

Pyelonephritis and Urinary Tract Infection

Ascending infection • Renal inflammation • Reflux and scarring

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Learning objectives

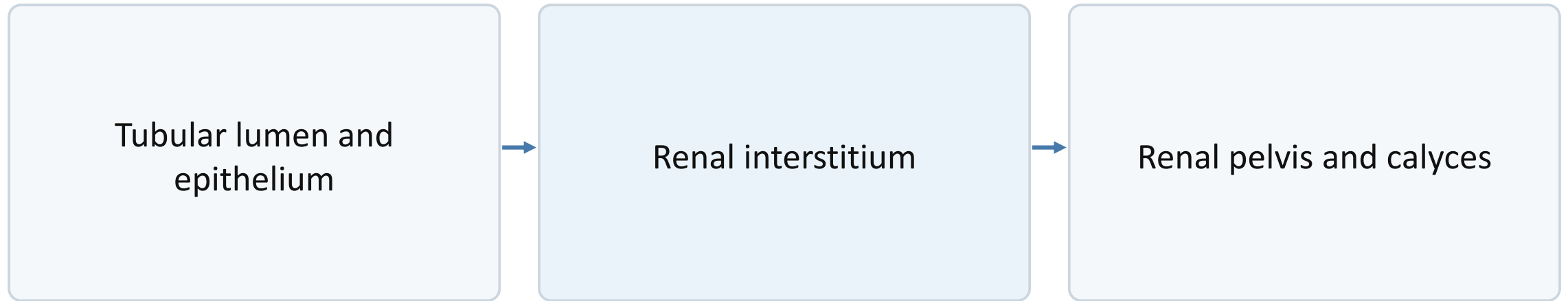
- Localize infection within the urinary tract and renal parenchyma.
- Explain ascending and hematogenous infection, including bacterial adherence.
- Connect urinary stasis, vesicoureteral reflux and intrarenal reflux to renal injury.
- Interpret the key morphologic, clinical and urinary findings of pyelonephritis.

Pyelonephritis is an infection-driven tubulointerstitial disease

The inflammatory process involves renal tubules, interstitium and pelvis.

- It belongs to the tubular and interstitial group of renal disorders.
- Infection can progress from the lower urinary tract to renal parenchyma.
- Recurrent injury in a susceptible kidney may produce scarring.

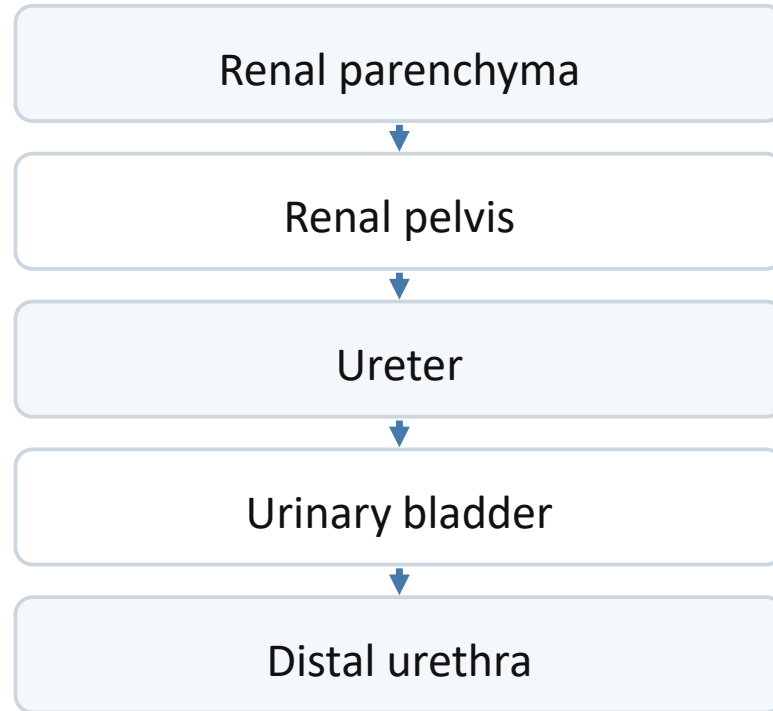
Three compartments define the lesion



The pathologic diagnosis is an anatomic one: Infection extends beyond bladder urine into renal tissue.

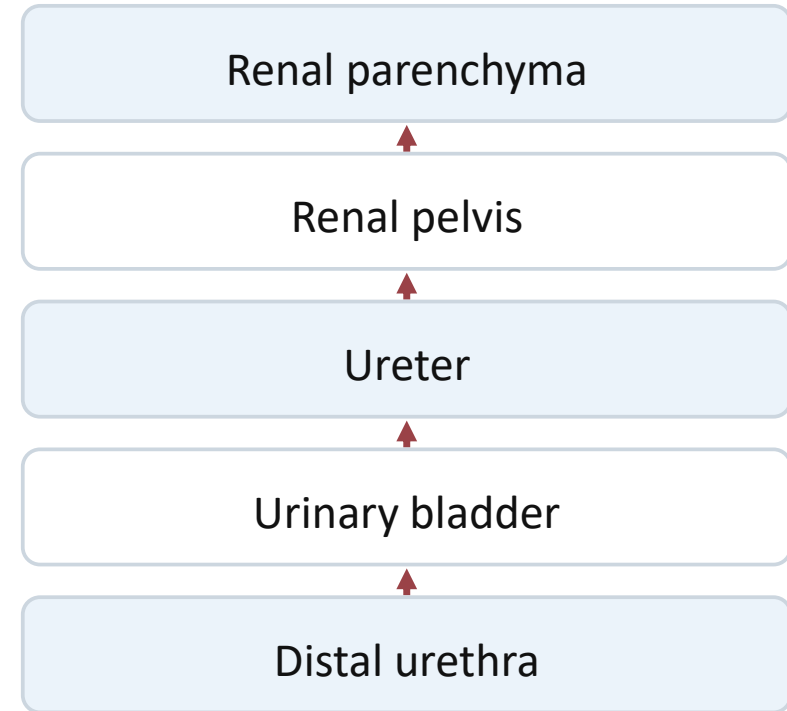
The urinary tract: Infection has a direction

Normal urine drainage



Downward

Potential ascending infection



Upward when barriers fail

Ascending infection is the dominant route to the kidney.

Lower and upper urinary tract infection

Lower tract

Urethra and bladder

Urethritis / cystitis

May remain anatomically localized

Irritative voiding symptoms predominate

Upper tract

Collecting system and renal parenchyma

Pyelonephritis

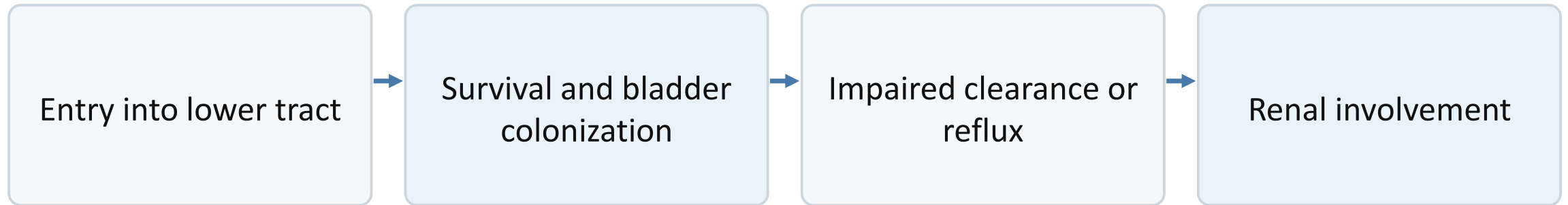
Tubules + interstitium involved

Systemic symptoms and flank pain may occur

Asymptomatic bacteriuria is not pyelonephritis

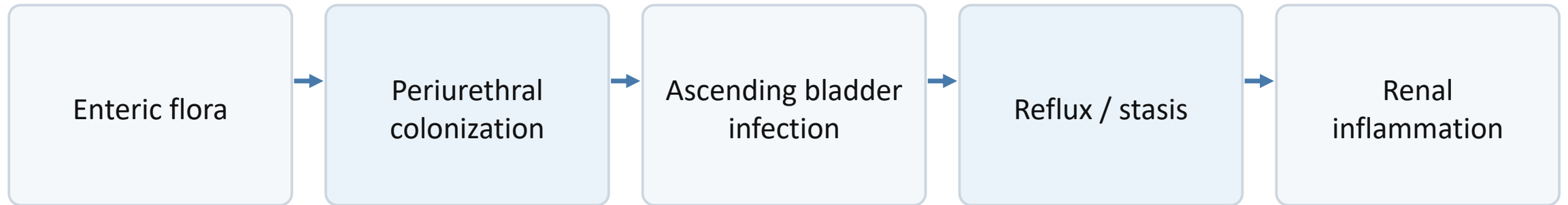
- Bacteria may be present in urine without symptoms.
- Bacterial colonization can remain localized to the lower urinary tract.
- An infected bladder does not necessarily imply renal parenchymal infection.
- Clinical localization must not rely on bacteriuria alone.

An uncomplicated ascent is not inevitable



The decisive transition is from lower-tract colonization to kidney exposure.

The central pathogenesis model



Microbial factors and host urinary-tract abnormalities act together.

Enteric gram-negative bacilli dominate

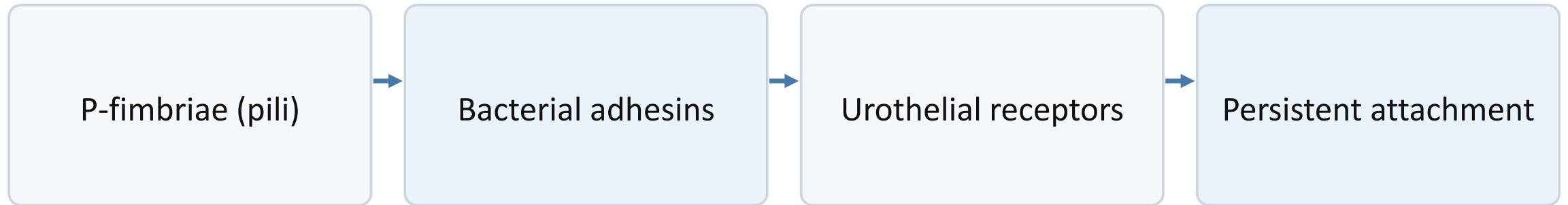
More than 85% of UTIs are attributed to enteric gram-negative bacilli in the supplied Robbins text.

- The organisms are commonly part of normal intestinal flora.
- Periurethral contamination links the enteric reservoir to urinary infection.
- This is an etiologic distribution of UTI, not a diagnostic threshold.

Major bacterial pathogens

Organism	Pathologic context
Escherichia coli	By far the most common cause
Proteus spp.	Enteric gram-negative bacillus
Klebsiella spp.	Enteric gram-negative bacillus
Enterobacter spp.	Enteric gram-negative bacillus
Enterococci and staphylococci	Additional bacterial causes

Adherence converts exposure into colonization



Adhesion permits establishment of bacteria along the mucosal surface.

Host and organism both determine whether infection progresses

- An organism must reach the mucosal surface and persist.
- Fimbrial adhesins promote contact with epithelial receptors.
- Urine flow and voiding oppose colonization.
- Abnormal anatomy or function shifts the balance in favor of ascent.

Unusual renal pathogens require clinical context

Context	Examples
Fungal or mycobacterial infection	Immunocompromised or transplant patient
Granulomatous renal inflammation	Polyomavirus, cytomegalovirus, adenovirus
Candida may accompany fungal pyelonephritis	Also nonenteric bacteria and certain fungi

Two routes can seed the kidney

Ascending route

Starts at lower urinary tract

Progresses via ureter / collecting system

Most common route in pyelonephritis

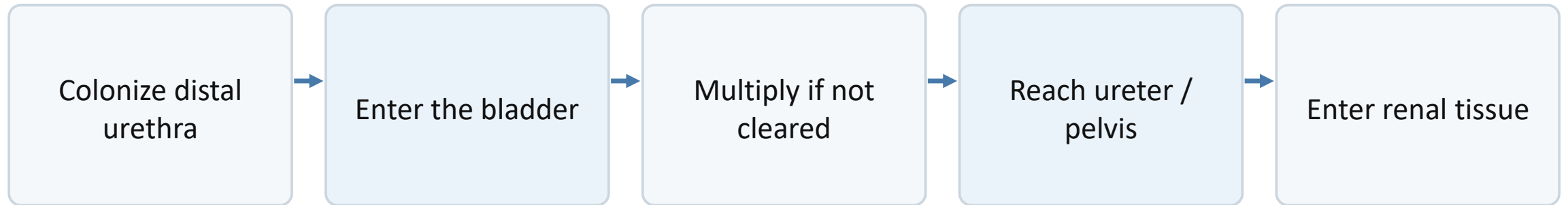
Hematogenous route

Originates in bloodstream

Seeding from a distant infection

Less common; Favors selected host settings

Ascending infection is a multistep process

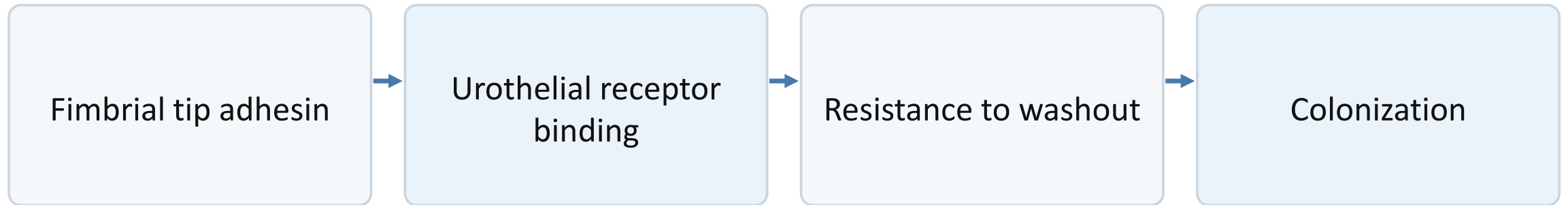


The steps explain why bladder infection is commoner than renal infection.

Initial colonization occurs at the distal urethra

- Enteric coliforms can colonize the urethra and female introitus.
- Bacterial adhesion influences persistence at these sites.
- This step precedes invasion of the bladder in the usual ascending pathway.

P-fimbriae are a microbial attachment apparatus



Surface recognition is a plausible mechanistic target—not simply passive contamination.

Bladder entry can follow urethral instrumentation

- Catheterization and instrumentation provide a route into the bladder.
- Long-term urinary catheterization markedly changes the exposure context.
- The source identifies catheterization as a common predisposing circumstance.

Why sex influences UTI frequency

Predisposing anatomy / physiology

Shorter female urethra

Shorter route from periurethral organisms to the bladder

Consequence for ascent

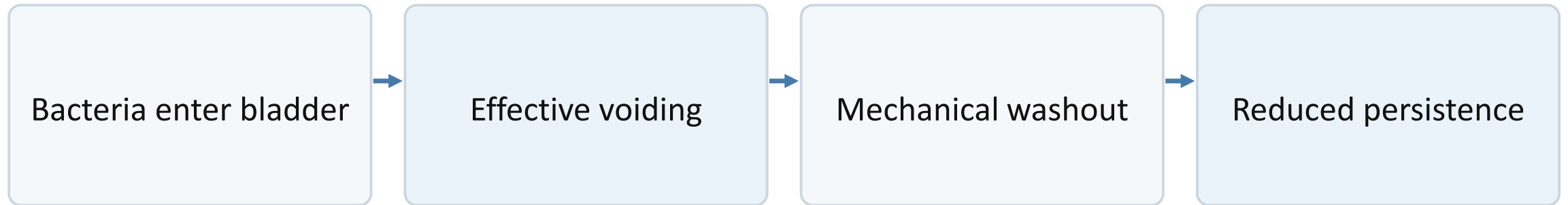
Absence of antibacterial prostatic secretions in females

Loss of one local antibacterial influence

Hormonal changes and intercourse-related urethral trauma

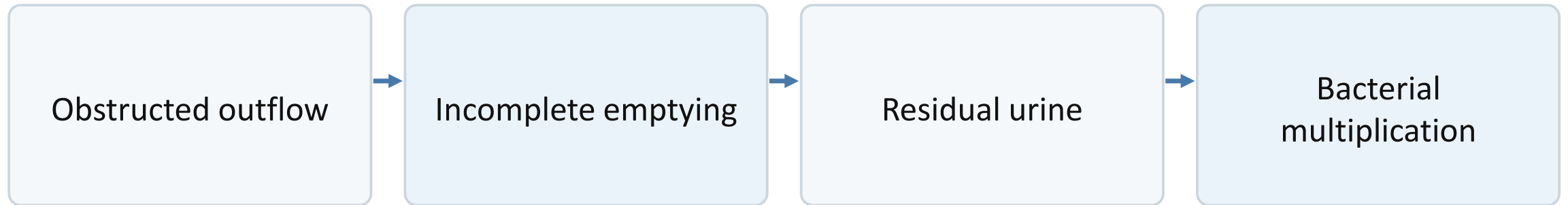
May alter adherence or bacterial access

Voiding is a major anti-infective mechanism



Retention of residual urine interrupts the clearance mechanism.

Urinary stasis favors bacterial proliferation

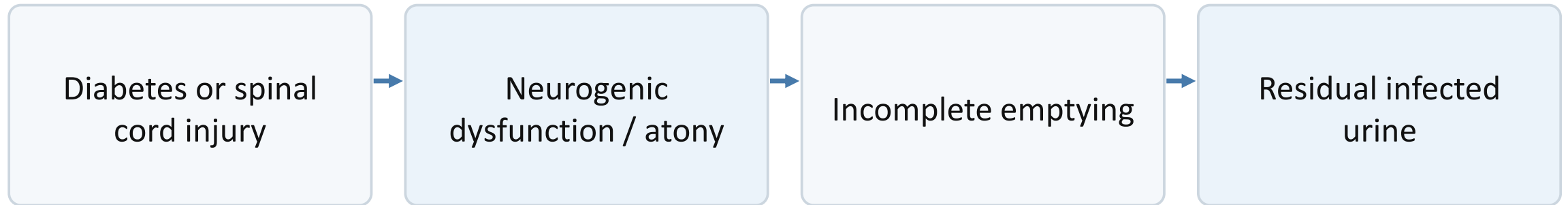


Obstruction increases risk by altering urinary flow, not by introducing a new organism.

Anatomic causes of obstruction and stasis

Abnormality	Pathogenetic effect
Benign prostatic enlargement	Bladder outlet resistance / residual urine
Tumor	Mechanical urinary outflow obstruction
Calculus	Luminal obstruction
Urinary-tract structural lesion	Interruption of normal passage and emptying

Functional stasis: Neurogenic bladder



A functional emptying defect can mimic the microbial consequences of obstruction.

Normal vesicoureteral junction versus reflux

Competent ureteric valve

Oblique intravesical ureter is compressed

Raised bladder pressure does not drive urine into ureter

Flow is predominantly one-way

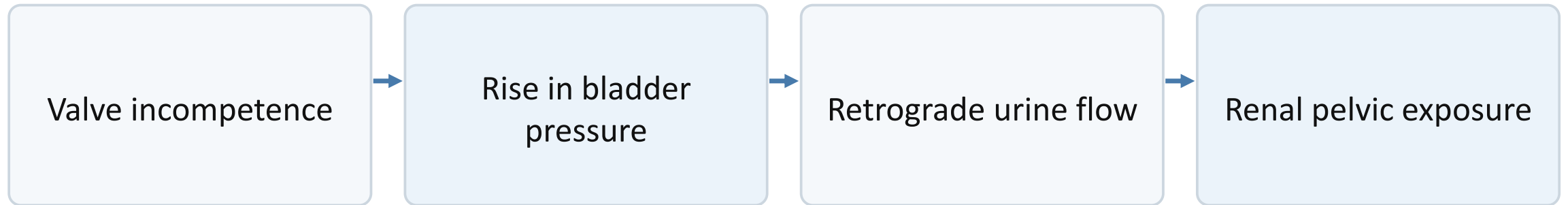
Incompetent ureteric valve

Shortened or incompetent intramural segment

Bladder urine can move retrograde into ureter

Ascending exposure to the renal pelvis

How vesicoureteral reflux develops



Reflux delivers bladder contents upward during filling or voiding.

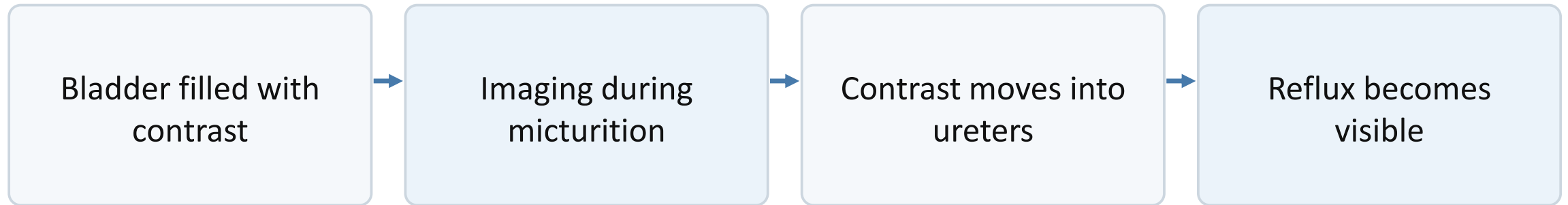
Primary reflux commonly reflects abnormal ureteric insertion

- Congenital deficiency or shortening of the intravesical ureter weakens the anti-reflux mechanism.
- During micturition the intramural ureter may fail to compress adequately.
- Affected children are especially important because recurrent injury can create polar scars.

Acquired reflux can accompany bladder disease

- Bladder infection and inflammation may affect the vesicoureteral junction.
- Altered ureteral contractility is proposed as a mechanism, especially in children.
- This mechanism is described as a postulate, not a universal rule.

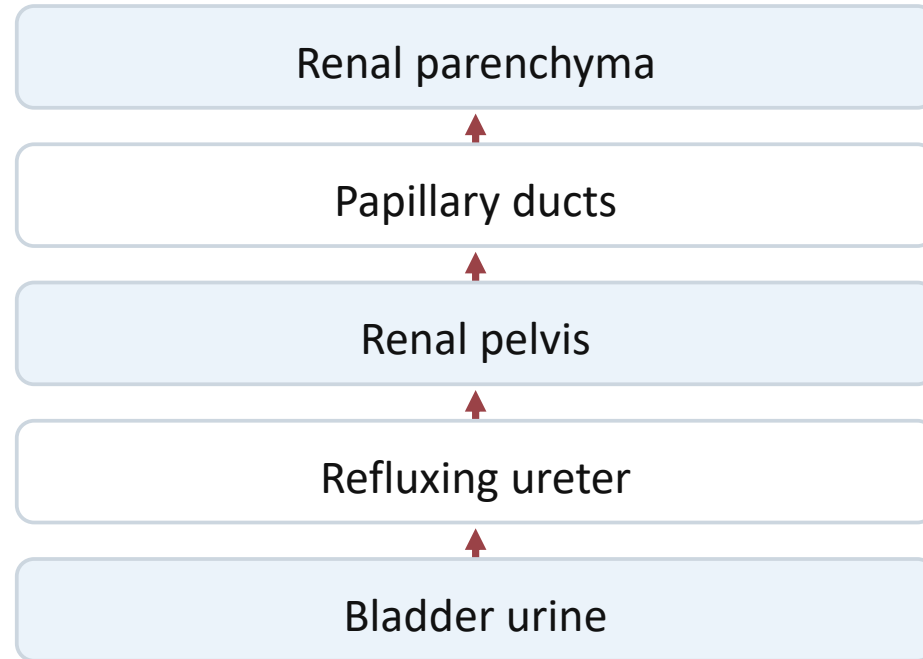
Voiding cystourethrography demonstrates reflux



The test documents retrograde movement of contrast; It does not by itself prove active renal infection.

Intrarenal reflux extends beyond the pelvis

Retrograde movement of infected urine



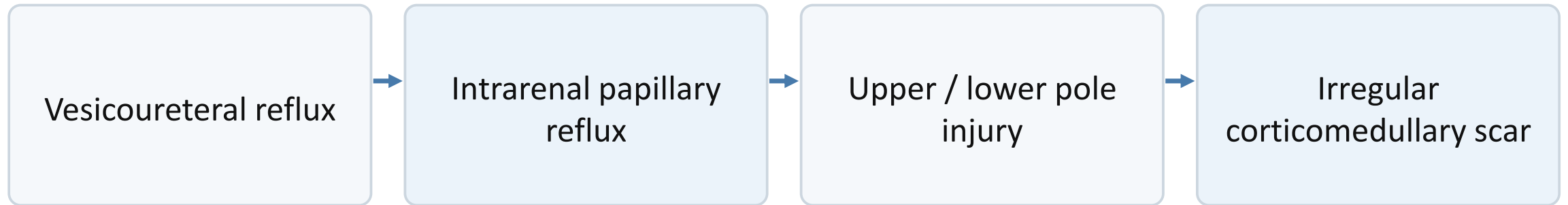
Read the mechanism upward: Bladder → ureter → renal parenchyma

Open collecting ducts at the papillary tip can transmit infected urine into kidney tissue.

Papillary anatomy creates polar vulnerability

- Upper and lower pole papillae are often relatively flat or concave.
- This shape favors open ductal orifices and intrarenal reflux.
- Midzonal convex, pointed papillae are relatively less susceptible.

Why pyelonephritic scars are often polar



The distribution of chronic scars reflects the route and site of ascending exposure.

Stasis and reflux are different but complementary

Urinary stasis

Increases bacterial residence time

Promotes bacterial growth in residual urine

Examples: Obstruction, atony

Vesicoureteral reflux

Permits retrograde flow toward kidney

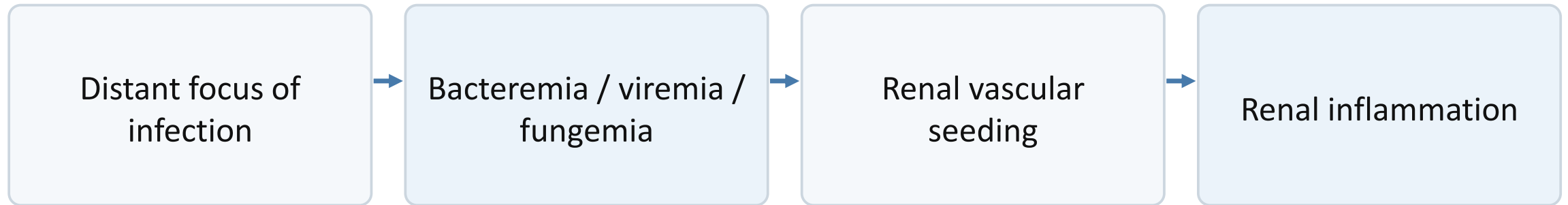
Moves infected bladder urine to renal pelvis

Often congenital; May be acquired

Most lower-tract infections do not become pyelonephritis

- The source emphasizes that infection often remains in the bladder without reflux.
- Repeated bacteriuria may produce cystitis or urethritis alone.
- A barrier failure or predisposing condition helps explain renal extension.

Hematogenous renal infection bypasses the lower tract



Bloodstream spread is less common than ascending infection.

Infective endocarditis is an example of hematogenous seeding

- Bacteria from a distant focus can enter the bloodstream.
- The vascular route can expose both kidneys to circulating microbes.
- Debilitated hosts and urinary obstruction increase susceptibility.

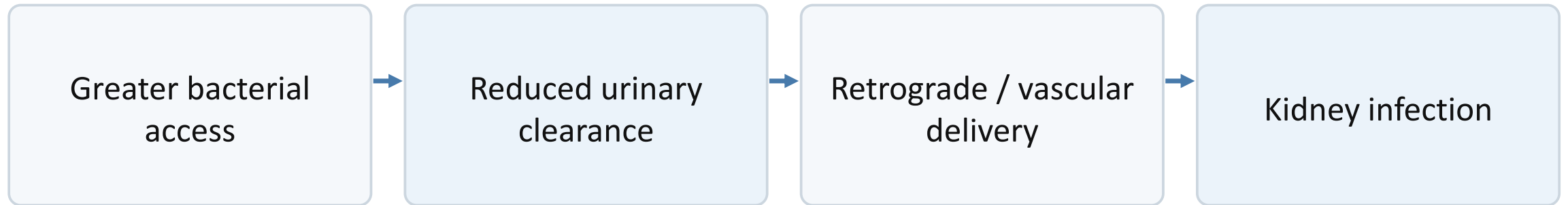
Immunosuppression changes the etiologic spectrum

- Renal transplant recipients and other immunocompromised hosts may develop nonenteric infections.
- Robbins mentions staphylococci, certain fungi and viruses.
- The host setting matters when interpreting infectious renal lesions.

Ascending and hematogenous infection: Clues

Feature	Ascending	Hematogenous
Primary starting site	Bladder / urethra	Bloodstream
Usual frequency	Predominant	Less frequent
Typical predisposing factor	Reflux or urinary stasis	Distant infection, host debility
Renal exposure	Pelvis → parenchyma	Vascular delivery

Clinical risks converge on three mechanisms

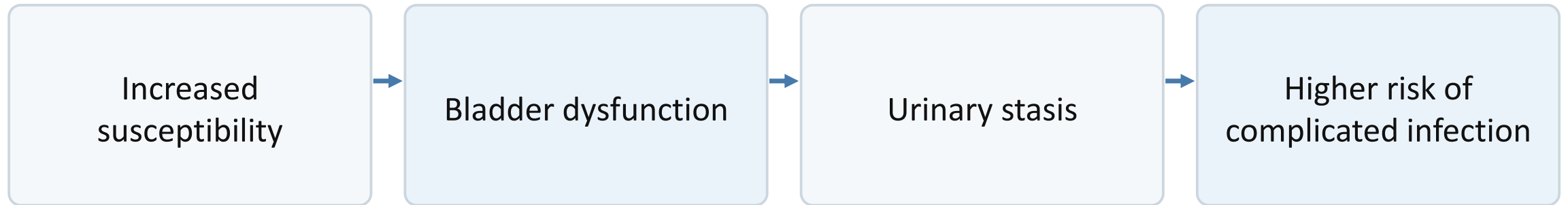


Anatomy, instrumentation, comorbidity and microbial virulence contribute at different steps.

Pregnancy can increase UTI susceptibility

- Pregnancy as a clinical setting associated with infection.
- Bacteriuria during pregnancy may progress to symptomatic infection.
- This teaching section focuses on predisposition; It does not specify screening or drug protocols.

Diabetes predisposes through more than one pathway



Diabetes also increases concern for severe complications such as papillary necrosis.

Age changes the predominant risk factors

- In young children, congenital urinary abnormalities are important.
- After infancy through early adulthood, UTIs are more frequent in females.
- In older males, prostatic enlargement and instrumentation become important.

Pyelonephritis becomes clinically apparent when the kidney is inflamed

Flank or costovertebral-angle pain with fever and malaise supports upper-tract involvement.

- Irritative bladder symptoms can coexist.
- The clinical syndrome reflects both local tissue injury and systemic inflammation.
- Symptoms alone do not document the microbiologic cause.

Local irritation and systemic inflammation

Lower-tract manifestations

Dysuria

Increased urinary frequency

Urgency

Renal / systemic manifestations

Costovertebral-angle pain

Fever

Malaise

The classic onset of acute pyelonephritis is abrupt

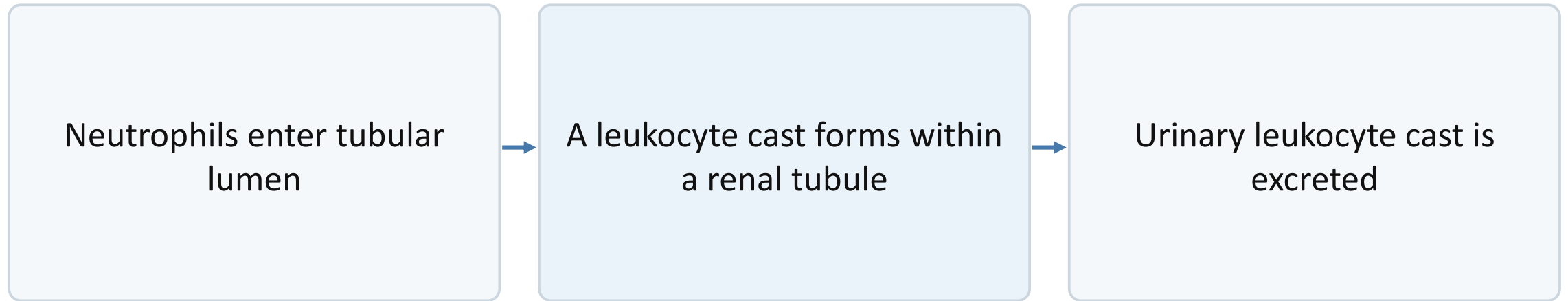
- The patient commonly develops fever and costovertebral-angle pain.
- Malaise supports the presence of a systemic inflammatory response.
- Cystitis-associated urinary symptoms may be present simultaneously.

Pyuria demonstrates inflammation—but not its location

Leukocytes in the urine occur in lower and upper tract infection.

- Pyuria arises from the inflammatory response.
- The finding cannot independently distinguish cystitis from pyelonephritis.
- Localization requires additional clinical and laboratory context.

Leukocyte casts implicate renal tubules



Casts are formed within renal tubules, providing a localization clue unavailable from isolated pyuria.

Urine culture establishes the microbiologic diagnosis

- The source identifies culture as the method establishing urinary infection.
- Interpret organism recovery with the symptoms and site of disease.
- Pyuria alone cannot identify the causative microbe.

Interpret urinary findings by what they prove

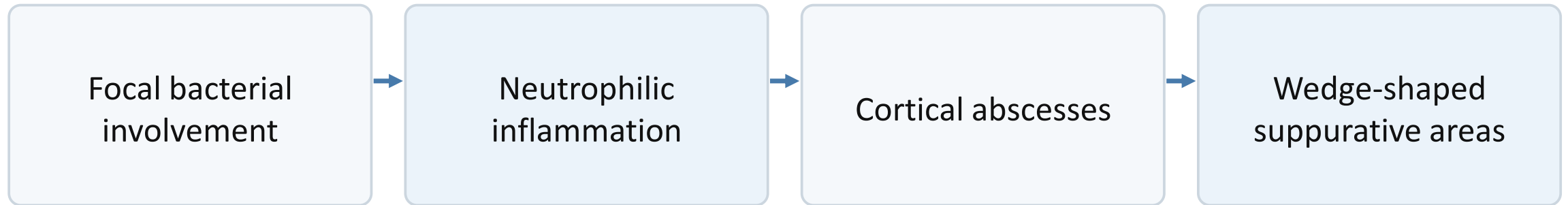
Finding	Supported interpretation	Limitation
Bacteriuria	Organisms present in urine	May be asymptomatic
Pyuria	Urinary tract inflammation	Does not localize upper vs lower
Leukocyte casts	Renal tubular inflammatory involvement	Not an organism identification test
Urine culture	Microbiologic evidence of infection	Needs clinical interpretation

Acute pyelonephritis is a suppurative renal lesion

Neutrophils infiltrate tubules and interstitium, with associated tubular injury.

- The process is often patchy.
- Infected tubular lumens can provide conduits for extension.
- Focal abscesses may form when the interstitial reaction becomes destructive.

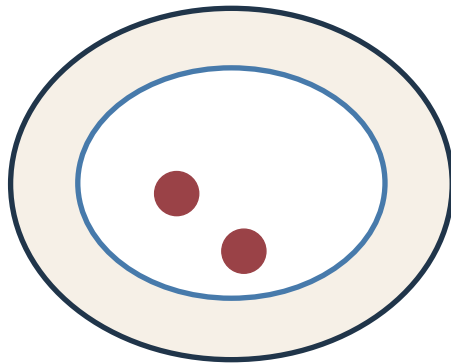
Acute gross lesions are often patchy



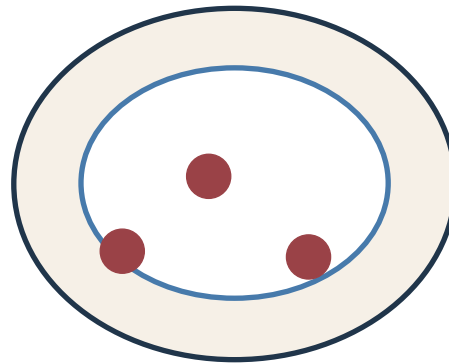
Schematic progression; Actual gross pathology requires authentic specimen evidence.

Intratubular neutrophils: The defining microscopic clue

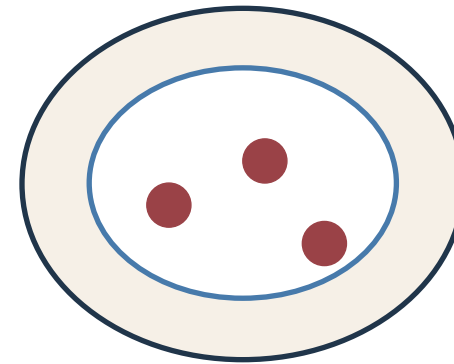
Neutrophils accumulate within tubular lumens during acute renal infection.



Tubular lumen



Neutrophil aggregates

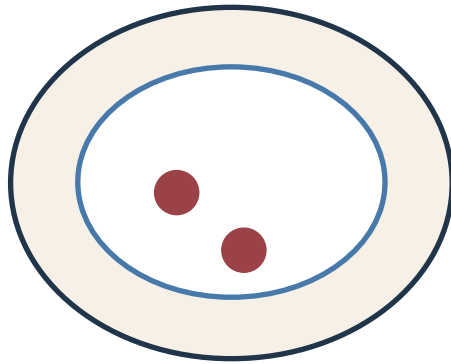


Injured epithelium

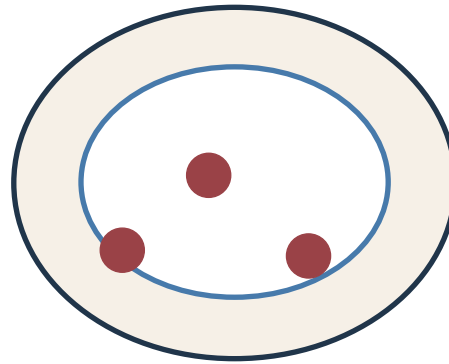
Schematic microanatomy — not an H&E photomicrograph.

Neutrophilic tubulitis indicates epithelial involvement

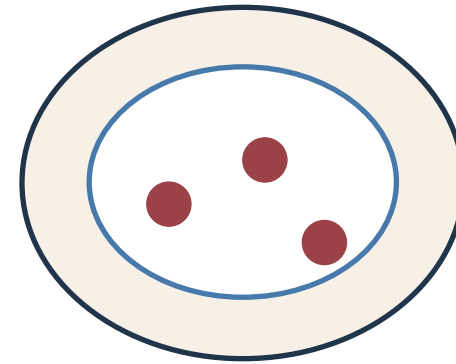
Neutrophils can cross or permeate injured tubular epithelium.



Tubular lumen



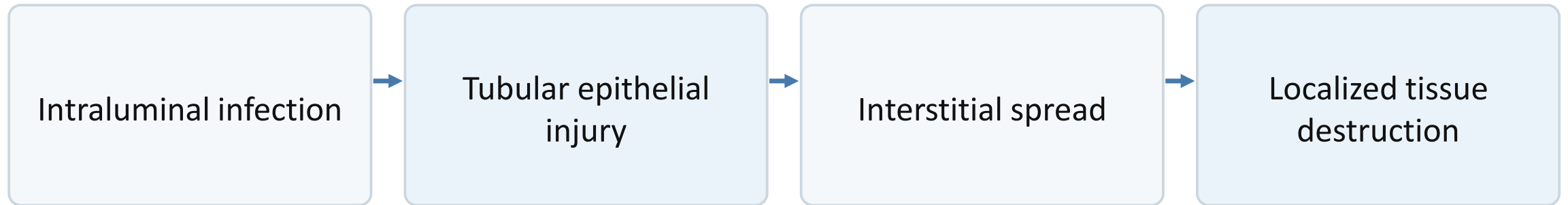
Neutrophil aggregates



Injured epithelium

Tubular wall inflammation links microbial infection to structural damage. Schematic only.

Interstitialium can develop a suppurative abscess



An abscess represents more than colonization: It is destructive parenchymal inflammation.

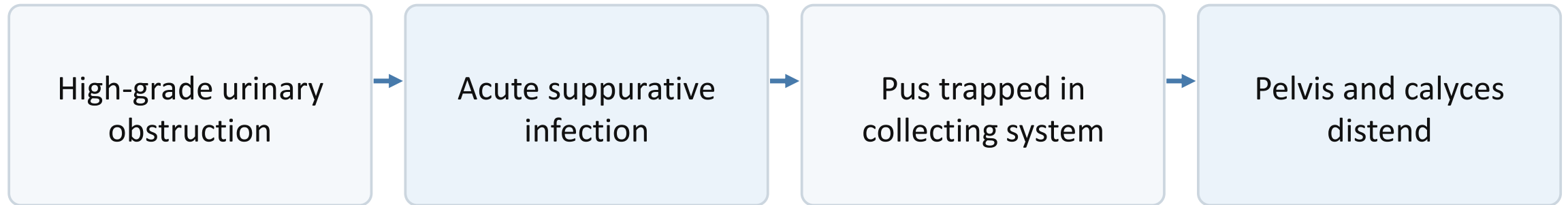
Glomeruli are initially relatively resistant

- Early acute pyelonephritis is predominantly tubular and interstitial.
- Glomeruli are often relatively spared in less extensive disease.
- Destructive infection can eventually involve glomeruli when severe.

Papillary necrosis: A severe complication

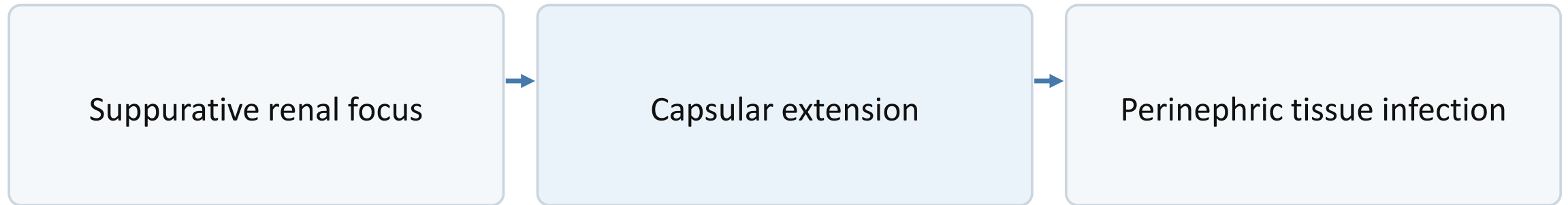
Predisposition	Morphologic consequence
Diabetes	Ischemic injury affecting renal papillae
Sickle cell disease	Susceptibility of medullary/papillary tissue
Urinary obstruction	Compromised medullary and papillary environment
Pathologic appearance	Coagulative necrosis of papillary tissue

Pyonephrosis means pus cannot drain



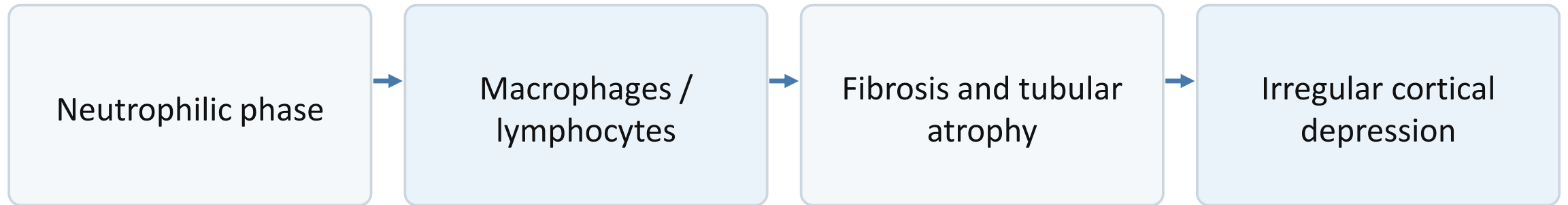
Obstructed infected urine is a distinct anatomic complication of pyelonephritis.

Perinephric abscess crosses the capsule



The site of disease is no longer confined to renal parenchyma.

Healing can convert acute inflammation into scar



Persistent or recurrent injury can permanently distort the renal architecture.

Chronic pyelonephritis has a calyceal fingerprint

Chronic tubulointerstitial injury is accompanied by scarring and deformation of the calyces and pelvis.

- The renal surface is often irregularly scarred.
- The calyx deep to the scar may be blunted or distorted.
- This anatomic pairing strongly supports reflux-related disease.

Scarring pattern helps classify chronic injury

Chronic pyelonephritis

Coarse, uneven, discrete scars

Often polar and asymmetric

Underlying calyceal abnormalities

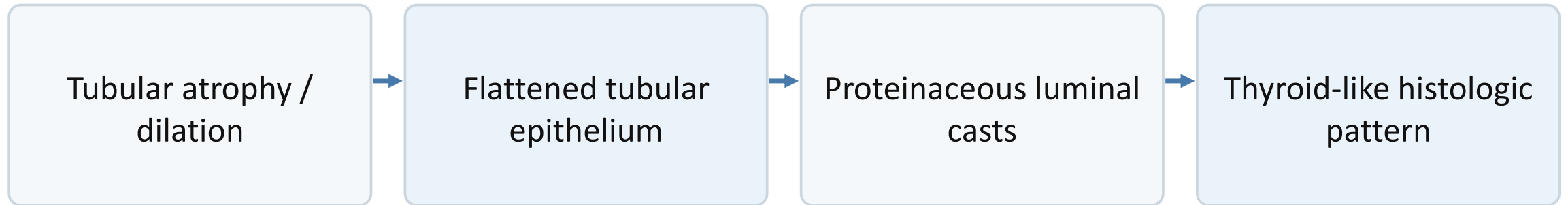
Chronic glomerulonephritis

More diffusely and symmetrically contracted kidneys

Primary glomerular process

Not defined by focal calyceal clubbing

Thyroidization represents chronically damaged tubules

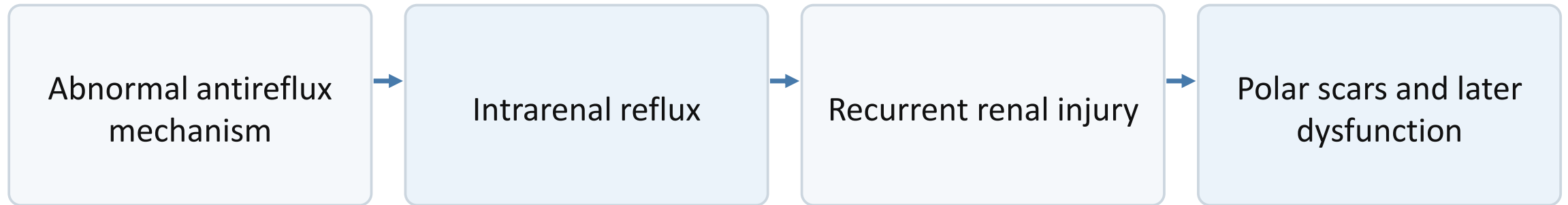


This pattern must be interpreted in an appropriate tubulointerstitial context.

Chronic scarring can impair tubular function

- Loss of urine-concentrating capacity may cause polyuria and nocturia.
- Progressive parenchymal loss can reduce renal function.
- Hypertension may accompany chronic reflux-associated renal damage.

Reflux nephropathy can begin in childhood



Underlying reflux and scarring can be present even without overt repeated acute episodes.

Acute and chronic pyelonephritis: Pattern comparison

Feature	Acute	Chronic
Dominant cell response	Neutrophils	Chronic mononuclear infiltrate
Tubules	Tubulitis and luminal pus	Atrophy, dilatation, thyroidization
Gross pattern	Patchy suppurative foci	Irregular corticomedullary scars
Collecting system	Active inflammation	Calyceal deformity and blunting

Not every tubulointerstitial lesion is infectious

Pattern	Useful discriminating clue
Pyelonephritis	Infectious context; Neutrophilic tubulitis / pelvic involvement
Drug-induced interstitial nephritis	Medication exposure; Variable eosinophils
Other chronic interstitial lesions	May scar tubules without characteristic reflux-pattern calyceal deformity
Analgesic nephropathy	Also may involve papillae and calyces

Clinical case 1: Where is the infection?

A patient has dysuria and urinary frequency. Urine contains many leukocytes, but there is no reported flank pain or fever.

Does pyuria alone establish acute pyelonephritis?

A. Yes—pyuria proves kidney involvement.

B. No—pyuria does not distinguish upper from lower UTI.

Case 1: Pyuria is not anatomically specific

No. Pyuria can arise from cystitis or pyelonephritis.

- Look for renal symptoms and systemic inflammatory features.
- A leukocyte cast, if present, supports intrarenal involvement.
- Culture is important for identifying the infectious agent.

Clinical case 2: Recurrent infection in a child

A child has repeated bacterial UTIs and imaging shows retrograde movement of contrast from the bladder into a ureter during voiding.

What mechanism increases the risk of renal scarring?

A. Vesicoureteral and intrarenal reflux

B. Isolated glomerular immune-complex deposition

Case 2: Reflux carries infection toward the poles

Valve incompetence permits ascending exposure of the renal pelvis.

- Intrarenal reflux transmits infected urine through papillary ducts.
- Flattened or concave polar papillae are more susceptible.
- Repeated injury can generate upper- and lower-pole scars.

Clinical case 3: Infected obstructed system

An adult with urinary outflow obstruction develops severe upper urinary tract infection. The renal pelvis and calyces contain purulent material that cannot drain.

Which complication does this describe?

A. Pyonephrosis

B. Isolated asymptomatic bacteriuria

Case 3: Pyonephrosis is suppuration behind an obstruction

An obstructed collecting system fills with purulent exudate.

- The fundamental combination is obstruction plus infection.
- The lesion involves the pelvis/calices, not simply bladder colonization.
- It is distinguished from perinephric abscess, which extends beyond the capsule.

Five principles to retain

- Pyelonephritis localizes to tubules, interstitium and renal pelvis.
- The dominant pathway is ascending infection by enteric organisms.
- Urinary stasis and reflux determine which infections reach the kidney.
- Neutrophilic tubulitis and leukocyte casts are strong renal clues.
- Reflux-related chronic injury creates irregular scars with calyceal deformation.

Textbook reference

Robbins, Cotran & Kumar: Pathologic Basis of Disease. 11th edition. Elsevier, 2026.

Relevant textbook sections: Pyelonephritis and Urinary Tract Infection; Acute Pyelonephritis; Chronic Pyelonephritis and Reflux Nephropathy.