molecules (adhesins) on the P-fimbriae (pili) of bacteria that interact with receptors on the surface of urothelial cells. Specific adhesins (e.g., those encoded by the pyelonephritis-associated pili [*pap*] gene) are associated with infection. In addition, certain types of fimbriae promote renal tropism, persistence of infection, or an enhanced inflammatory response.

- *From the urethra to the bladder*, organisms gain entrance during urethral catheterization or other instrumentation. Long-term catheterization, in particular, carries a risk of infection. In the absence of instrumentation, *urinary infections are much more common in females*, and this has been ascribed to the shorter urethra in females, as well as the absence of antibacterial properties found in prostatic fluid, hormonal changes affecting adherence of bacteria to the mucosa, and urethral trauma during sexual intercourse, or a combination of these factors.

The mechanisms by which microbes move *from the bladder to the kidneys* are described below.

- *Urinary tract obstruction and stasis of urine.* Ordinarily, organisms introduced into the bladder are cleared by continual voiding and by antibacterial mechanisms. However, outflow obstruction or bladder dysfunction results in incomplete emptying and residual urine. In the presence of stasis, bacteria introduced into the bladder can multiply unhindered. Accordingly, urinary tract infection is frequent among patients with lower urinary tract obstruction, such as may occur with benign prostatic hypertrophy, tumors, or calculi, or with neurogenic bladder dysfunction caused by diabetes or spinal cord injury.
- *Vesicoureteral reflux.* Although obstruction is an important predisposing factor in ascending infection, it is *incompetence of the vesicoureteral valve* that allows bacteria to ascend the ureter into the renal pelvis. The normal ureteral insertion into the bladder is a one-way valve that prevents retrograde flow of urine when the intravesical pressure rises, as in micturition. An incompetent vesicoureteral orifice allows the reflux of bladder urine into the ureters *(vesicoureteral reflux)* (Fig. 20-26). Reflux is most often due to a congenital absence or shortening of the intravesical portion of the ureter, such that the ureter is not compressed during micturition. In addition, it may be acquired by bladder infection itself. It is postulated that bacteria themselves or the associated inflammation can promote reflux by affecting ureteral contractility, particularly in children. Vesicoureteral reflux is estimated to affect 1% to 2% of otherwise normal children. *Acquired vesicoureteral reflux* in adults can result from persistent bladder atony caused by spinal cord injury. The effect of vesicoureteral reflux is similar to that of an obstruction in that there is residual urine in the urinary tract after voiding, which favors bacterial growth.
- *Intrarenal reflux.* Vesicoureteral reflux also affords a ready mechanism by which the infected bladder urine can be propelled up to the renal pelvis and deep into the renal parenchyma through open ducts at the tips of the papillae (intrarenal reflux). Intrarenal reflux is most common in the upper and lower poles of the kidney, where papillae tend to have flattened or concave tips rather than the convex pointed type present in the midzones of the kidney (and depicted in most textbooks). Reflux can be demonstrated radiographically by a voiding cystourethrogram, in which the bladder is filled with a radiopaque dye and films are taken during micturition. Vesicoureteral reflux can be demonstrated by this method in about 30% of infants and children with urinary tract infection (Fig. 20-26).

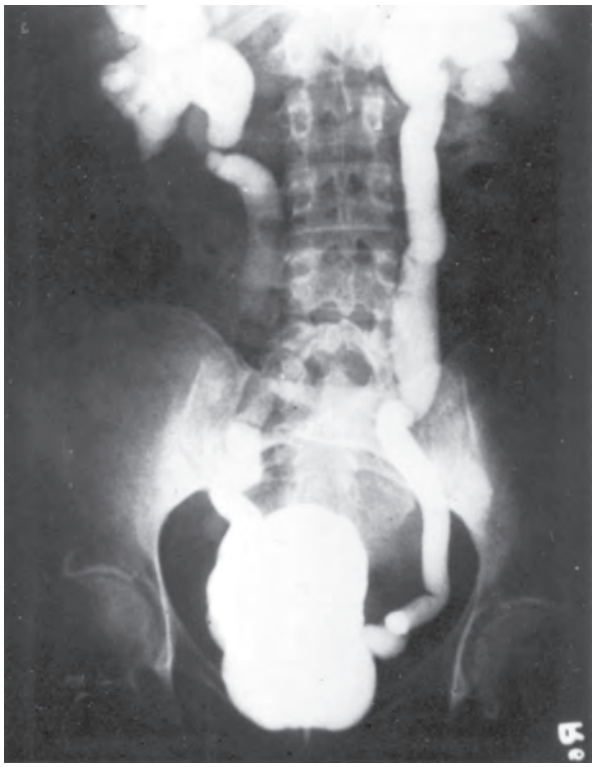

Figure 20-26 Vesicoureteral reflux demonstrated by a voiding cystourethrogram. Dye injected into the bladder refluxes into both dilated ureters, filling the pelvis and calyces.

In the absence of vesicoureteral reflux, infection usually remains localized in the bladder. Thus, the majority of individuals with repeated or persistent bacterial colonization of the urinary tract suffer from cystitis and urethritis *(lower urinary tract infection)* rather than pyelonephritis.

Acute Pyelonephritis

Acute pyelonephritis is a suppurative inflammation of the kidney caused by bacterial and sometimes viral (e.g., polyomavirus) infection, which can reach the kidney by hematogenous spread or, more commonly, through the ureters in association with vesicoureteral reflux.

MORPHOLOGY

The hallmarks of acute pyelonephritis are **patchy interstitial suppurative inflammation, intratubular aggregates of neutrophils, neutrophilic tubulitis and tubular necrosis**. The suppuration may occur as discrete focal abscesses or large wedge-like areas and can involve one or both kidneys (Fig. 20-27).