tube failed to drain and the abdominal distention continued. Signs of bronchopneumonia set in and he died in four days. Autopsy revealed no peritonitis or organic obstruction, but

a thin-walled and enormously dilated colon, moderate distention of the small intestine, and a hypertrophic, chronically dilated bladder. Gross and microscopic examination of the brain and spinal cord established the diagnosis of meningovascular syphilis with recent patchy ischemic lesions of the spinal cord.

The patient died of paralytic ileus. The process involved his entire intestinal tract, but most particularly the cecum and ascending colon. From what we have learned through subsequent investigation the evidence clearly indicates that the acute intestinal paralysis was caused by a syphilitic vascular process with acute degeneration of the sensory and reflex mechanism which mediate defecation.

Colonmetry has since been carried out in three other patients with neurosyphilitic disturbances of defecation:

Case 7.—Frank C., male, age 72. Taboparesis with megacolon.

This patient, the first to be studied by colonmetry, entered the hospital in December, 1938. He was a Cape Verde Island Negro, with much mental deterioration, and an

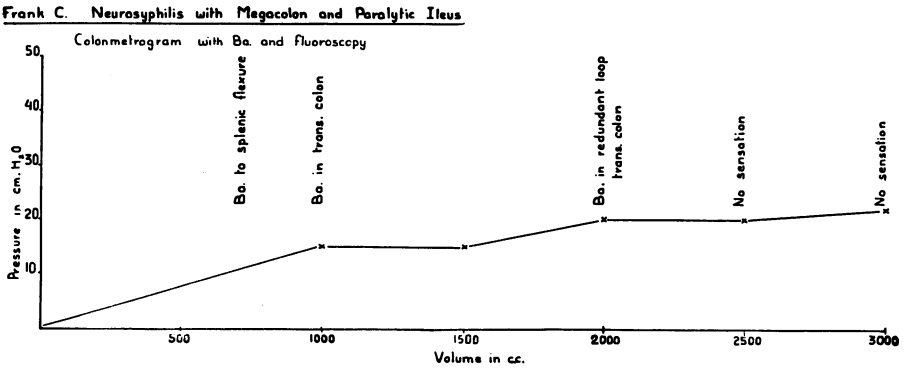

FIG. 8.—Case 7: Extreme atonia and megacolon which may occur in neurosyphilis with involvement of posterior root fibers in sacral cord.

enormously distended abdomen. He said that the illness had begun four months before with pain in the abdomen and increasing constipation. Although vomiting was denied, peristalsis was visible and audible. His pupils were unequal and did not react to light. Position sense in his hands and feet was practically nonexistent and his gait moderately ataxic. His knee jerks were much reduced and ankle jerks absent. Examination of the cerebrospinal fluid was characteristic of general paresis, *i.e.,* protein 45 mg.; eight cells (lymphocytes); Wassermann positive; and gold sol. 5555532110.

Operation for intestinal obstruction was considered, but Dr. G. W. Holmes, who examined the plain roentgenograms, made the diagnosis of megacolon and felt that this could be on a luetic basis. Therapy consisted in colonic irrigations which removed an enormous quantity of fecal material and reduced distention.

A colonmetrogram was performed, using a dilute barium mixture and combining fluoroscopic observation with determination of intracolonic pressure (Fig. 8). At the time of this test his colon was already distended with a large amount of barium which he had been unable to expel after a previous fluoroscopic examination, yet he was able to hold an additional 3,000 cc. without any sense of distention or evidence of peristaltic contractions. A cystometrogram, made a few days later, did not show a similar degree of bladder atonia, although the patient noticed no sensation until over 500 cc. of liquid had been introduced.

Colon- and cystometrograms were made upon two other patients with latent neurosyphilis. Both had positive spinal fluid findings, but failed to show characteristic neurologic signs of the disease. The first case was of interest

from a general surgical viewpoint because constipation and straining at stool had caused a recurrence of his bilateral inguinal herniae after careful repair carried out with fascia lata. Although his cystometrogram was normal, a colonmetrogram disclosed a large bowel of abnormal capacity (3,000 cc.) with low basic tone, absent peristalsis, and markedly diminished sensation. He was able to move his bowels only with extreme difficulty every three to five days and it was felt that this was the cause of his recurrent herniae. The second patient was tested routinely while he was in the hospital for investigation of a urinary residual of from 120 to 400 cc. Cystometry showed a typical tabetic bladder with very poor tone and greatly reduced sensation. His colon had an equally low basic tone and feeble peristalsis, although its sensation was within the normal range.

B. In "Combined System Disease" of Spinal Cord

Case 8.—John D., male, age 69. Pernicious anemia with spastic-ataxic legs and retention of urine from subacute degeneration of posterior and lateral columns of spinal cord.

Unsteadiness in gait had forced the patient to use a cane for three years. Sixteen months before admission he had lost all position-sense in his legs and the ability to walk at all. Difficulty in urination had been present for a week and progressed to complete retention in the last 24 hours; constipation had been troublesome for many years. Blood examination showed: R.B.C. 2,500,000. Hemoglobin 55 per cent. Color index 1.1. Gastric acidity was absent in fasting stomach contents and after histamine. Neurologic examination showed extreme ataxia and spasticity. He had sufficient strength in his legs to stand, but no sensation below the knees and an absence of position and vibration sense from the waist down. In addition his legs were extremely spastic. Figure 9 shows an atonic dilation with absence of peristalsis and abnormal sensation in both the colon and bladder.

Discussion.—In both tabes dorsalis and combined system disease of the spinal cord there is injury to the posterior columns of Goll and Burdach,[7] and in tabes to the sensory root fibers as well. In the tabetic, the spinal stretch reflexes are abolished and reflex contractility of the bladder and colon may be lost. In combined system disease, where there is usually degeneration of both the pyramidal and dorsal tracts, the legs may become spastic. As we have seen, spasticity alone is usually accompanied by hypertonia of the colon and bladder, but whenever there is extensive damage to the posterior roots which carry sensation from the colon and bladder, or of the reflex arc at any point, an atonic dilatation will result. The so-called "tabetic bladder" has long been recognized as a dreaded complication of syphilis of the spinal cord, and a similar condition in severe primary anemias and cachexias is well known. But it is not common knowledge that the degenerative process may also destroy the detrusor mechanism of the colon. We wish, particularly, to bring this to the attention of surgeons, so that it may be recognized that these conditions can produce megacolon, simulate intestinal obstruction, and cause a breaking down of herniae which have been adequately repaired.

In addition to the typical neurogenic disturbances of defecation described above, we have obtained colonmetric evidence of dilatation of the colon with

severe degrees of hypotonia in psychotic depressed patients and others after prolonged constipation from neglect. A flaccid dilatation of the colon has often been observed during fluoroscopic examinations in this group of patients

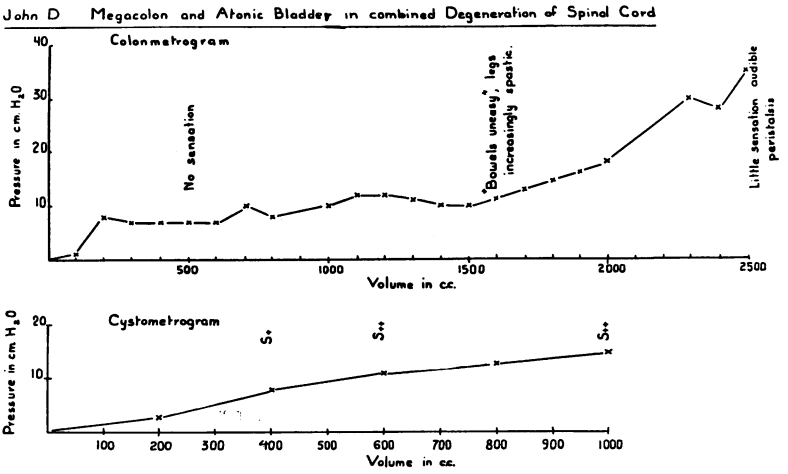

FIG. 9.—Case 8: Flaccid paralysis of colon and bladder with dilatation seen in a patient with combined system disease.

by Dr. J. R. Lingley,[8] who has made a special study of this problem. The condition may be classified as "acquired megacolon" and is not due primarily to lesions of the descending pathways or of the spinal reflex arc.

TABLE I

NEUROGENIC DISTURBANCES OF THE COLON

Case No.	Pathologic Lesion	Uninhibited Colon	Reflex Colon	Autonomous Colon	Atonic Colon	Peristaltic Waves	Sensation	Colon Capacity
1	Parasellar cyst, epidermoid	+				Increased	Normal	Greatly decreased
2	Left frontotemporal glioma	+				Increased	?	Greatly decreased
3	Spina bifida, with transverse myelitis to T_{11}		+			Increased	0	Increased
4	Epidural abscess, with incomplete destruction of cord T_4–T_6		+			Increased	Present but abnormal	Slightly decreased
5	Compression fracture of T_{12} vertebra, with recovery down to lower lumbar segments			+		Absent	0	Greatly increased
6	Chemical destruction of sacral nerves			+		Reduced	Much reduced	Normal
7	Taboparesis, with paralytic ileus				+	Absent	0	Megacolon
8	Combined degeneration of spinal cord				+	Absent	0	Greatly increased

General Discussion.—Injuries to the brain, spinal cord, and sacral parasympathetic nerves may be followed by serious disturbances in defecation. Similar neurogenic disturbances in vesical function have been recognized for years and referred to, both ungrammatically and unphysiologically, as "cord-

bladder." Through the physiologic investigations of Elliott,[9] and the more recent neurologic and clinical studies of Denny-Brown and Robertson,[10] Langworthy and Kolb,[11] Munro[5] and McLellan,[2] it has been established that the bladder reacts reflexly to distention and stretching of its walls. Since this response of smooth muscle is mediated by a reflex arc through the spinal cord, it is affected by a neurologic lesion in a manner quite analogous to that observed in skeletal muscle. It is the purpose of this communication to show that a similar mechanism governs the activity of the colon and that injury to its cortical centers, descending pathways, or reflex arcs can be fitted into an exact neurologic classification. By observing the reaction of the colon to distention, we can determine whether its muscular tone is normal, increased, decreased, or absent; whether the upper or lower motor neuron is functioning abnormally; and whether the lesion involves the sensory or the motor portion of the reflex arc.

Disease or injury of the brain and descending tracts of spinal cord removes cerebral control over the reflex peristaltic contractions which sweep the fecal contents down the colon and pack it into the rectum. In the baby, and in some adult idiots, cerebral voluntary control of micturition and defecation is not developed. Urine and feces are ejected at irregular intervals in response to a stretch reflex. With the gradual development of cortical function, a cerebral control is established over these spinal reflexes. Its elimination results in increased reflex contractions in the smooth muscle which lines the hollow viscera. Injury to the brain or to the tracts in the spinal cord produces an identical increase in the tone of the colon and bladder. After the initial flaccid paralysis has been replaced by the permanent spastic state, a reversion to the infantile condition is common, with precipitate evacuation of urine and, to a lesser extent, feces. In spinal lesions sensation is lost in addition to cortical control. The resulting disturbances are shown in Figures 3 to 5.

Elliott[9] found that destruction of the spinal cord at progressively lower levels did not destroy reflex evacuation of the bladder until the second, third, and fourth sacral segments were removed. Destruction of these segments, which give rise to the parasympathetic motor as well as the sensory fibers to the bladder, abolishes reflex activity. This also appears to be the case with the colon in man. It would seem, furthermore, that the sacral nerves constitute the only motor and sensory pathway to the colon. We have made colonmetric studies upon two patients before and after extensive lumbar ganglionectomies, and on two others with bilateral lumbar ganglionectomy plus splanchnicectomy, and have been unable to detect any significant change either in the motor response to filling or in sensation.* Figures 6 and 7 illustrate the reduction in tone and peristaltic contractions which, together with a loss of the normal sensation of distention, characterizes destruction of the spinal reflex arc, *i.e.*, cells in the sacral segments of the cord or of their axones

* The conclusion that the thoracolumbar sympathetic rami carry no important sensorimotor fibers to the bladder has already been reached by Munro[5] and McLellan.[2]

in the cauda equina and pelvic nerves. Lesions of this sort cause a much greater disturbance in the excretory processes than those which affect the tracts and brain.

An even greater disturbance of the bladder and colon results from destruction of the afferent fibers in the posterior sacral roots or in the sacral portion of the spinal cord. The bladder disturbances in tabes dorsalis and combined system diseases have been commonly recognized, but this has not been the case with the colon. Disturbances of the nervous mechanism that evacuates the colon may be very severe and lead to fatal ileus or simulate intestinal obstruction. Because the paralysis of the colon is of the flaccid type, colostomy is more likely to do harm than good. These patients may also develop striking degrees of megacolon (Fig. 8), but there is no reason to suppose that the dilated, atonic bowel can be improved by sympathectomy. The only logical way to handle these conditions is by early, adequate treatment. The filling curves of the bladder and colon should be determined when the patient with neurosyphilis or pernicious anemia first complains of sensory disturbances, because medical treatment of these diseases can prevent their neurologic complications far more effectively than it can correct them in their advanced stages.

A final point, which we wish to emphasize, is that the neurogenic mechanism is not necessarily upset to the same degree in both bladder and colon. For example, the filling curves in Case 6 (Fig. 7) illustrate a distinctly greater loss of tone and reflex activity in the bladder than in the colon. On the other hand, in Case 7, and in the next patient with neurosyphilis described above, there was much less paralysis and sensory loss in the bladder than in the colon. While the reflex arcs to the bladder and colon follow a closely similar course, it is evident that they are not exactly similar.

CLASSIFICATION OF NEUROGENIC DISTURBANCES OF THE COLON

Munro[5] has proposed a valuable classification of bladder disturbances which result from neurologic lesions. This has been expanded in McLellan's[2] recent monograph on the "neurogenic bladder." The same classification can be applied with equal satisfaction to neurogenic disturbances of the colon, and is reproduced, herewith, in the form given by McLellan with necessary minor adaptations to the colon. This classification should be compared with the data given in Table 1.

GROUP I: THE UNINHIBITED COLON (FIGS. 3 AND 4)

Resulting from lack or loss of cerebral inhibition, either from failure of development, cortical disease, or subtotal destruction of the spinal cord pathways—defecation is imperative, but voluntary. Sensory pathways are intact.

GROUP II: THE REFLEX COLON (FIG. 5)

Resulting from widespread injury of the controlling mechanisms from disease or injury of the brain (sensory as well as motor cortex or brain stem),

or from destruction of the cord (above the sacral segments)—defecation is purely reflex, but often less imperative or precipitate than the evacuation of urine. Sensation is abolished.

GROUP III: THE AUTONOMOUS COLON (FIGS. 6 AND 7)

Resulting from nuclear or infranuclear lesions of the sacral cord, cauda equina, or sacral plexus with interruption of both afferent and efferent fibers of the spinal reflex arc. Only segmental peristalsis (haustral markings) remains and is presumably mediated by the intrinsic plexuses of Meisner and Auerbach. Emptying of the colon is impaired, but less so than the bladder. Mild degrees of megacolon may result. Sensation is abolished.

GROUP IV: THE ATONIC COLON (FIGS. 8 AND 9)

Resulting from lesions of the pelvic parasympathetic nerves, or posterior sacral roots and columns with interruption of the afferent fibers of the reflex arc. There is a profound disturbance of normal voluntary and reflex evacuation, which may be as severe in the colon as in the bladder. Extreme degrees of megacolon may result. Sensation is abolished.

SUMMARY AND CONCLUSIONS

(1) The colonmetrogram is the filling curve obtained by slowly distending the large intestine with warm water. The resultant graph, in which the intracolonic pressure is plotted against the volume of liquid introduced, closely resembles the cystometrogram. A normal colon can accommodate itself to a volume roughly four times greater than the bladder.

(2) Colonmetry gives a picture of the motor activity and sensation of the colon as a whole. It fails to bring out circumscribed disturbances in the rectum, sigmoid, or upper portions of the large bowel. This is not a serious objection in nerve lesions, because neurogenic disturbances characteristically affect the entire length of the colon.

(3) The longitudinal and circular smooth muscle of the large intestine reacts to increased filling by periodic attempts to evacuate. This is illustrated in the colonmetrogram by intermittent rises in pressure and in the fluoroscopic examination by peristaltic rush waves which sweep the fecal contents down into the rectum.

(4) The peristaltic contractions are a form of "stretch-reflex." The afferent and efferent arcs of this spinal reflex run over the parasympathetic sacral rami; the second, third, and fourth sacral roots in the cauda equina; and the corresponding segments in the lower end of the spinal cord.

(5) The normal patient becomes aware of a sensation of filling in his colon or bladder at a pressure between 20 and 30 cm. of water. At 40 to 50 cm. there is a real urge to defecate or urinate, and at higher pressures distinct low abdominal pain.

(6) Lesions to the brain, spinal cord, and sacral nerves produce characteristic disturbances in the physiologic mechanism of evacuation, which are

common to both colon and bladder. These are analogous to alterations in the knee jerk and other tendon jerks, which are dependent upon the stretch-reflex of skeletal muscle.

(7) The colonmetrogram shows a hypertonic response to filling with lesions of the motor fibers in the brain or in the descending spinal tracts (spastic paralysis); and an atonic bowel when the lesion is situated in the sacral segments of the cord, cauda equina, or pelvic plexuses (flaccid paralysis). In addition, much depends on the degree of sensory loss, the severest grades of paralysis being found in patients with degenerative disease of the sensory fibers in the sacral cord.

(8) These changes are illustrated by a series of colonmetrograms obtained from patients with lesions at various levels of the nervous system.

(9) It is shown that the same neurologic classification that has been adopted for injuries of bladder innervation can be applied to the colon. The colonmetrogram, like the cystometrogram, is a valuable aid for differential diagnosis of the level of the nervous system which is destroyed by injury or disease.

(10) Neurologic disturbances of defecation, which are of importance to the general surgeon, can best be evaluated by colonmetry. These comprise cases of acute ileus seen after injury to the spinal cord and in rarer instances of spinal neurosyphilis. A variety of megacolon, as well as of atonic paralysis of the bladder, is not uncommon in patients with neurosyphilis or combined system disease. These patients are forced to strain so hard to move their bowels that herniae may be produced. In addition, the patient with spastic or flaccid paraplegia often complains of difficulty in evacuating his bowels as well as his bladder.

We wish to express our thanks to the members of the Roentgenologic Department of the Massachusetts General Hospital for their assistance in studying pressure-volume reactions of the colon by direct fluoroscopic observations in the course of colonmetry.

REFERENCES

[1] Rose, D. K.: Determination of Bladder Pressure with the Cystometer. J.A.M.A., **88**, 151–157, 1927.

[2] McLellan, F. C.: The Neurogenic Bladder. Charles C. Thomas, Springfield, Ill., 206, 1939.

[3] Joltrain, E., Baufle, P., and Coope, R.: Essai de mesure de la pression du gros intestin. Bull. et Mém. Soc. Méd. Hôp. de Paris, **43**, 211–213, 1919.

[4] Denny-Brown, D., and Robertson, E. Graeme: An Investigation of the Nervous Control of Defecation. Brain, **58**, 256–310, 1935.

[5] Munro, D.: The Cord Bladder. Jour. Urol., **36**, 710–729, 1936.

[6] Adamson, W. A. D., and Aird, I.: Megacolon: Evidence in Favour of a Neurogenic Origin. Brit. Jour. Surg., **20**, 220–233, 1932.

[7] Wechsler, I. S.: A Textbook of Clinical Neurology. W. B. Saunders Co., Philadelphia, 3rd ed., 759, 1933.

[8] Lingley, J. R.: Personal communication.

[9] Elliott, T. R.: The Innervation of the Bladder and Urethra. Jour. Physiol., **35**, 367–445, 1907.

[10] Denny-Brown, D., and Robertson, E. Graeme: On the Physiology of Micturition. Brain, **56**, 149–190, 1933.

[11] Langworthy, O. R., and Kolb, L. C.: The Encephalic Control of Tone in the Musculature of the Ordinary Bladder. Brain, **56**, 371–382, 1933.

DISCUSSION.—DR. PETER HEINBECKER (St. Louis, Mo.): I wish to express our gratitude to Doctor White for this presentation in which he has depicted for us the development of colonmetrography. I feel that this method, especially when combined with anesthesia at the proper level, should help us to decide whether or not interference with the sympathetic nerve supply would do good in many cases of functional disturbance of the bowel.

DR. JAMES C. WHITE (Boston, Mass., closing): I might take just one moment to say that I think the next stage in this work is going to be to see what happens after different operative lesions. I know that after a satisfactory cordotomy the bladder sensation is little changed and the bladder reflexes are preserved. We have been interested in doing colonmetrograms as well as cystometrograms after injury to the sympathetic pathways alone. We have found that the colonmetrogram in a patient after bilateral lumbar ganglionectomy for Raynaud's disease or in a patient in whom the upper lumbar ganglia as well as both splanchnic nerves have been removed for hypertension, shows no change in the motor responses of the colon or bladder. We have not been able to detect any sensory changes either. All of these tests have been made upon normal colons, and it looks as though all sensation, as well as all motor control, must come over these second, third, and fourth pairs of sacral parasympathetic rami. That is the conclusion reached by Munro, McLellan, and Denny-Brown and Robertson, who did such careful work on the bladder, and by the last two investigators for the rectal innervation as well. We wonder what happens in children with Hirschsprung's disease, who we know react so well to removal of the sympathetic nerve supply. To date, no opportunity has presented itself to test the motor and sensory responses in a case of megacolon before and after sympathectomy.