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Normal Micturition

The micturition cycle (urine storage and voiding) is a nearly subconscious process that is under complete voluntary control. Bladder filling is accomplished without sensation and without an appreciable rise in detrusor pressure until a critical bladder volume is reached at which point one begins to feel the gradual onset of the urge to void. As bladder filling continues, the sensation of the need to void increases, but micturition can normally be delayed for an hour or more once this is felt. Voiding is normally accomplished by activation of the micturition reflex – a coordinated neuromuscular event characterized by an orderly physiologic sequence (Fig. 2.1). The first recorded event is a sudden and complete relaxation of the striated sphincteric muscles, characterized by complete electrical silence of the sphincter electromyogram (EMG). Next, there is a fall in urethral pressure followed almost immediately by a rise in detrusor pressure as the bladder and proximal urethra become isobaric. The vesical neck and urethra open and voiding ensues. The reflex is normally under voluntary control and is organized in the rostral brain stem (the pontine micturition center). It requires integration and modulation by the parasympathetic and somatic components of the sacral spinal cord (the sacral micturition center).

During urine storage, there are a number of physiologic mechanisms to maintain continence Fig. 2.2. (1) During bladder filling, there is a gradual increase in sphincter EMG activity (2) Immediately prior to cough there is a reflex contraction of the sphincter manifest as a rise in urethral pressure. (3) During straining or valsalva, there is equal transmission of pressure from the abdomen to the urethra. (4) If a person wants to stop in the midst of voiding or to prevent voiding during an involuntary detrusor contraction, he or she contracts the sphincter, interrupting the stream and then, through a reflex mechanism, the detrusor contraction abates (see Figs. 2.9–2.11).

In clinical practice, urethral pressures are no longer measured during routine urodynamic studies. The format for urodynamic studies usually includes synchronous measurement of uroflow (Q), vesical pressure (pves), abdominal pressure (pabd), detrusor pressure (pdet) sphincter EMG and infused bladder volume (Fig. 2.3). Normal micturition in a man and woman is depicted in Figs. 2.4 and 2.5, respectively. In some patients, mostly women, urethral resistance is so low that when the detrusor reflex is activated, there is either a very low or no discernible rise at all in detrusor pressure. Rather, when the detrusor contracts, because of low urethral resistance, all of the energy is converted to flow (Figs. 2.6–2.8). This is considered to be a normal variant.

Some patients are unable to urinate in their normal fashion because of the embarrassing and unfamiliar setting of the urodynamic laboratory.

In these circumstances, one can infer that the study is normal by extracting data from the study during the filling phase (sensation, capacity, continence) and voiding (detrusor pressure), and extrapolating from prior or subsequent unintubated uroflows to assess the detrusor pressure/uroflow characteristics (Fig. 2.8): Figures 10 and 11 depict normal urine storage mechanisms.

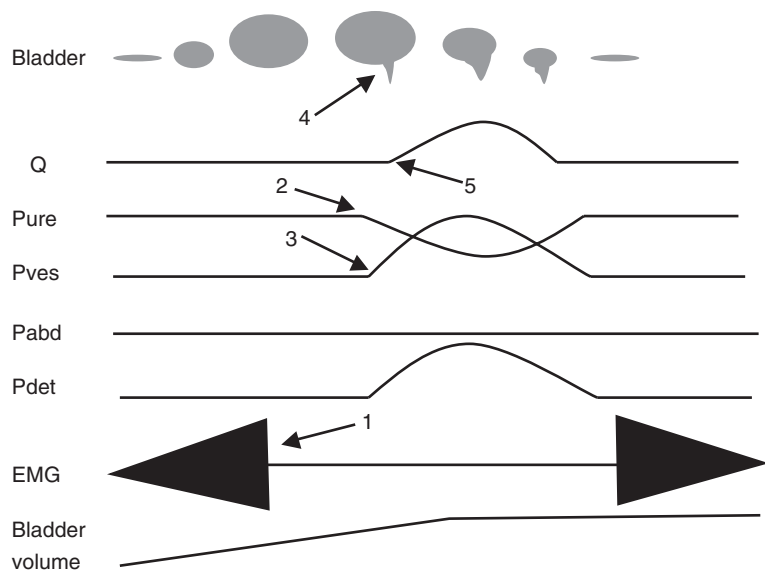


Fig. 2.1 The micturition reflex is characterized by an orderly sequence of events: (1) relaxation of the striated muscles of the sphincter (EMG silence), (2) fall in urethral pressure, (3) rise in detrusor pressure, (4) opening of the urethra, and (5) uroflow. Q = uroflow; Pure = urethral pressure; Pves = vesical pressure; Pdet = detrusor pressure; EMG = sphincter electromyogram.

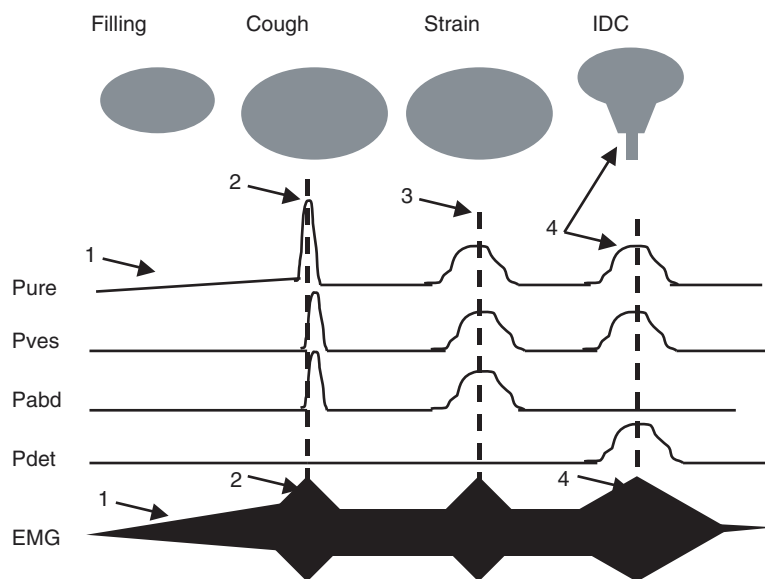


Fig. 2.2 Normal storage reflexes: (1) During bladder filling, there is a gradual increase in sphincter EMG activity that causes a gradual increase in urethral pressure. (2) Immediately prior to cough there is a reflex contraction of the sphincter manifest as a rise in urethral pressure. (3) During straining or valsalva, there is equal transmission of pressure from the abdomen to the urethra. (4) If a person wants to stop in the midst of voiding or to prevent voiding during an involuntary detrusor contraction, he or she contracts the sphincter, raising urethral pressure, interrupting the stream and then, through a reflex mechanism, the detrusor contraction abates.

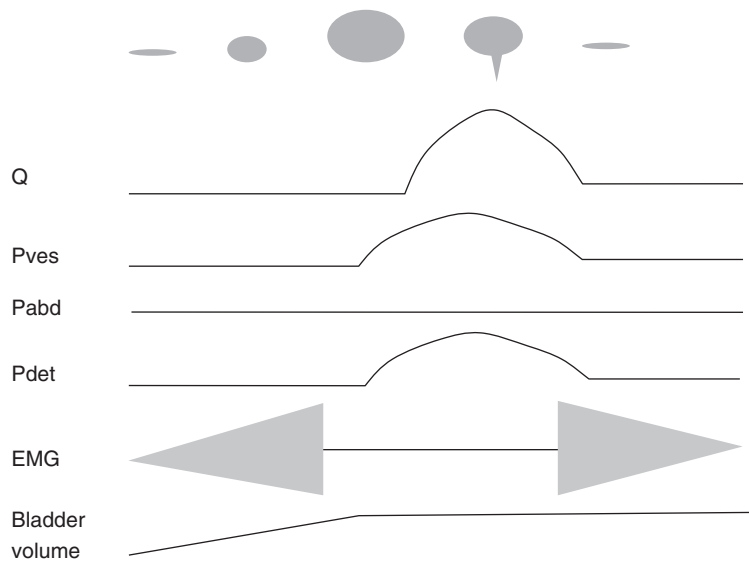
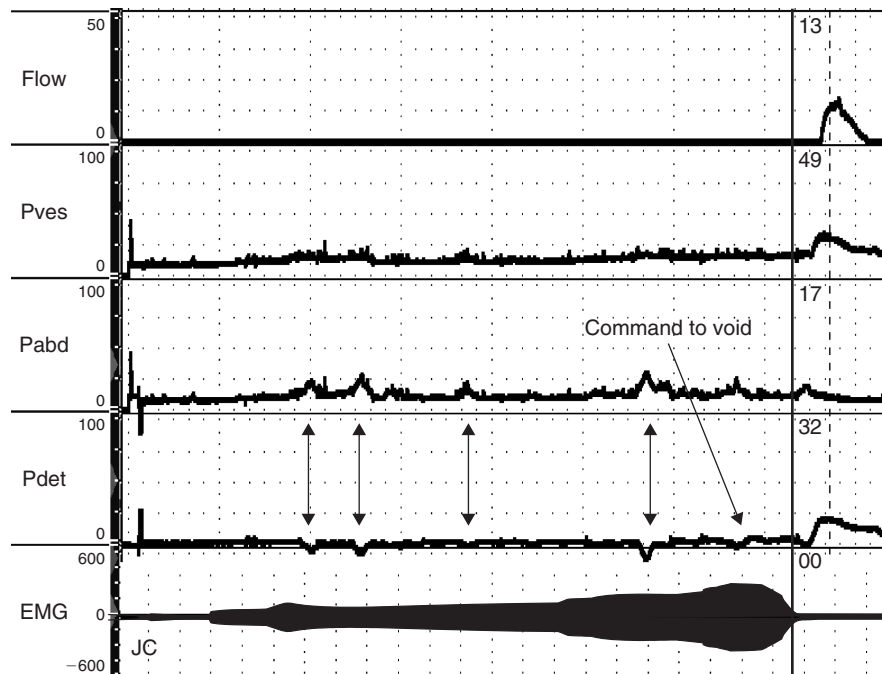


Fig. 2.3 Format for depiction of videourodynamic studies in this book. In most studies either EMG or bladder volume is displayed.

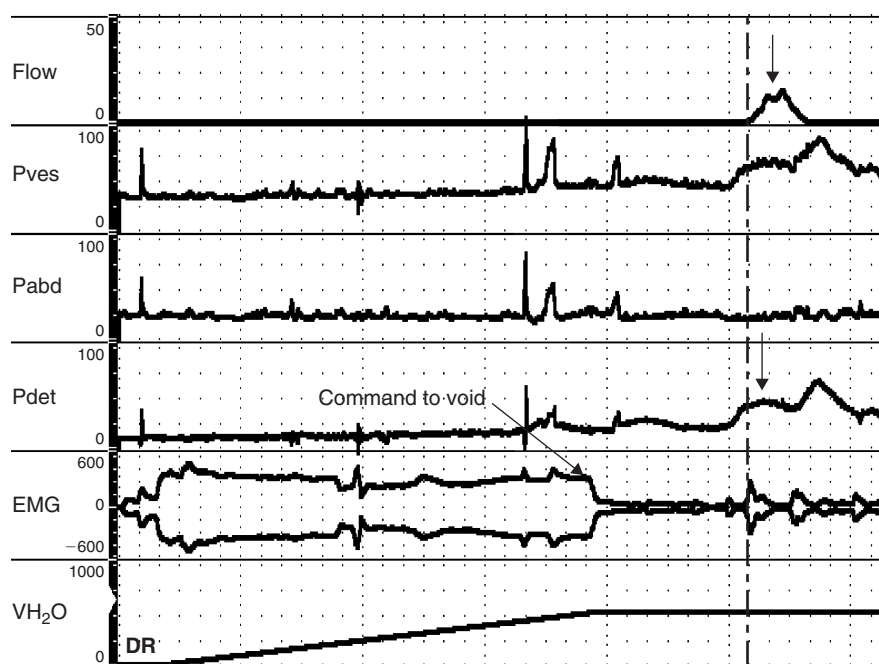


(A)



(B)

Fig. 2.4 Normal micturition in a 74-year-old man who was evaluated because of a history of urinary frequency that was determined to be caused by polyuria due to excessive fluid consumption based on his belief that "it is healthy to drink a lot of water." (A) Urodynamic tracing. FSF = 93ml, 1st urge = 210ml, severe urge = 597ml, and bladder capacity = 673ml. Note that there are several rectal contractions (arrows) that cause an artifactual fall in Pdet. When asked to void, the EMG sphincter relaxation (vertical solid line) occurred prior to the onset of the detrusor contraction. $Q_{max} = 16\text{ml/s}$, and $Pdet@Q_{max} = 20\text{cmH}_2\text{O}$ (vertical dashed line). (B) X-ray obtained during the first third of voiding shows a normally funneled bladder neck and an open urethra.



(A)



(B)

Fig. 2.5 Normal micturition in a 59-year-old woman referred for evaluation of elevated residual urine found unexpected during CAT scan done for abdominal pain. She denied any urologic symptoms. Uroflow was normal (VOID: 25/230/0). (A) Urodynamic study. FSF = 75 ml, 1st urge = 210 ml, severe urge = 523 ml, bladder capacity = 533 ml. At the command to void, the sphincter EMG tracing becomes silent and there is a slight rise in detrusor pressure followed by a sustained detrusor contraction and near normal uroflow curve. During voiding there were several small increases in EMG activity. The first one (the vertical dotted line) momentarily prevents micturition, but as she relaxes, she voids with a normal upswing in the flow curve. The second one occurs after flow has begun to decline and appears to have no effect on flow (i.e. an artifact). Once she emptied her bladder and flow ceased, there is a further rise in detrusor pressure (an aftercontraction). Aftercontractions are considered to be normal variants. $Q_{max} = 16$ ml, $P_{det@Qmax} = 43$ cmH₂O, $P_{detmax} = 50$ cmH₂O, voided volume = 533 ml, and PVR = 0 ml. (B) X-ray obtained during voiding shows a normal, funneled bladder neck (black arrows) and open urethra.

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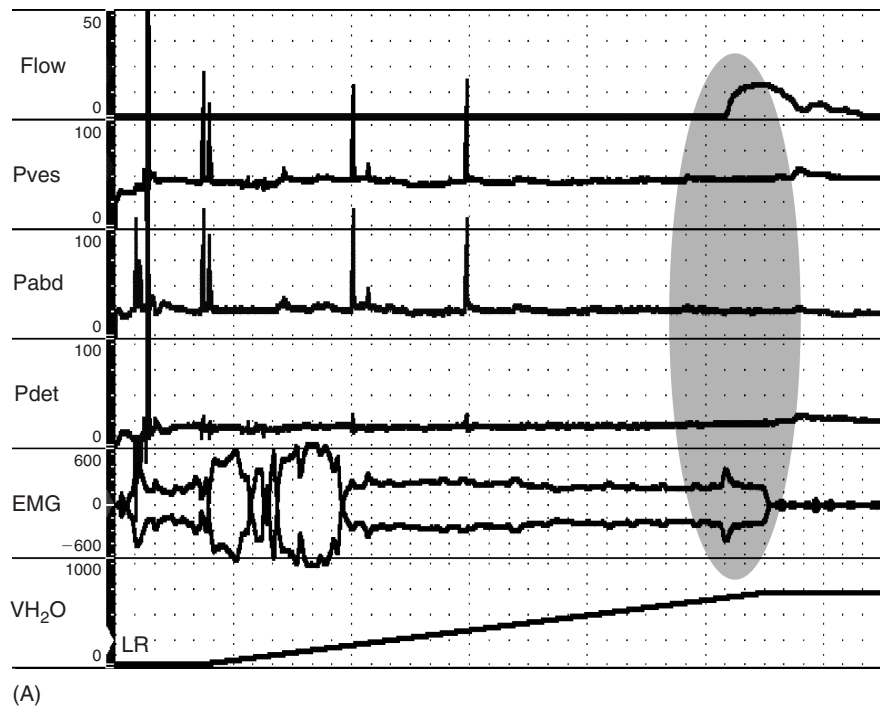
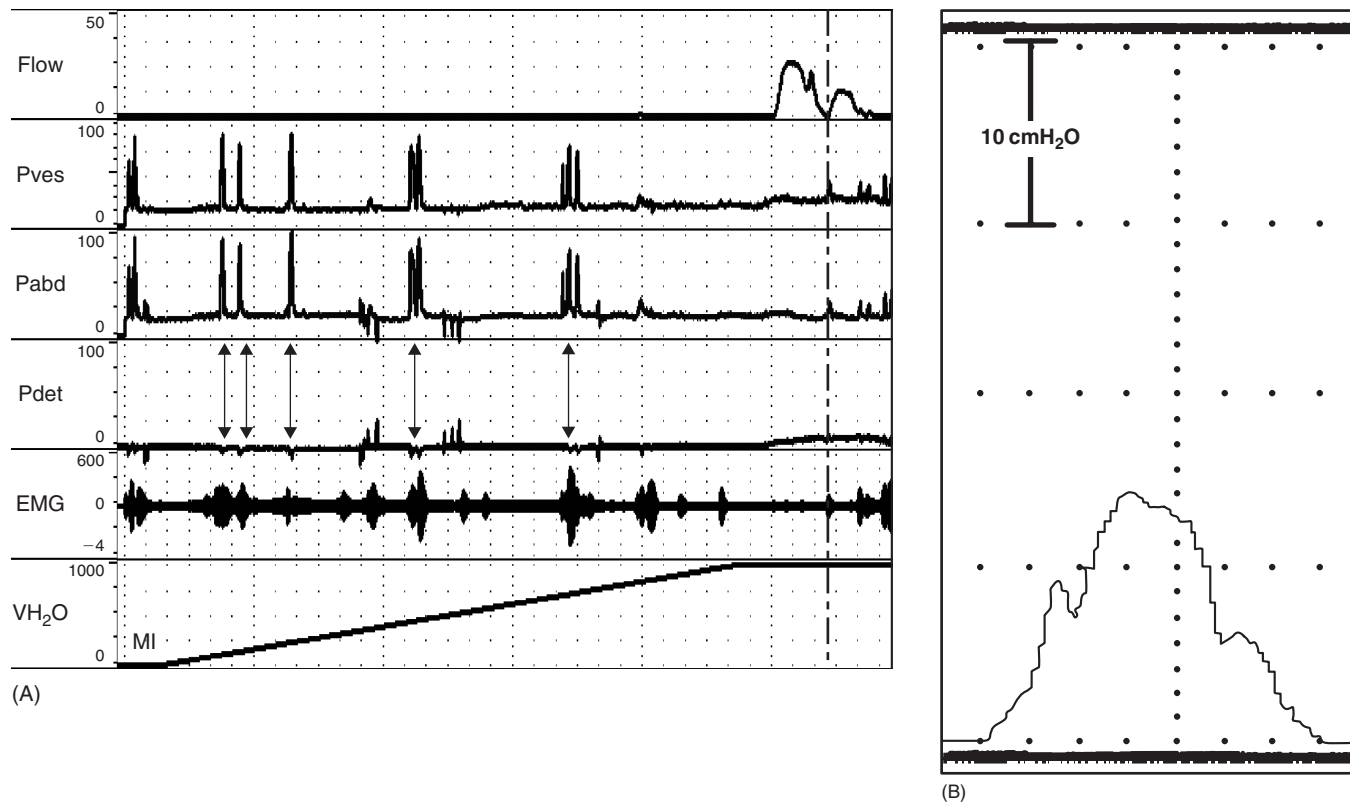
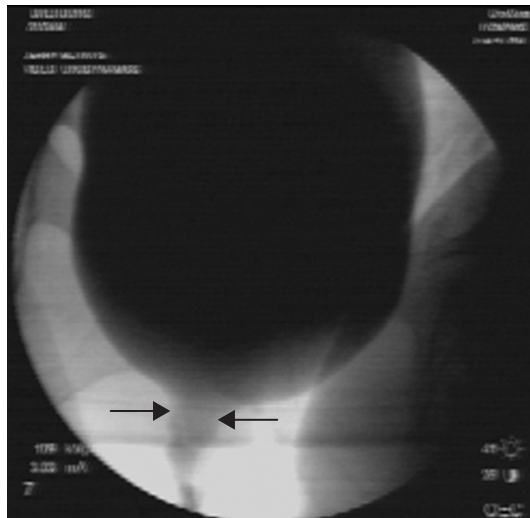


Fig. 2.6 In this 74-year-old woman, normal micturition is accomplished without an appreciable rise in Pdet. Since there is no rise in Pabd either, the only possible explanation for this is that there is a detrusor contraction, but all of the energy is converted to uroflow because urethral resistance is very low. (A) Urodynamic tracing. In this patient there is an apparent increase in sphincter EMG activity at the beginning of voiding. That it is an artifact is demonstrated by the fact that there is no rise in detrusor pressure despite a smooth rise in uroflow (shaded oval). $Q_{\max} = 16 \text{ ml/s}$, $P_{\text{det}@} Q_{\max}} = 23 \text{ cmH}_2\text{O}$, $P_{\text{detmax}} = 28 \text{ cmH}_2\text{O}$, voided volume = 624 ml, and PVR = 89 ml. (B) X-ray obtained during the first part of voiding shows the proximal two-thirds of the urethra to be wide open, but there is an apparent narrowing in the distal third. However, the Pdet/Q curve excludes any possibility of urethral obstruction, so this is considered a normal variant, sometimes termed a “spinning top” urethra.



(A)

(B)



(C)

Fig. 2.7 Normal micturition in a 62-year-old woman with a low Pdetmax and a large bladder capacity. (A) Urodynamic tracing. FSF = 394 ml, 1st urge = 755 ml, severe urge occurred at 911 ml, and bladder capacity = 1001 ml. During bladder filling she was asked to cough a number of times to test for stress incontinence (arrows). The slight fall (negative deflection) in pdet is due a small subtraction error and of no significance. During the voluntary detrusor contraction, there is a single interruption of the stream caused by a momentary contraction of the striated sphincter (vertical dotted black line). Since her prior uroflow was normal (see Fig. 2.5(B)), we consider this to be a normal variant due to the unfamiliar setting of the urodynamic study. Qmax = 27 ml/s, Pdet@Qmax = 5 cmH₂O, Pdetmax = 9 cmH₂O, voided volume = 856 ml, and PVR = 141 ml. (B) Uroflow just prior to urodynamic study. Qmax = 14 ml/s, voided volume = 106 ml, and PVR = 0 ml. (C) X-ray obtained early in micturition shows a normally funneled bladder neck and open urethra (arrows).

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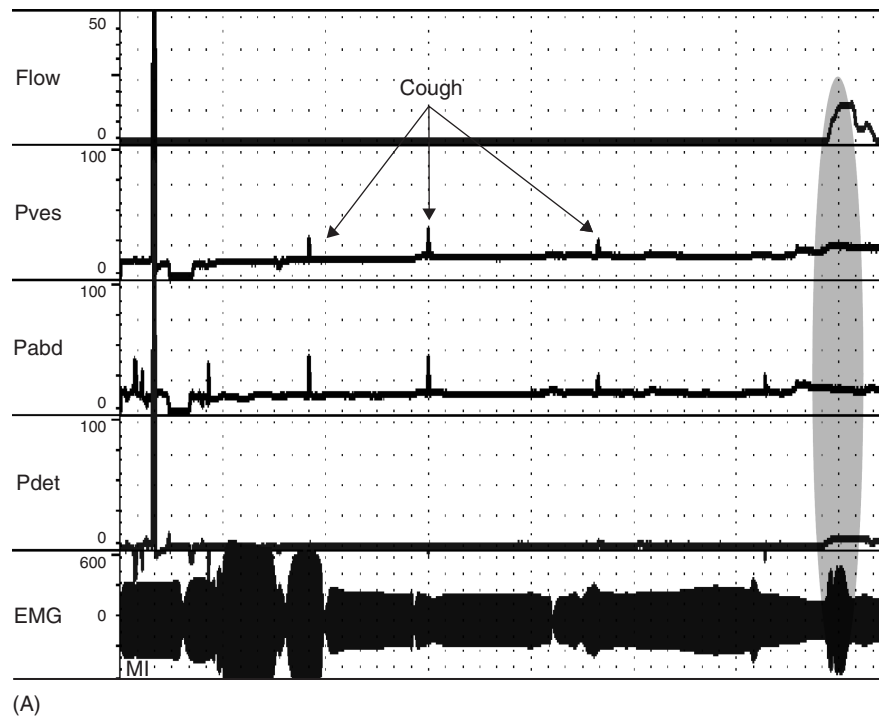


Fig. 2.8 ML is an 82-year-old woman evaluated because of recurrent episodes of bacterial cystitis. She denies lower urinary tract symptoms (LUTS). (A) Urodynamic study. FSF = 290ml, 1st urge = 348ml, severe urge = 382ml, bladder capacity = 382ml, Qmax = 15ml/s, Pdet@Qmax = 7 cmH₂O, Pdetmax = 7 cmH₂O, voided volume = 382ml, and PVR = 0ml. The apparent rise in EMG activity (shaded oval) is likely an artifact since there is neither a rise in Pdet nor a fall in uroflow. Note that during each cough, pressure is transmitted equally to the bladder and abdomen (and urethra, not pictured here). This is one of the mechanisms to maintain continence.

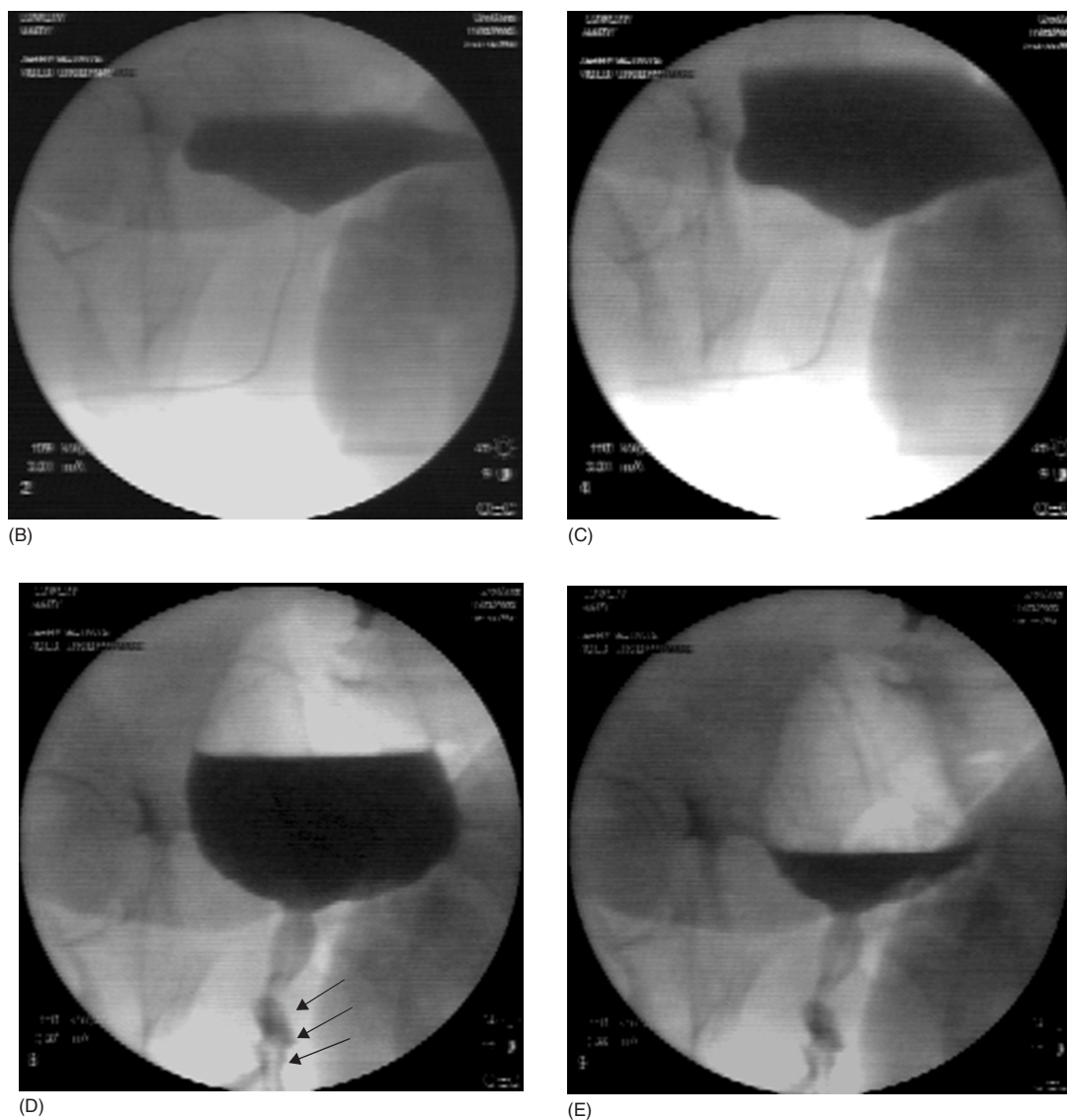


Fig. 2.8 (continued) (B+C) X-rays obtained during bladder filling showing a normal bladder contour. (D) X-ray obtained at Q_{max} shows a urethra of normal contour and some contrast in the vagina (arrows). (E) X-ray obtained near the end of micturition.

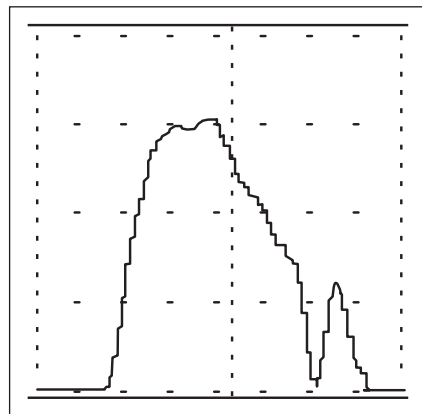
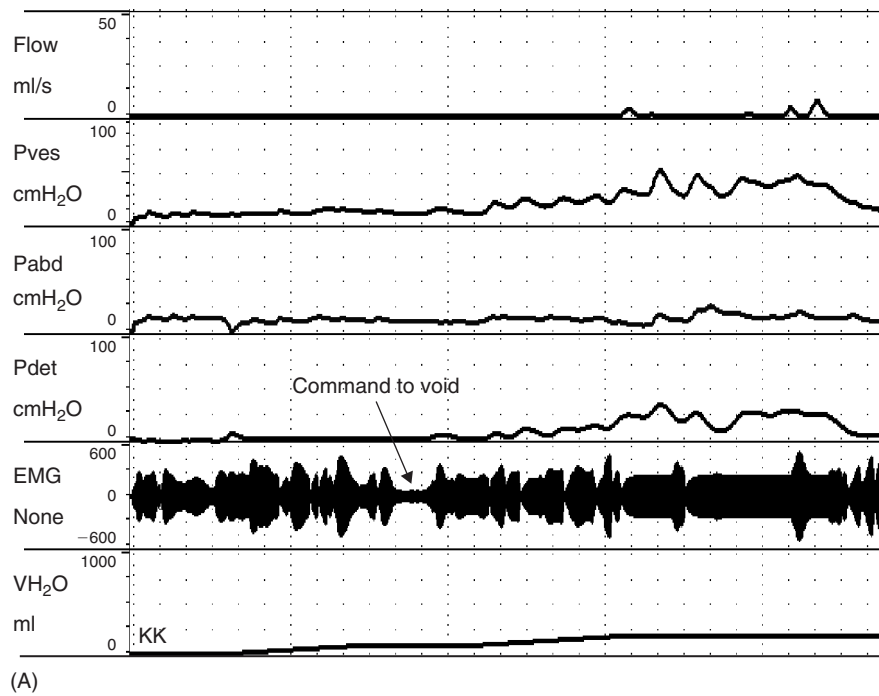
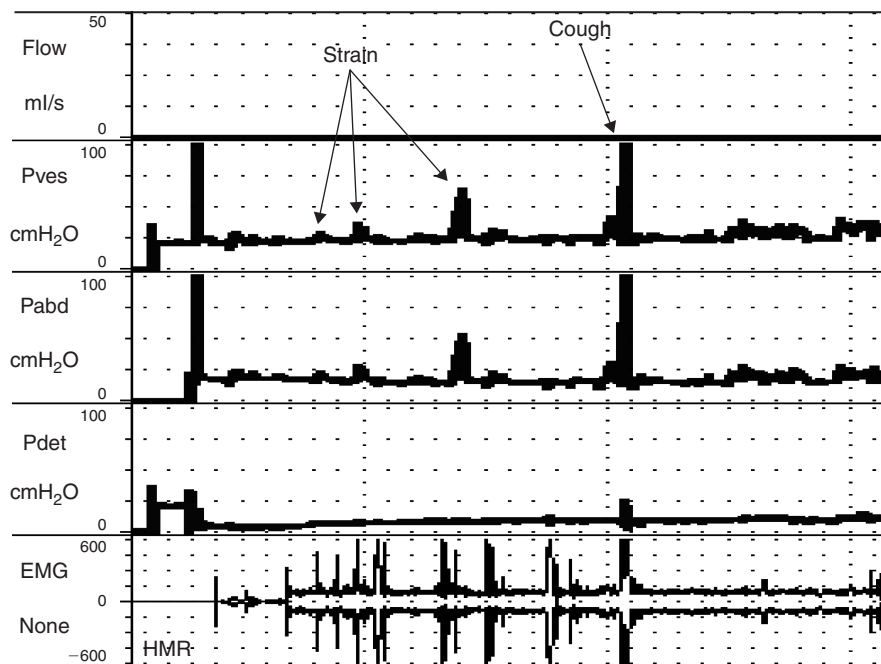


Fig. 2.9 Normal variant KK is a 23-year-old woman evaluated because of recurrent urinary tract infections associated with sexual activity. Bladder diary was normal, maximum voided volume was 360ml and uroflow was normal. (A) Urodynamic study. FSF = 28 ml, 1st urge = 102ml, severe urge = 124ml, and bladder capacity = 192ml. At the command to void, she relaxes her sphincter (EMG becomes silent) and develops a detrusor contraction, but involuntarily contracts her sphincter (increased EMG activity) and that reflexly aborts the detrusor contraction. This process is repeated over and over again during the study and she voids with a markedly interrupted stream. She stated, though, that she never voids like this and admitted that she was simply unable to relax during the study. Since her Pdetmax (43 cmH₂O) is normal and her unintubated uroflow was normal (see Fig. 2.8(B)), we concluded that she is normal. Of course, if this were representative of the way she usually voids, we would consider it to be an acquired voiding dysfunction. Q_{max} = 8 ml/s, Pdet@Q_{max} = 26 cmH₂O, Pdetmax = 43 cmH₂O, voided volume = 117 ml, and PVR = 67 ml. Normal uroflow done 1 week prior to urodynamic study. Q_{max} = 30 ml/s; Q_{ave} = 9 ml/s, voided volume = 252 ml, PVR = 0 ml, (C) X-ray obtained at Q_{max} shows a normal bladder and urethra.



(A)



(B)

Fig. 2.10 Storage mechanisms: (A) Urodynamic tracing. During cough and strain there is equal transmission of pressure to the bladder and urethra accompanied by an increase in sphincter EMG. (B) The urethra remains closed (arrows) and continence is preserved during straining. Note that the bladder base has descended well below the pubis.

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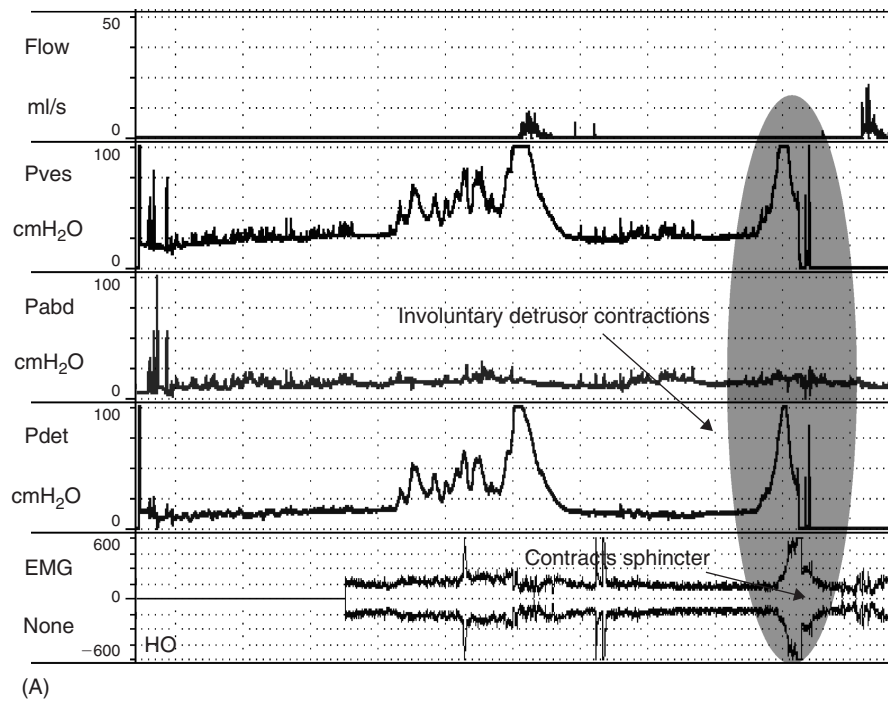


Fig. 2.11 Storage reflexes interrupting the urinary stream and aborting the detrusor contraction: The patient is a man with mostatic obstruction. (A) Urodynamic tracing. During an involuntary detrusor contraction, the patient voluntarily contracts his sphincter, obstructing the urethra. The detrusor contraction subsides and he is not incontinent (shaded oval). (B) X-ray obtained as he contracts his sphincter to prevent incontinence. One would expect the contrast to stop at the membranous urethra, but since he has prostatic obstruction the entire proximal urethra, is narrowed.