THE JOURNAL OF UROLOGY
Vol. 87, No. 6 June 1962

FUNCTIONAL RESULTS OF AN ARTIFICIAL BLADDER. SECTION II

S. GIL-VERNET, J. M. GIL-VERNET, JR., J. BONET VIC AND J. M. ESCARPENTER

From the Department of Urology, School of Medicine, University of Barcelona, Spain

Similar to the heart, the bladder is a hollow muscle cavity which presents its successive stages of systole and diastole. The smooth muscle is capable of responding before a stimulus.

Vertebrates do not have an exclusively muscular bladder; but lower vertebrates do. In the latter group, there are some muscular structures which have no nerve supply and which respond from a direct environmental stimulus. We can understand the idea of a human bladder without any nerve supply and which is reacting from a natural surrounding, such as the urine, which it holds and must expel. The specific and physiological stimulus of the vesical muscular fibers is to distend.

An exclusively muscular bladder would react slowly and its sensitiveness would be thus restricted. There is a need for complete efficiency, the intervention of a governing element to adjust its activities. The presence of an intrinsic nerve root in the bladder results in co-ordination in the action of the various muscular bundles, as well as an increase in sensitiveness of the bladder thus creating an organ capable of efficacious and autonomous activity. The neuromuscular mechanisms of the original type exist and persist in men. They form the metasympathetic or local autonomous system, which is also found in the heart, blood vessels, gastrointestinal tract and genitourinary organs.

It should be mentioned here that the bundles and muscular systems are disposed in such a way that direct stimulus would be sufficient to promote micturition with tightening of the detrusor and opening the sphincters. This explains why a completely disconnected bladder can work as an autonomous organ.

In order to establish solidarity and harmony between the vesical function and the rest of the body, the existence of a superstructure of the nervous type is necessary. Such a superstructure is centralized in the medulla spinalis.

To the central medullary reflexes arrive the afferent fibers which transmit the impulses from the bladder. From these centers depart the efferent fibers which in turn go through the hypogastric plexus innervating the bladder and thus forming the vesical plexus.

Accepted for publication July 30, 1961.

The vesical nerve plexus forms the terminal medium from which the vesical musculature is induced by the neuro-vegetative system.

But it is also necessary to distinguish the vesical plexus from the intrinsic pseudo-nervous plexus.

The nerve endings of the vesical plexus are not acting directly upon the muscular elements, but through the local autonomous system. Thus, we can understand why, although a complete denervation of the bladder promotes some transient distrubances, there is not much delay in the return of micturition to normal or almost so.

The tone control and the detrusor capacity to accommodation are not located in a diencephalic center, but are independent from the axial nervous centers.

It is a fundamental error to believe that vesicourethral muscular activity is controlled by pathways similar to those that control striated musculature. If this were true, one could not understand how voiding could take place after disconnecting the bladder from the medullary centers by total sectioning of the erectae and presacral nerves.

Yet, one could much less explain the functioning of the new intestinal bladder which bears no connection whatsoever with the medullary centers.

PHYSIOLOGY OF THE ISOLATED INTESTINAL LOOP INTERPOSED BETWEEN THE URINARY TRACT

Following total cysto-prostato-vesiculectomy, the intestinal sigmoid segment is anastomosed to the membranous urethra or to the prostatic apex in an end-to-end or end-to-side fashion (techniques 1 and 2 of Gil-Vernet, Jr.)

What then is the explanation for the almost normal function of the new intestinal bladder? Which are the nervous pathways that are carrying either the afferent or efferent impulses?

What role do the central medullary reflexes play?

At present, no satisfactory explanation can be offered. When the newly formed bladder distends and stimulates the sympathetic nerve endings, these cannot transmit the stimulus to the central medullary reflexes of micturition, because there is no connection whatsoever with them, as far as the afferent pathway of the reflex arch is concerned. If an analysis is made of what is taking place in the efferent pathway of the same arch, the explanation tends to be more difficult, because the preganglionic fibers, departing from the sacral portion of the medulla and reaching the hypogastric plexus, have no connection whatsoever with the intestinal loops. The only possible explanation for such a biological phenomenon, unusual in appearance, of an intestinal loop equally functioning as the bladder, has to be sought among the inherent properties of the neuromuscular tissue of the intestinal loop.

The new intestinal bladder forms a muscular sac covered on the inside by mucous membrane and by the peritoneum on the outside. Therefore, it presents some anatomic similarity to the normal bladder. But here the nervous constituent is different. The Auerbach and the Meissner plexus presents a different structure from that of the local autonomic system of the bladder.

Our personal impression is that the new bladder functions, at least from the beginning, exclusively at the expense of the muscular constituent. This complies with what we have referring to on several occasions, i.e. in all neuromuscular association of the vegetative type, the predominant role is assumed by the muscular constituent, and this either from a normal or pathological status. Neither can one discard the possibility that the myo-enteric (Auerbach's) plexus can adjust to the new qualities and function as the local autonomic system of the normal bladder.

One possibility is that the afferent impulse may reach the nerve centers via the peritoneal nerves. A remarkable fact is the celerity with which the normal function of the new colonic bladder is established. This is in contrast to the slowness of recovery of paraplegic patients with a partial or total medullary lesion who never attain a degree of perfection such as exists in the intestinal bladder.

What causes the difference? It can be due to multiple facts, the most important of which is the anatomic constitution of the bowel, whose

FIG. 1. *A*, new colonic bladder 21 days after operation. Initial bladder tone, 12 mm. Hg. There are two types of waves: 1) frequent waves with slight force (12 mm. Hg) and 2) expatiated waves and of great intensity (70 mm. Hg). *B*, new colonic bladder 20 months after operation. Initial bladder tone 6 mm. Hg. Rhythmic waves of approximately 50 mm. Hg.

autonomous nervous system is functioning with greater independence than that of the bladder. In the function of the intestine, the will does not intervene. Conversely, the bladder is under the will's control being at the same time a remarkable resonance box of the emotions.

CYSTOMETROGRAPHIC STUDY

From the cystometrographic curves of patients with new colonic bladders created in accordance with technique 2 of Gil-Vernet, Jr., we have been able to demonstrate the presence of some peristaltic waves, intermittent, rhythmic and with great contractile power. The frequency and rhythm of such waves vary in accordance with the time elapsed after surgical intervention. We call "protest" phase of the intestinal segment the stage which takes place between the first 15 to 20 days in the postoperative period, during which the patient presents some imperious and anarchical voidings every 15 to 30 minutes, with projection force of the urinary stream. This phase is followed by the so-called "accommodation stage" which lasts for about 3 to 6 months, micturition becoming normal after that (every 2–3 hours, slight residual urine and good urinary stream). After the first and second year the "adaptation phase" sets in. Voidings occur every 3 to 5 hours during the day, with no mucus, and good diurnal control, and enuresis or voidings every 2–3 hours at night. Perfect awareness of the necessity to void, with a powerful projection of the urinary stream, is present.

Contraction. From the immediate postoperative phase to the first 6 or 7 months, the cystometrogram shows some almost continuous waves every 15 seconds and an average intensity of 12 mm. Hg. Intermixed with these types of waves are some other powerful ones, with an intensity far superior to that of the external urethral sphincter, a widely spread rhythm (every 3 to 4 minutes) and a force even up to 70 mm. Hg (fig. 1, *A*).

After approximately the first 7 months have elapsed following the operation, the aforementioned contractions, so frequent and with such a slight intensity, tend to disappear completely. The dotted line reveals some curves of great potency, generally superior to the basal tone of the external urethral sphincter. They are the equivalent of the 70 mm. Hg waves that appeared during the immediate phase. Here, these curves

FIG. 2. *A*, cystometric curve of normal bladder. Initial tone 8 mm. Hg. T = abdominal wall straining. E = external urethral sphincter (64 mm. Hg). M = micturitional plateau. *B*, micturition of new colonic bladder, 10 mm. Hg of base tone with four contractile waves (second one of 56 mm. Hg).

present themselves with rhythmic frequency, every one and a half or two minutes, their potency being about 40–60 mm. Hg (fig. 1, *B*).

Tone. In the normal bladder there is an initial tone of 3–6 mm. Hg, which increases in relation to the amount of retained urine. In new intestinal bladders this initial tone likewise exists (fig. 1, *B*).

Micturition. As far as evacuation of urine is concerned, a normal bladder at the moment of micturition shows a wave of sustained contraction forming a plateau (fig. 2, *A*).

The new intestinal bladder, however, empties itself by a truly discontinuous peristaltic contraction of waves. In the cystometrogram, they are great powerful waves of 45–60 mm. Hg over a basal tone of the aforementioned new intestinal bladder which at the act of micturition is about 14–20 mm. Hg. Those elevated contractile curves, about 3 to 4, present themselves one after another and attain complete evacuation of the reservoir (fig. 2, *B*).

CLINICAL INTERPRETATION AND CONSIDERATIONS OF THE CYSTOMETRIC STUDY

In functioning artificial bladders intense peristaltic waves are taking place while they reach an average of 60 mm. Hg pressure. The new sigmoid bladder has adequate power to evacuate its contents. The patients can control their voidings and even promote them. The latter is due perhaps to a conditioned reflex; the patient is promoting the beginning of these peristaltic waves at a given moment in order to void.

Nocturnal enuresis, which develops in some patients undergoing operation, could be explained by the appearance, while the patients are sound asleep, of some contractile waves of far superior power to the external urethral sphincter, and which the patients cannot control at the moment as in the vigil stage.

Continence is accomplished by the external sphincter of the membranous urethra and the bulbocavernosus muscle is influenced by the status of the perineal musculature and the pa-

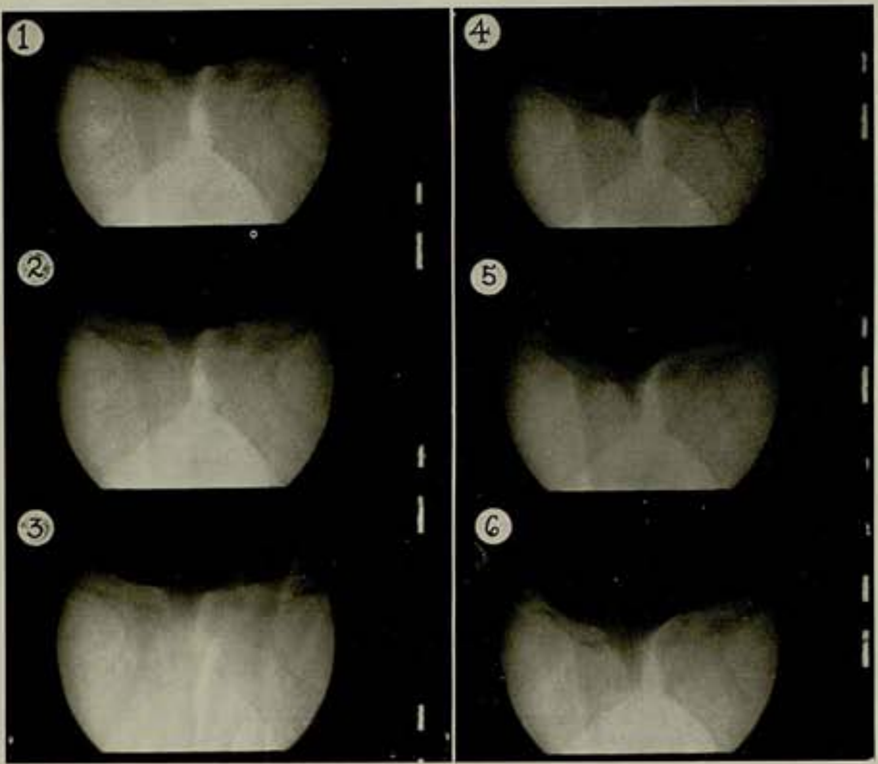

FIG. 3. First three aspects imply pre-voiding stage where micturitional strain is initiated. In last three, it can be seen so-called "lowering of bladder neck" with cystourethral funnel formation in which its end is being located at level of external sphincter where it still remains closed.

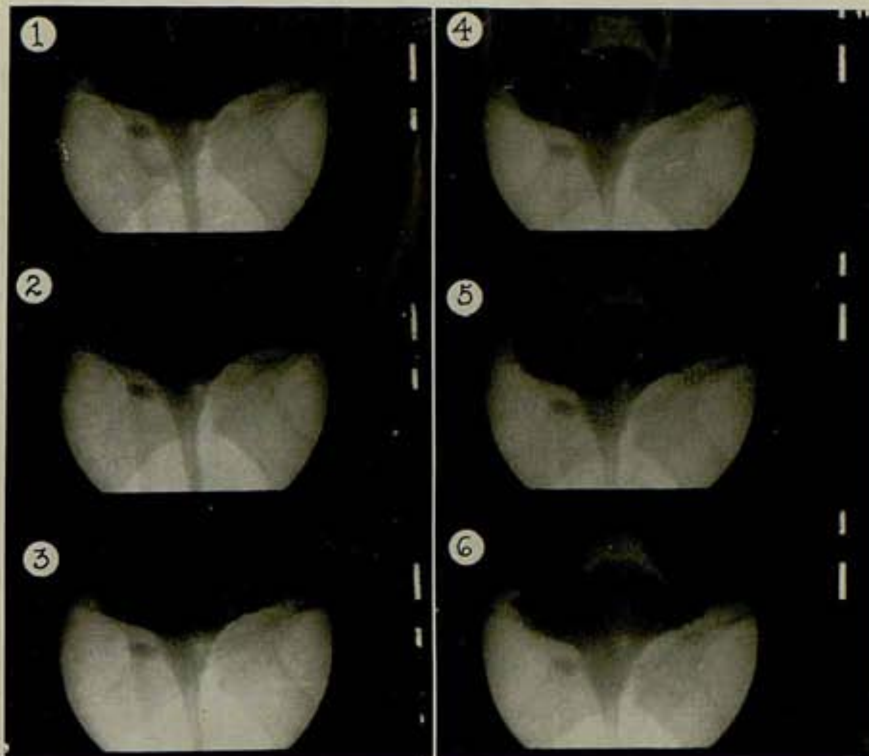

FIG. 4. Beginning of micturition. Aperture of external sphincter. Progressive filling of urethra. At level of colo-urethral anastomosis there is small cavity which communicates with urethra.

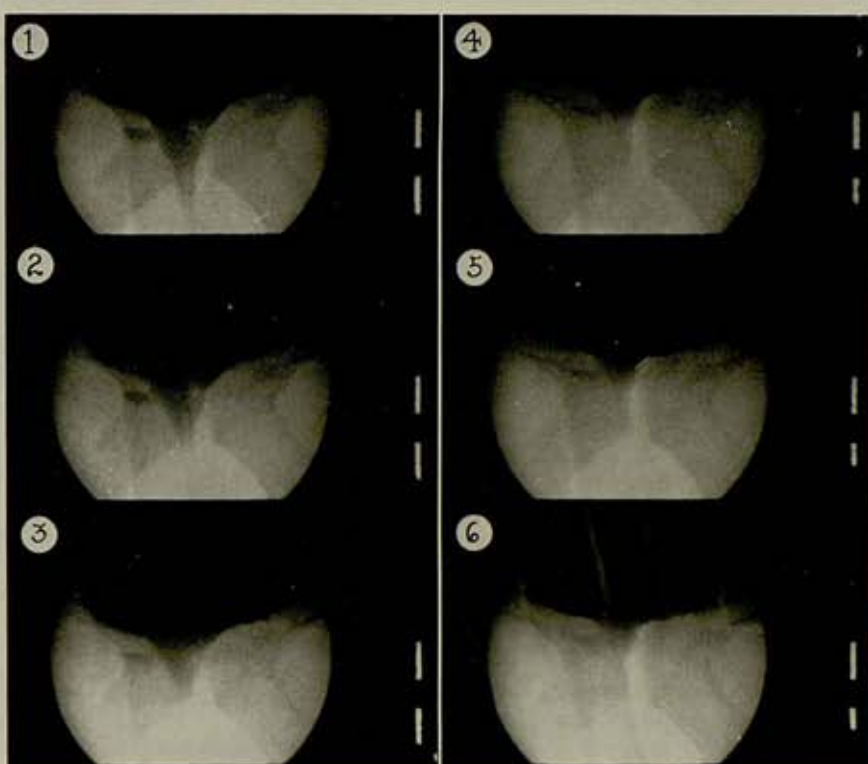

FIG. 5. Patient has been instructed to suddenly stop voiding. Note outline of cystourethral funneling

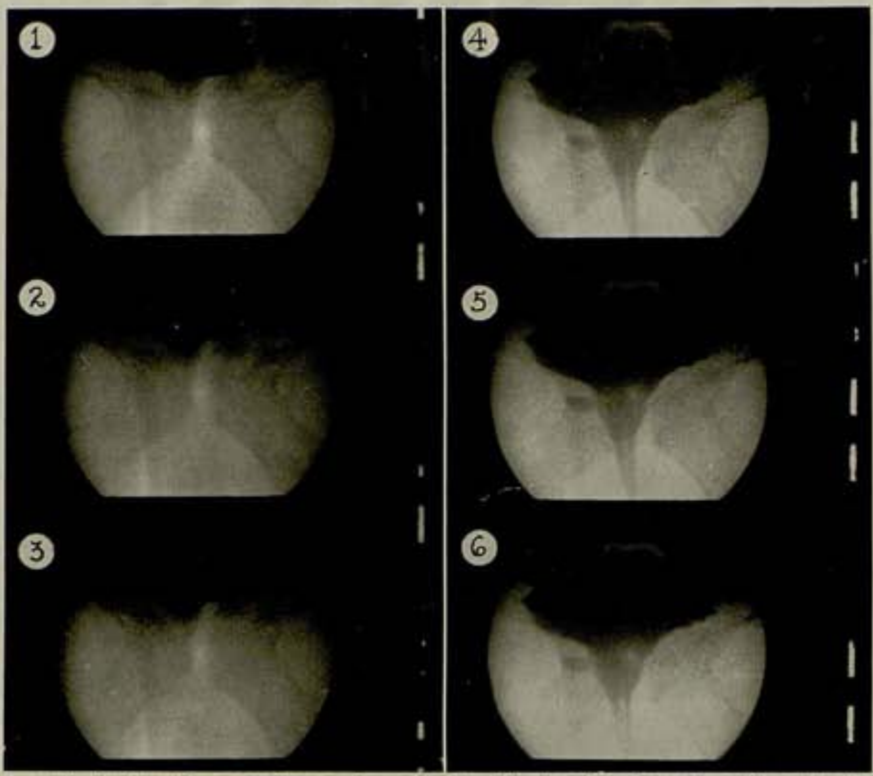

FIG. 6. *A*, end of micturition can be clearly noticed, with rise of colo-urethral funnel to its original position. *B*, patient has been instructed to resume micturition (study by successive voidings).

tient's age. At present, we cannot correlate the degree of control with the level of the urethra where the anastomosis is done.

Cystometrographic recordings obtained from the new ileal bladders show that in the ileum the tone is much lower. The powerful rhythmic contractions, noted when the colon is used, are absent.

CINEMATORADIOGRAPHIC STUDY

In the studies by the cinematoradiographic method, which was developed by Noix, one can objectively appreciate the dynamic modifications being created at the level of the cysto-urethral crossway at the moment of micturition.

In a normal bladder, at the moment of initiating the micturitional strain, the so-called cinematoradiographic phenomenon "lowering of the bladder neck" takes place due to a widening of the bladder neck and to shortening of the posterior urethra intimately connected with the vesical contraction, thus creating a true micturitional cysto-urethral funnel, the apex of which is located at the level of the external sphincter which still remains closed. At this moment a

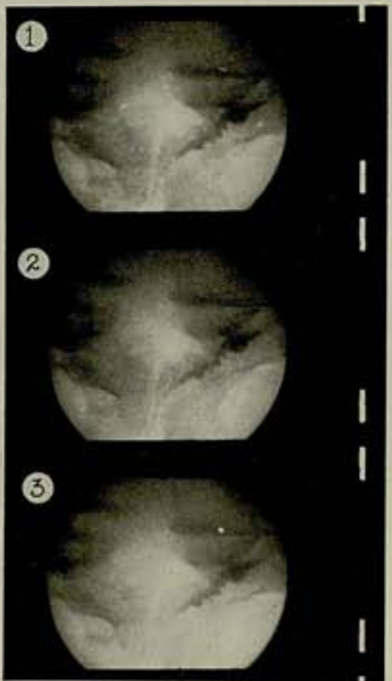

FIG. 7. Last stages of micturition. Funnel still persists while total emptying of new bladder is taking place. No residual urine.

functional modification is under the will's control, since it is possible to re-establish the original position by muscular relaxation, according to Noix.

The appearance at the beginning, during or at the end of micturition has constant and well defined characteristics.

In micturition by successive voidings, different stages of the micturitional dynamics follow rapidly and repeately.

The cinematoradiographic sequences in a patient with an artificial bladder, created in accordance with technique 2 of Gil-Vernet, Jr. (figs. 3-7), give complete information regarding the initial mechanism as well as the end of micturition. It is difficult to understand why in the new colonic bladder the sequences of a normal bladder repeat themselves. At the beginning of micturition, a "lowering" of the intestinal segment zone anastomosed to the urethra forms a true funnel and a simultaneous aperture of the external urethral sphincter.

Which factors intervene in this particular case so that this "lowering" can be explained? In here rests only the prostatic apex and the membranous urethra encircled by its own sphincter.

In our opinion, it is contraction of the new bladder which, stimulated by distention that the retained urine promotes over its muscular fibers, plus the aid of the abdominal wall, that originates such a lowering and creates the cystourethral funnel.

If a patient with a new colonic bladder were studied by cinematoradiography during succesive voidings, i.e. asking him to void with sudden intermissions (start and stop voiding) one would notice that each time the patient stops voiding the funnel disappears inmediately and returns the zone of colo-urethral anastomosis to its original position, to form again during micturitional strain.

In short, there are no cinematoradiographic differences between the micturitional dynamics of the new colonic bladder and the ones from a normal bladder.

RESIDUAL URINE

Almost no residual urine has developed in these patients after operation, in some cases about 40 cc at the most.

SUMMARY

At the beginning of the postoperative period, the patient has marked pollakiuria; but after a few months have elapsed voidings become similar to normal with good urinary control. Nocturnal enuresis frequently exists. The patient notes the sensation to void, or rather a sensation of suprapubic fulness.

He voids at will, sometimes with the aid of abdominal wall contraction and some other times without it; he can likewise stop voiding at will. This usually takes place at intervals from 2 to 4 hours, i.e. with a normal frequency or almost so. After voiding, no residual urine remains, or at least just a few cubic centimeters.

In some patients, at the beginning, voiding takes place along with some desire to defecate. At a later date, in those same patients, such a sensation tends to disappear. As far as the desire to void is concerned, when the new colonic bladder reaches a certain degree of filling it seems possible that the afferent impulse approaches the superior nerve centers via the neighboring peritoneal nerves, or through some other proximal nerves. Is this a result of anastomosis of the mesenteric plexus with the hypogastric?

Evacuation of urine retained in the new bladder takes place by muscular wall contraction of the colonic loop plus the aid of the abdominal musculature. This permits the urine to enter the urethral channel and from a reflex action, the sphincteric system of the membranous urethra inhibits itself.

The patient has a full and concrete awareness of the voiding act, the expulsive force being such that the urinary stream is far more powerful than in the normal person.

The authors express appreciation to Dr. F. Manchon and to Dr. A. Modolell for conscientious assistance throughout the preparation of the cinematoradiographic sequences.