

Management of the Critical Care Patient

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Day-to-day management of critically ill patients in intensive care units (ICUs) can be challenging. Not only are the clinical data of many ICU patients complex and changing frequently, but their medical records are often voluminous. Furthermore, their clinical status often changes rapidly and unexpectedly. Adding to these challenges is that specific etiologies of acute events that resulted in ICU admission may remain unknown for days, if not weeks or longer, after admission. As such, short- and long-term prognoses may likewise remain unclear along with the family's or patient's goals of care. Patient- and family-centered (Chapter 104) day-to-day management depends on effective communication, handoffs ("handovers"), and other collaborative practices that, in turn, depend on daily multidisciplinary rounds (Chapter 103). This chapter describes the principles and practices of successful day-to-day management of ICU patients. It highlights the key information that ICU clinicians should obtain and assess to maximize efficiency and accuracy in day-to-day patient management.

A Primer on Data Collection

In the modern ICU, large amounts of patient data are generated on a daily basis and need timely review and evaluation. These include not only the data at hand but also what may be referred to as *meta-data*—that is, trends or other changes in today's data compared to data from yesterday and prior days and patterns of changes in the current data compared to prior patterns (Box 13.1). As a result, ICU clinicians are required to assimilate and codify an extraordinary number of details for each of their ICU patients in order to make decisions and organize a plan of care.

Three processes are involved in memory: encoding, storage, and retrieval. *Encoding* refers to how something is processed for memory in the brain. Once it has been encoded, it can then be *stored* in the form of a short-term or long-term memory. *Retrieval* is the process of getting information from a memory. Most ICU data are stored in a subdivision of the short-term memory, termed the working memory, for quick processing. However, humans can only process a limited number of details (about seven) for short intervals in the working memory.

However, a typical ICU clinician is required to be familiar with many more than seven details daily for each ICU patient. This presents an intrinsic challenge to successful processing of ICU data on rounds and day-to-day management of critically ill patients, especially when the ICU clinician must also follow trends or evolving patterns of changes in data. Additionally, the data are often subject to irregular sampling, measurement error, and interpretation error, as well as the inherent bias of the individual clinician in terms of what to believe and base decisions on. Accuracy and consistency can thus be difficult to achieve.



Additional online-only material indicated by icon.

BOX 13.1 ■ Essential Data in the Day-to-Day Management of the ICU Patient**History, Interval**

- Review overnight events with nursing and covering providers, including abnormalities on ECG telemetry, and telemedicine providers' report, if applicable
- Review chart for updated consults or progress notes
- Medication reconciliation

Physical Exam

- Vital signs
- Mental status, including level of pain (see Figure 5.1 and Table 5.1, Chapter 5), sedation (RASS score) (Table 5.2, Chapter 5) and presence or absence of delirium (CAM-ICU) (Figure 37.1, Chapter 37)
- Focused physical examination

Bedside Data

- Assessment of catheters and tubes
- Mechanical ventilator settings
- Intravenous infusions (including sedatives and vasopressors and their trends or past 24 hours)

Labs and Other Studies**Common Laboratory Tests**

- Basic metabolic panel (+/- liver function tests)
- CBC
- Coagulation studies
- Arterial/venous blood gases
- Blood and other cultures

Common Radiographic Studies

- Chest and other radiographs
- CT scans

CBC, complete blood count; CT, computed tomography; RASS, Richmond Agitation-Sedation Scale; CAM-ICU, Confusion Assessment Method for the Intensive Care Unit.

Monitoring of Overnight Events and Patient Assessment

In this age of medical care, information is passed from clinician to clinician with greater frequency than in the past (e.g., so-called handoffs or handovers). It is therefore crucial that a detailed account of overnight events be given at the beginning of each day. A recommended approach is for the daytime ICU clinicians to discuss major events from the previous night with the physicians and nurses who cover the nighttime shift, followed by a review of notes and documentation. ICU nurses spend the largest percentage of time at the bedside of their patients, and are thus an invaluable resource. Input from clinicians based on telemedicine units that remotely monitor certain ICU patients (Chapter 111) can also be an important source of information about the nighttime events.

The daily assessment proceeds with systematic review of vital signs and fluid balance (i.e., intake and output—I's and O's) over the previous 24 hours. In the ICU, vital signs include temperature, blood pressure, pulse, respirations, oxygen saturation (by pulse oximetry), and pain and other important signs and symptoms (e.g., level of sedation and presence of delirium).

In evaluating the patient's temperature curve, awareness of both hyperthermic and hypothermic episodes can provide useful information about infectious and inflammatory conditions in addition to common complications of ICU stays such as atelectasis and drug reactions.

Blood pressure is of vital importance to maintain normal body homeostasis. Adequate blood pressure is a key component in enabling the body to successfully deliver oxygen to the tissue and cellular level. Assessment of blood pressure should include both a review of systolic and diastolic pressures as well as the mean arterial pressure, which can serve as an indirect assessment of organ perfusion pressure.

Review of the patient's pulse should include both a quantitative assessment of heart rate as well as a qualitative assessment of rhythm. Additionally, it is important to review the alarm history on the telemetry monitor to diagnose any arrhythmias that may have occurred over the interval of interest.

Assessment of respiratory status and arterial oxygen saturation should include both breathing rate and pattern. Awareness of abnormal rates can be useful to diagnose increased work of breathing, which may subsequently lead to respiratory failure, or very slow rates, which may result from oversedation with respiratory depressant medications. Unusual patterns of respirations, such as Cheyne-Stokes or Kussmaul breathing or episodes of obstructive apneas, can also be valuable in diagnosing a patient's pathology.

Patients with respiratory failure who require mechanical ventilation should have their ventilator mode and relevant settings reviewed as well as serial arterial blood gases (ABGs) to assess acid base status, ventilation, and oxygenation. The latter includes assessing how closely the pulse oximetry readings of O₂ saturation are to the calculated or measured O₂ saturation by ABGs or co-oximetry, respectively. In association with respirations and O₂ saturations and ABGs, ventilator settings and functions should be reviewed at the bedside, including tidal volume (total and mL/kg predicted body weight [PBW], Appendix E), airway pressures (peak and plateau), minute ventilation, and evidence of auto positive end expiratory pressure (auto-PEEP) (see Chapters 2, 3, and 47).

Because of its importance for patient- and family-centered care, some argue that pain measurement (e.g., Figure 5.1 in Chapter 5 and Figure 87.1 in Chapter 87) should be regarded and treated as the "fifth vital sign" in ICU patients. The same could be argued regarding the patient's level of consciousness (e.g., level of sedation or agitation and the presence and severity of delirium). Regarding the latter, it is recommended that both the goal of sedative therapy and actual level of sedation achieved be communicated by a standard method, such as by using the Richmond Agitation-Sedation Scale (RASS) (Chapter 5). Likewise, a standard method of evaluating for the presence of delirium (e.g., the Confusion Assessment Method for Intensive Care Unit [CAM-ICU]) is preferred over less systematic methods.

Lastly, volume status (intravascular and total body fluid volumes) should be reviewed. Assessment of total intake and output, including a breakdown in type of intake (e.g., parenteral versus enteral) and output (urine, stool, drains, and tubes) can help clarify the significance of imbalances between "ins" and "outs." Urine output, in particular, is a simple way to assess for adequate organ perfusion (with usual threshold of adequate urine output being 0.5 mL/kg PBW/h). If patients have indwelling central catheters, notation of accurate measurements of central venous pressure (CVP) or pulmonary arterial wedge pressure (PAWP) can aid in the assessment of volume status.

Once the assessment of vital signs is complete, providers should examine the patient and talk with the patient and family members, if present (Chapter 104). At a minimum, one should perform a focused physical exam, including breath and heart sounds, mental status, and other neurologic signs, and inquire about the presence and intensity of pain, dyspnea, and other symptoms. When doing one's physical exam, one should carefully evaluate the skin to measure skin turgor; identify new pressure ulcers (Chapter 42), ecchymoses, or rashes (Chapter 43); assess temperature and capillary refill time in all extremities; and look for signs of infection at the insertion site of medical devices (Chapters 11 and 14). A mental status exam should be tailored to the individual patient, with either a qualitative assessment (alert, delirious, somnolent, obtunded, etc.) or a quantitative

assessment, such as the Glasgow Coma Scale (GCS) (Chapter 99), a sedation scale (e.g., RASS) (Chapter 5), or a delirium assessment (e.g., CAM-ICU) (Chapter 37).

A review of the ICU flow sheet (paper or electronic) can be helpful for assessing changes in clinical status of patients over the past 24 hours or longer as documented by the patient's nurses and respiratory therapists. Likewise, a review of the medical record (paper or electronic) for results of diagnostic tests in the past 24 hours as well as notes and recommendations by consultants, house staff, or other members of the ICU clinical team is recommended to round out the daily picture.

Medication Reconciliation and Nutritional Management

Examination of intravenous (IV) fluids and drugs that are being administered as continuous IV infusions ("drips") and other medications is an essential part of the daily patient assessment. Common IV drips in an ICU setting include IV fluids, vasopressors, sedatives, analgesics, and antimicrobials. Pertinent information about IV drips includes the type and rate, changes over the past 24 hours or longer, as well as whether an IV drug is being administered continuously or by bolus. When assessing vasopressors, it is important to note any trends of dosage changes that may reflect a change in the patient's hemodynamic status. For patients on sedation, awareness of whether patients are on continuous infusions or bolus or if they receive a daily sedation interruption (i.e., a spontaneous awakening trial SAT, see Chapter 5) and its results are key components of the assessment of mental status, as sedation can adversely impact a patient's degree of alertness and cognition (see Chapter 36).

Antimicrobials should be reviewed in a systematic manner to avoid overutilization, which can result in antimicrobial resistance. When possible, a daily therapeutic plan should exist for each antimicrobial, including knowledge of the rationale for its use, the current number of days of therapy, and the planned number of days of treatment.

All medication orders should be reviewed daily, and any medications that are judged to be no longer necessary should be discontinued. Lastly, knowledge of other medications should include awareness of the dose and frequency as well as an assessment of administration (e.g., being administered, and if not, why being held) and awareness of potential drug side effects and interactions.

As with medications, the patient's current nutritional support should be reviewed in terms of type (Chapter 15), route of administration (Chapter 16), and whether or not it's at the nutritional goal as recommended by nutritional consultants. How the patient is tolerating the current level of nutritional support (e.g., presence of gastric residuals, abdominal distension and discomfort, and presence and type of stool) is an important element to keep on top of as well as whether the nutritional therapy is having its desired effect in terms of the patient's body weight and malnutrition indices (e.g., albumin and prealbumin) starting to trend in the appropriate directions of improved nutrition status (Chapter 15).

Laboratory Data

Critically ill patients routinely have an enormous amount of laboratory data. First, as a general imperative for all hospitalized patients, one should not order a laboratory study ("lab") if it is not needed. Just because patients are in the ICU doesn't necessarily mean they must have all or even most of their labs drawn daily.

Commonly, labs fall into one of three categories: metabolic, cellular, or coagulation. The most common *metabolic* studies include the basic metabolic panel (BMP) or "panel 7," which includes the serum sodium (Na^+), potassium (K^+), chloride (Cl^-), and bicarbonate (CO_2^-) as well as serum blood urea nitrogen (BUN), creatinine (Cr), and glucose (Glu). The complete or comprehensive metabolic panel (CMP) includes BMP elements plus serum calcium (Ca^+),

albumin (Alb⁻), phosphate (P), and liver function tests (LFTs). Assessment of electrolytes is useful to review water and acid/base balance, renal function, and glycemic control. LFTs and albumin aid in evaluating hepatic function and the patient's nutritional status.

The *cellular* test most commonly ordered is the complete blood count (CBC), which allows for assessment of the white blood cell (WBC), hemoglobin and hematocrit (H&H or Hgb & Hct), and platelet (Plt) count. A review of the WBC should include not only total WBC count (leukocytosis or leukopenia) but notation of type of circulating WBC (polymorphoneutrophils [PMNs or “polys”], immature PMNs or bands, lymphocytes, etc.). A decrease in H&H can help to explain subjective dyspnea, pallor, new blood loss, or derangements in oxygen delivery. Finally, a review of the platelet count and its trend from ICU admission can help to explain new bleeding or ecchymoses or signs of a drug-induced thrombocytopenia (Chapter 45).

Coagulation studies most commonly involve measurement of prothrombin time (PT/INR) and partial thromboplastin time (PTT), standard measurements of extrinsic and intrinsic clotting function.

Other labs may prove helpful in certain clinical circumstances. These include lactic acid levels and central venous assessments of oxygen saturation (ScvO₂), both of which relate to how well tissues are oxygenated and perfused, especially in shock states (see Chapters 8, 9, and 10), as well as microbiologic data. When reviewing microbiologic data, it is essential to be aware of the source and date of the lab as well as results, including culture and sensitivities. As an example, if a patient with a fever underwent blood cultures, the provider should know the site of the culture (e.g., peripheral right arm), the organism (e.g., *Staphylococcus aureus*), and the sensitivities (e.g., pan-resistant except to vancomycin). As described in Chapter 14, one should avoid drawing blood cultures through an indwelling catheter because such blood cultures have high false-positive rates (unless the cultures are taken when the catheter is freshly placed under aseptic conditions).

Other Studies

As with laboratory data, ICU patients commonly undergo a considerable number of other diagnostic studies such as chest radiographs (CXR) and computed tomography (CT) scans. As a rule of thumb, ICU providers should be aware of all study results of radiological studies performed or interpreted during the interval since the prior daily rounds and be prepared to discuss them on the current rounds.



The differential diagnosis in ICU patients for falling urine output and rising creatine, as well as fever/hypothermia and leukocytosis, and an annotated bibliography can be found at www.expertconsult.com.

Falling Urine Output and Rising Creatinine

With rare exception, a falling urine output (UOP) typically heralds the onset of acute renal failure (ARF) or, under more current terminology, acute kidney injury (AKI) (Chapter 81). AKI is a common occurrence in the ICU, with up to one third of patients experiencing some degree of AKI during an ICU admission. The drop in UOP is typically a result of decreases in the glomerular filtration rate (GFR) and is associated with the accumulation of urea, creatinine, and body fluids. The differential diagnosis for a rising creatinine and BUN in ICU patients is shown in [Table 13.E1](#). These, in turn, result in various clinical abnormalities, e.g., changes in mental status, electrolyte abnormalities, derangements in acid-based balance, and volume overload. The presence of AKI can have a profound impact on ICU care and outcomes, resulting in prolonged ICU and hospital stays as well as a higher risk of death (~50% of ICU patients who develop AKI in the ICU die). Additionally, it can result in substantial increases in cost. However, renal failure is typically a reversible process, provided an underlying etiology can be determined.

The kidneys have three major functions: filtration of the blood to eliminate metabolic waste, solute and acid-base balance, and volume management. AKI can therefore result in a loss of the ability to regulate any of those responsibilities. AKI typically occurs over a period of hours to days and can occur *de novo* or in addition to underlying chronic renal dysfunction. Renal failure can be defined as *nonoliguric* (> 400 mL UOP/day), *oliguric* (< 400 mL UOP/day), and *anuric* (< 100 mL UOP/day). All three result in variable reductions in the ability to maintain the necessary renal functions.

There are three classifications of AKI: prerenal, intrarenal (intrinsic), and postrenal. Briefly, prerenal AKI results from renal hypoperfusion, intrinsic AKI results from parenchymal disease, and postrenal AKI results from urinary tract obstruction ([Box 13.E1](#)).

Prerenal AKI is the most common of the three and occurs because of a deficit in effective intravascular circulating volume. Therefore anything that reduces renal perfusion can precipitate prerenal AKI. Examples include hypotension, volume depletion (e.g., dehydration, hemorrhage, gastrointestinal losses, burns, renal losses, increased insensible losses), redistribution of volume (e.g., capillary leak syndromes, vasodilation, disorders of oncotic/hydrostatic pressure), cardiac dysfunction (e.g., congestive heart failure [CHF]), and medication effects on the renal vasculature (e.g., nonsteroidal anti-inflammatory drugs [NSAIDs], angiotensin-converting enzyme [ACE] inhibitors).

Intrinsic AKI results from disorders that affect the renal parenchyma, including the vasculature, glomerulus, interstitium, and tubules. The most common form of intrarenal AKI is acute tubular necrosis (ATN). ATN has multiple etiologies, including ischemia and exposure to nephrotoxic medications. Common nephrotoxic drugs encountered in the ICU include NSAIDs, aminoglycosides, angiotensin converting enzyme inhibitors (ACE-I) and angiotensin receptor blockers

TABLE 13.E1 ■ Differential Diagnoses for Elevated Creatinine and Increased Blood Urea

Elevated Serum Creatinine Level	Elevated Blood Urea Nitrogen-to-Creatinine Ratio (> 20:1)
Rhabdomyolysis	Excessive protein loading (e.g., > 1.5 g protein/kg/day)
Drugs that interfere with tubular secretion of creatinine (cimetidine and trimethoprim)	Increased catabolism (glucocorticosteroids, tetracyclines)
Drugs that interfere with laboratory assay for creatinine (serum ketones, cefoxitin)	Intravascular volume contraction with low urine flow states
Renal failure (acute kidney injury)	Gastrointestinal bleeding (with digested blood causing disproportionate rise in BUN)

BUN, blood urea nitrogen.

BOX 13.E1 ■ Differential Diagnosis for Acute Renal Failure/Acute Kidney Injury in the ICU

Prerenal

- Hypotension
- Volume depletion
 - Dehydration
 - Hemorrhage
 - Gastrointestinal losses
 - Burns
 - Renal losses
 - Insensible losses
- Redistribution of volume
 - Reduced oncotic pressure
 - Increased hydrostatic pressure
 - Capillary leak syndromes
 - Vasodilation
- Cardiac dysfunction
- Medication effects
- Other
 - Auto-PEEP
 - Intra-abdominal hypertension

Intrinsic Renal

- Tubular injury
 - Acute tubular necrosis (ischemia, toxin)
- Renal interstitial disease
 - Interstitial nephritis (infection, drugs)
- Glomerular injury
 - Glomerulonephritis (infection, autoimmune)
- Vascular dysfunction or injury

Postrenal

- Obstruction

Auto-PEEP, auto-positive end expiratory pressure

(ARBs), and radiocontrast agents (e.g., IV contrast dye). Additionally, it is important to note that persistent prerenal AKI can progress to ATN if not adequately treated.

Postrenal AKI results from obstruction of the urinary tract. Most commonly it is a consequence of obstruction at the level of the neck of the bladder (the communication between the bladder and urethra), either from intrinsic obstruction (e.g., urinary tract infection) or extrinsic compression (e.g., prostatic hypertrophy) in an uncatheterized patient. In a patient with a urinary catheter, it can result from obstruction of the catheter. Less commonly, postrenal AKI results from a more proximal site of obstruction at the level of the ureter. However, postrenal AKI in this case requires either bilateral ureteral obstruction or unilateral obstruction in a patient with a single kidney in order to result in renal failure.

The diagnostic approach to the patient with AKI (see [Figure 13.E1](#)) includes a careful assessment of the patient's history and physical exam, evaluation for obstruction, microscopic and other examination of a freshly voided urine sample, serologies, and other diagnostic tests. Important elements of the history and physical to address include an underlying history of renal disease, pertinent events in the preceding 24 hours, medication reconciliation for the presence of nephrotoxic agents, the presence or absence of a urinary catheter, and a review of the total intake and output

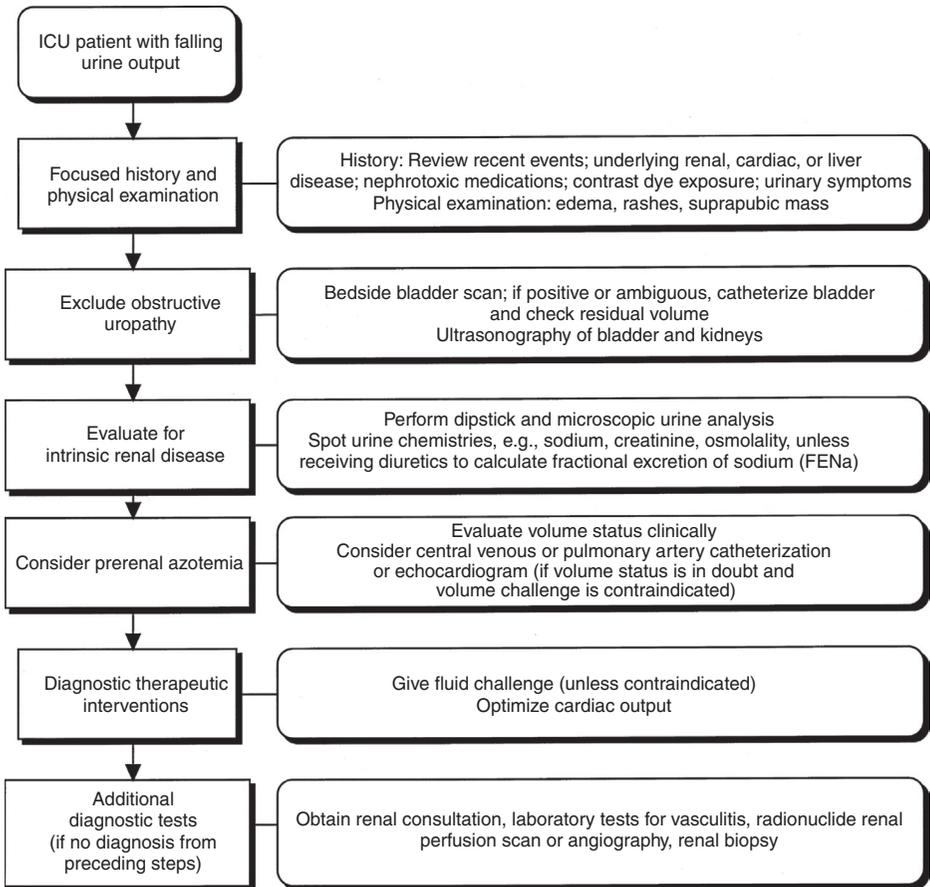


Figure 13.E1 Schematic flow diagram that illustrates the general diagnostic approach to the development of acute kidney injury in ICU patients.

throughout the hospital stay, in particular the previous 24 hours. Additionally, an assessment of hemodynamics, jugular venous pressure, skin turgor, presence and degree of soft tissue edema in extremities or other dependent locations and presence and degree of ascites can provide information about the etiologies of AKI.

Once the general evaluation is completed, the workup for AKI should first rule out obstruction as the etiology. In a noncatheterized patient, a urinary catheter should be placed to decompress an obstruction at the bladder neck. In a catheterized patient, the catheter can either be flushed or replaced. Alternatively, a bedside bladder scan can be obtained to look for retained urine. If there is no evidence for obstruction at this site, a renal ultrasound should be obtained to rule out ureteral obstruction. Lastly, a urinalysis can reveal a potential infectious etiology for obstruction. Abnormal findings suggestive of infection can include pyuria, hematuria, positive leukocyte esterase, or presence of urine nitrites.

If no obstruction is identified, assessment of urinalysis and urine electrolytes can help distinguish between prerenal and intrinsic AKI. In patients with prerenal AKI, the specific gravity tends to be higher (often > 1.020). Measurement of fractional excretion of sodium (FE_{Na}) is characteristically < 1% (where $FE_{Na} = [\text{urine Na} \times \text{plasma Cr} \times 100] / [\text{plasma Na} \times \text{urine Cr}]$).

Conversely, urine specific gravity tends to be lower and FE_{Na} higher ($> 1\%$) with intrinsic AKI. Other urinalysis findings consistent with intrinsic AKI are the presence of protein, which can suggest glomerular disease; blood, which can represent glomerular or tubular injury; and sterile pyuria with or without eosinophils, suggestive of acute interstitial nephritis (AIN). (See Chapter 81 for more details). An analogous fractional excretion of urea can be calculated when $FENa$ would be inaccurate, such as after diuretic administration.

Other laboratory data may provide additional clues to systemic illness manifesting, in part, with AKI. Thrombocytopenia with hemolytic anemia can suggest a consumptive coagulopathy such as thrombotic thrombocytopenic purpura (TTP) or disseminated intravascular coagulation (DIC) (Chapter 45). Eosinophilia may aid in the diagnosis of AIN. Elevated creatinine kinase (CK) could suggest rhabdomyolysis (Chapter 81). In the appropriate clinical setting, electrolyte abnormalities could be consistent with tumor lysis syndrome. Lastly, specific serologic studies for collagen vascular disease could reveal evidence of vasculitis (e.g., Wegener granulomatosis, Churg-Straus syndrome) or antglomerular basement membrane disease (Goodpasture syndrome) with or without associated diffuse alveolar hemorrhage (Chapter 78).

When the etiology of the AKI remains unclear, additional invasive testing can be performed, including radionuclide scans to assess for vascular occlusion or a CT-IV pyelogram to further evaluate possible obstructive etiology. Renal biopsy is also a possible diagnostic test that can further clarify types of intrinsic AKI. When considering these tests, renal consultation is indicated.

One final test worth discussing further is the measurement of bladder hydrostatic pressures, which can be obtained via a transducer that attaches to the urinary catheter. Bladder pressures are surrogates for intra-abdominal pressure measurements and are useful to diagnose intra-abdominal hypertension (IAH) or abdominal compartment syndrome (ACS) as the source for impaired renal perfusion (Chapters 90 and 97). Patients in the ICU—particularly those receiving large-volume resuscitation for sepsis or surgical patients with intra-abdominal surgeries or trauma—are at high risk for developing IAH and ACS, which can impair blood flow to the kidneys and result in either prerenal AKI or ultimately intrinsic AKI (ATN). Assessments of bladder pressure can be used to rule out ACS as the source of AKI in this context. A normal bladder pressure is < 10 mm Hg, with AKI commonly occurring in the setting of bladder pressures > 20 mm Hg. (See Chapter 97.)

Management of all types of AKI (Table 13.E2) should be directed at optimizing volume status and renal perfusion, avoiding nephrotoxic drugs, correcting electrolyte and acid-base abnormalities, and treating the underlying etiology. The therapeutic interventions for postrenal AKI are directed to relief of the obstruction. Treatment of intrinsic AKI consists mainly of supportive care and reversal of the underlying disorder.

Treatment of patients with prerenal AKI is based on the etiology of the prerenal state. In prerenal AKI resulting from volume depletion or redistribution of volume away from the intravascular space, a volume challenge should be performed. Two types of fluids can be administered: crystalloid and colloid. In multiple randomized trials, use of colloid-containing solutions has not improved outcomes compared to crystalloids in terms of mortality or reversal of AKI in ICU patients (and may increase risk of AKI in some studies). However, one current exception to this practice of avoiding colloids for volume expansion is in the use of albumin products in cirrhotic patients with either spontaneous bacterial peritonitis (SBP) or undergoing large-volume paracentesis. In this one specific context, evidence suggests that albumin administration may result in better outcomes than infusing crystalloid as the resuscitating fluid.

When infusing a crystalloid, an isotonic solution should be selected. The type of isotonic solution is generally not critical and, although still subject to debate, sodium bicarbonate solutions may reduce risk of contrast nephropathy when compared to isotonic saline (0.9%). The appropriate volume and rate of a crystalloid infusion is not standardized, but generally boluses of 500 to 1000 mL (~ 15 mL/kg PBW) of isotonic crystalloid over 1 to 2 hours is a reasonable starting point. In prerenal AKI, the goal of resuscitation should be, at the very least, to match

TABLE 13.E2 ■ General Approach to the Management of Acute Renal Failure/Acute Kidney Injury

Management Steps	Description
1. Assess for recent changes in medical status	Events of last 24 hours, focused physical exam, review of exposure to nephrotoxic agents, assessment of intake and output
2. Rule out obstruction as the precipitating factor	Place or replace urinary catheter, bladder scan, renal ultrasound, urinalysis
3. Correct prerenal factors, maintain renal perfusion, and establish urine output	Fluid challenge, inotropic agents, diuretics
4. Address biochemical complications	Measure electrolytes at least daily; correct electrolyte and acid-base abnormalities
5. Prevent further renal injury	Avoid nephrotoxins; volume expansion diuresis for crystalluria, pigmenturia, significant trauma, major vascular surgery, radiocontrast agents, amphotericin B, cisplatin
6. Fluid and electrolyte management	Maintain euvolemia (e.g., match intake = prior day's output plus insensible losses), limit daily potassium and sodium intake, avoid magnesium-containing antacids, give phosphate binders enterally
7. Provide adequate nutrition	Minimize negative nitrogen balance
8. Monitor drug therapy	Adjust dosing; measure drug levels
9. Hemodialysis or ultrafiltration	Indicated for symptomatic uremia, fluid overload that is unresponsive to conservative measures, intractable hyperkalemia, acidemia, pericarditis or bleeding

total output in real time. In other words, it is important to pay attention to the patient's total output at least every 4 to 8 hours to avoid falling behind in matching intake and output. Of note, when volume depletion or redistribution of intravascular volume results in hypotension, vasoconstricting medications may be necessary in addition to IV fluids in order to generate sufficient systemic vascular resistance (SVR) to maintain mean arterial pressure (MAP) (usually at or above MAP of 60-65 mm Hg is regarded as sufficient) and thus renal perfusion pressure.

Alternatively to intravascular volume depleted states, when prerenal AKI results secondary to cardiac dysfunction (e.g., CHF), the intravascular volume is elevated. In this situation, it may be necessary to administer a diuretic, rather than a fluid challenge, to reduce cardiac work and improve renal perfusion. Afterload reducing agents and inotropic agents may need to be administered in conjunction with the diuretic to facilitate effective diuresis (Chapter 52).

When volume status is unclear, invasive monitoring may be needed to provide more insight into the circulating blood volume. A central venous catheter (CVC) can be placed to allow measurement of a central venous pressure (CVP) as well as central venous oxygen saturation ($ScvO_2$). Alternatively, a pulmonary artery catheter (PAC) can be placed to measure pulmonary arterial and occlusion pressures and mixed venous oxygen saturation (SvO_2) (Chapters 7 and 11). Bedside ultrasound that measures percent collapse of inferior vena cava (IVC) during inspiration (which correlates with right atrial [RA] pressure) may also provide useful information on the volume status of the right side of the circulation: 100% IVC collapse correlates with a RA pressure of 0-5 mm Hg; > 50% collapse with RA of 6-14 mm Hg; < 50% collapse with RA of 15-19 mm Hg and 0% collapse with RA pressure of 20 mm Hg or greater.

When management of AKI does not result in improvements in renal function and UOP, renal replacement therapy (RRT), e.g., dialysis, may be required to treat sequelae of renal failure. In the ICU, the most common consequences of persistent renal failure that result in a need for RRT include mental status changes or severe nausea and vomiting due to uremia, volume overload,

electrolyte imbalances, acid-base derangements, uremic pericarditis and a uremic bleeding diathesis. Any of these complications warrants consultation with the renal service for evaluation for RRT (Chapter 20).

Fever/Hypothermia and Leukocytosis

Fever (or hypothermia), leukocytosis, or both are common in the ICU and can have infectious and noninfectious etiologies (Tables 13.E3 and 13.E4). Because of the challenges ICU patients face (multiorgan failure, immunosuppression, indwelling lines and catheters, sedation, paralysis, etc.), it is reasonable to presume a rise in a patient's temperature curve or a rise in a patient's WBC count is in response to an infectious process. Since ICU patients are susceptible to infections in multiple locations, a thorough and systematic evaluation process is required.

Traditionally in hospitalized patients, fever is defined as a temperature exceeding 38° C (100.4° F) and hypothermia is defined as a temperature less than 35° C (95° F). However, because every patient has a unique temperature range, attention to trends in temperature can be more useful than isolated measurements. There are a number of methods for measuring temperature. In general, measurement of core body temperature is more accurate than axillary or skin temperature. Core temperature can be estimated by the oral, rectal, or tympanic membrane route. Rectal measurement is the most accurate representation of core body temperature. However, in the ICU population, rectal temperatures can be difficult to perform because of issues with patient mobility and are contra indicated in neutropenic patients. Likewise, oral temperatures can be challenging because of the presence of an endotracheal tube in the mouth. One additional source of temperature measurement unique to the ICU setting is bladder catheters with self-contained temperature probes, facilitating continuous measurement that can be displayed on the room monitor.

TABLE 13.E3 ■ Infectious Causes of Fever in the Intensive Care Unit

Abdominal, gastrointestinal	Acalculous cholecystitis; appendicitis; diverticulitis; intra-abdominal, pelvic, or retroperitoneal abscess; liver abscess; mesenteric infarction; peritonitis; pseudomembranous colitis; viral hepatitis (transfusion related)
Nosocomial infections	Intravascular catheter–related infection (phlebitis; cellulitis; bacteremia/fungemia; endocarditis, septic thrombophlebitis, or both), pneumonia, sinusitis, systemic candidiasis, tracheobronchitis, urinary tract infection
Surgical	Deep operative infection, infected prosthesis, retained surgical sponge, wound infection

TABLE 13.E4 ■ Noninfectious Causes of Fever in the Intensive Care Unit

Inflammatory	Allergic drug reaction, allograft rejection, aspiration pneumonitis, atelectasis, crystalline arthritis (gout, pseudogout), neoplasm, pancreatitis, postpericardiotomy syndrome, transfusion reaction, vasculitis
Metabolic	Alcohol and sedative withdrawal (Chapter 31), hypoadrenalism, malignant hyperthermia (Chapter 55), neuroleptic malignant syndrome (Chapter 55), serotonin syndrome (Chapter 57), thyrotoxicosis (Chapter 85)
Neurologic	Aseptic meningitis, dysautonomias, spinal cord injury (C4 and C5), subarachnoid hemorrhage, thermoregulatory disorders resulting from hypothalamic injury (e.g., after cardiac arrest [Chapter 49] or head trauma [Chapter 99])
Vascular	Aortic dissection, deep venous thrombosis, myocardial infarction, pulmonary embolism, hemorrhage

Acute infection can present with hypothermia or with a fever. Patients considered more likely to present in this way include the immunocompromised, the elderly, and patients with chronic hepatic or renal disease. A common noninfectious cause of hypothermia is large-volume IV resuscitation, most commonly seen with trauma, sepsis, burn, and gastrointestinal (GI) bleed patients. Unless the resuscitation fluid is warmed or passes through a fluid warming device on route to the patient, IV administration will lower body temperature. Additionally, GI bleed patients frequently undergo gastric lavage as part of the diagnostic evaluation, which can have an effect similar to IV resuscitation.

Body temperature is regulated by the hypothalamus. Fever occurs when cytokines such as interleukins, tumor necrosis factor, or interferon disrupt the natural set point. Cytokines can be released in response to both infectious and inflammatory conditions. Infections are the most common cause of fever in ICU patients. As such, diagnostic and therapeutic interventions should address infection first.

As with abnormal temperature, a rise in the WBC count (leukocytosis) can result from both infectious and noninfectious conditions. The infectious causes of fever/hypothermia and leukocytosis are similar and are discussed next. An increase in the percentage of neutrophils, in particular immature band forms, on differential blood cell count analysis suggests an infectious cause.

Similar to hypothermia, there are infectious and noninfectious conditions that can result in a reduction in WBC count (leukopenia) rather than an increase. Most commonly, this occurs in the setting of bone marrow suppression. Sepsis-induced bone marrow suppression is one classic example of this phenomenon, though it is far more common that a patient will present with leukocytosis rather than leukopenia. The most common noninfectious etiology of incident leukopenia in the ICU is medication side effect.

INFECTIOUS CAUSES OF FEVER

Intravascular Infections

The majority of nosocomial infections are bacterial and involve the urinary tract, surgical wounds, respiratory tract, or intravascular devices (Chapter 14). Intravascular infections are one of the most common preventable causes of fever/leukocytosis in the ICU. As noted previously, patients frequently have vascular access devices such as central venous, dialysis, and arterial catheters to enable real-time monitoring of hemodynamics and to administer life-sustaining therapies. However, vascular devices also provide a direct conduit from the skin to the intravascular space, which can result in bloodstream infections (BSIs). Additional intravascular sources of infection include septic deep venous thromboses (DVT) and endocarditis. BSI can frequently be diagnosed with serial blood cultures. BSIs are discussed in detail in Chapter 14.

Respiratory Tract Infections

Respiratory tract infections, including tracheobronchitis and pneumonia, are another common cause of fever and leukocytosis particularly in mechanically ventilated patients. As with intravascular devices, the presence of an endotracheal tube tends to allow oral or aspirated microorganisms to gain access to the respiratory tract. Additionally, an endotracheal tube often necessitates the use of sedation for patient comfort. An unintended consequence is impairment of swallowing and cough reflexes, increasing the potential for aspiration and lower respiratory tract infections. Some clinical findings that may suggest a respiratory tract infection in the setting of fever include tachypnea, hypoxia, increased tracheal secretions, greater dependence on mechanical ventilation, abnormal chest radiograph (CXR), and abnormal sputum culture.

Nosocomial respiratory tract infections can be challenging to diagnose. First, there are a variety of noninfectious pulmonary processes that can precipitate fever, including atelectasis and pulmonary embolism. Second, the airways of patients with endotracheal tubes are routinely colonized

with microorganisms, making cultures unreliable. However, demonstration of WBC and the absence or only a few epithelial cells in the sputum Gram stain can help differentiate infection from colonization. Third, radiographic abnormalities can be misleading and may not represent a true pneumonia. Nevertheless, CXR and sputum (or tracheal aspirate) culture should be routinely ordered to aid in the diagnosis. If these initial studies are unrevealing but respiratory tract infection remains high on the differential diagnosis, additional tests such as chest CT scan, bronchoscopy or catheter-directed bronchoalveolar lavage (BAL) should be considered.

Chest CT scanning is a superior imaging technique to routine CXR and can be used to diagnose both parenchymal and pleural disease. Additionally, chest CT with pulmonary embolism protocol, i.e., with the use of IV contrast, can rule out pulmonary embolism (PE). However, CT requires transportation of a potentially unstable patient to radiology, making CXR the preferred *initial* imaging study.

The pleural space is an additional site that can harbor microorganisms and result in fever. Ultrasound of the chest is a safe, non-invasive test that can be performed at the bedside to evaluate for pleural effusions. The presence of increased fluid in the pleural space, especially in the context of a respiratory tract infection, can suggest a parapneumonic effusion or even an empyema that may require further evaluation and possibly drainage.

If sputum cultures or tracheal aspirates are unhelpful and imaging suggests the presence of parenchymal lung disease, bronchoscopy can be performed at the bedside to obtain better samples for diagnostic evaluation (e.g., bronchoalveolar lavage [BAL]). The sensitivity of BAL for diagnosing ventilator-associated pneumonia (VAP) is relatively high (~75%) as long as it is done prior to starting new antimicrobial therapy. After the start of new antimicrobials, however, BAL's sensitivity is too low (< ~25%) to be useful in some ICU clinicians' judgment.

Genitourinary Infections

Urinary tract infections (UTIs) are another source of fever and leukocytosis. As with vascular devices and endotracheal tubes, nosocomial UTIs are commonly catheter associated. Patients with critical illness often have indwelling bladder catheters to facilitate continuous measurement of urine output. Once again, an unintended consequence of an indwelling catheter is an increased risk of infection. As with respiratory cultures, positive urine cultures can represent either infection or colonization resulting from the chronic presence of indwelling urinary catheters during hospitalization. The recommended diagnostic strategy for a catheterized patient with a suspected UTI is to send a urinalysis (U/A) first without a culture (Chapter 14). If the U/A demonstrates evidence of infection, the catheter should be changed and a repeat U/A sent prior to initiating antimicrobial therapy. A positive repeat U/A suggests infection rather than colonization, and a quantitative urine culture should be sent. Additionally, empiric antimicrobial therapy may be started while awaiting results of the culture.

Abdominal Infections

The abdomen is an important potential site of infection in critically ill patients, in particular surgical patients. There are a number of intra-abdominal sites where infection can occur, including the hepatobiliary tree, solid organs, intestine, and peritoneal space. Acute cholecystitis is the most common infection of the hepatobiliary tree. In the general population, most cases of cholecystitis are due to gallstones. However, in the postoperative ICU population, up to 50% of cases of acute cholecystitis are *acalculous* (without stones). Cholecystitis is diagnosed by ultrasound of the hepatobiliary tree. Diagnostic abnormalities include gallbladder wall tenderness during scanning (sonographic Murphy sign), gallbladder wall thickening, pericholecystic fluid, and distention of the gallbladder. In the absence of these findings being definitively diagnostic, a hepatobiliary iminodiacetic acid (HIDA) scan (a nuclear medicine study) is an additional test that can aid in diagnosis. HIDA scans (when done in conjunction with IV morphine sulfate administration to stimulate the sphincter of

Oddi) has a sensitivity of 95% and a specificity of 85% to diagnose acute cholecystitis compared to an ultrasound's sensitivity of 85% and specificity of 60%. However, performing the HIDA scan correctly requires transport of the patient out of the ICU for several hours.

Solid organ causes of infection include abscesses and pancreatitis. These conditions can usually be made with abdominal CT. However, IV and oral contrast are required for an optimal study, which can be challenging in patients with multiorgan dysfunction (e.g., acute or chronic renal failure or bowel obstruction/ileus).

Intestinal etiologies include bacterial infection, in particular infection by *Clostridium difficile* associated with alteration of the normal gastrointestinal flora resulting from antibiotic use. The majority of patients developing a *C. difficile* infection have fever, diarrhea, and leukocytosis (and typically *extreme* levels of leukocytosis). Other intestinal etiologies of infection include appendicitis, diverticulitis, and perforation of the intestine secondary to intestinal infection, infarction, or obstruction. Testing stool for toxins of *C. difficile* is highly sensitive for ruling out *C. difficile* if negative. Abdominal CT scan with IV and oral contrast is usually sufficient to diagnose the majority of nosocomial intestinal infections.

Other Infections

Central Nervous System and Head and Neck Infections. The most common head and neck infection in the ICU is sinusitis. Patients are placed at higher risk because of the placement of nasogastric or nasoenteral tubes used for enteral administration of medication and nutrition (Chapter 16). Sinusitis is diagnosed by CT scan of the sinuses. Although uncommon, sinusitis must be considered in patients with nasal tubes and fever who do not have another obvious source of infection.

Nosocomial central nervous system (CNS) infections such as meningitis are extremely rare. Thus, lumbar puncture (LP) to sample cerebral spinal fluid and CNS imaging are not recommended as part of the routine evaluation of fever in the ICU. However, attention to the physical exam can reveal situations where CT of the head or LP might be appropriate (e.g., focal neurologic or meningeal signs). Exceptions where an LP might be warranted are neurosurgical and head trauma patients, patients with infections that are known to involve the meninges, and situations where the evaluation of mental status is limited (e.g., as a result of opioids or sedation).

Musculoskeletal Infections. Infections involving the musculoskeletal system include soft tissue infections such as cellulites, fasciitis, or abscesses and bone infections such as osteomyelitis. Cellulitis can be diagnosed by physical exam and requires no further testing. Fasciitis is a surgical emergency and requires prompt evaluation, including surgical consultation and, if necessary, imaging (Chapter 66). Osteomyelitis is best evaluated by nuclear or magnetic resonance imaging and requires prolonged antibiotic therapy. Abdominal abscesses can best be discovered via CT scanning with IV and oral contrast and usually require percutaneous or surgical drainage.

Perhaps the most common soft tissue infection seen in the ICU patient population occurs in areas of skin breakdown caused by immobility. Despite concerted efforts at skin care (e.g., turning patients routinely, keeping skin dry, minimizing volume overload, cleaning patients regularly), skin breakdown and ulcer formation occur with regularity in the ICU population at high risk for such complications (Chapter 42). Once the skin barrier is compromised, microorganisms can enter the space and cause both local and systemic infection. It is now a standard of care that skin be evaluated at regular intervals to ensure early identification of areas of concern and escalating management of persistent or worsening pressure ulcers.

Postoperative Infections. There are a number of classic infectious and noninfectious causes of fever in the postoperative patient. The timing of fever may give clues to the diagnosis. Fevers in the first 24 hours of surgery are most commonly secondary to noninfectious causes. Fevers 48 to 72 hours

after surgery are more commonly due to bloodstream infections and venous thromboembolism. Wound infections and pneumonia usually occur after ~5 days. Intra-abdominal abscesses usually do not present until ~1 week after surgery. Urinary tract infections can occur at any time in the postoperative period.

Fungal Infections. Fungal infections are an increasing problem in the ICU. Critically ill patients are frequently immunocompromised, are treated with broad-spectrum antibiotics, may receive corticosteroids (which further suppress the immune system), have various indwelling catheters and tubes, may have variable glucose control, and occasionally require nutrition to be administered parenterally. These are all independent risk factors for fungal infection. The most common type of fungal infection is due to *Candida*. Sites of *Candidal* infection include the bloodstream (fungemia), solid organs (particularly spleen and liver), skin, and eyes (endophthalmitis). Additionally, *Candidal* fungemia can sometimes result in endocarditis, a potentially devastating complication of ICU hospitalization. Another less common fungus seen in the ICU is *Aspergillus*, typically occurring in patients with neutropenia secondary to malignancy or chemotherapy (Chapter 24).

NONINFECTIOUS CAUSES OF FEVER

Noninfectious illnesses are an important cause of nosocomial fever in the ICU. Many of these conditions are discussed in greater detail in other chapters. Drug reactions commonly occur and are often manifested by fevers and skin rashes (see Chapter 43). Patients with prolonged immobility or recent surgical intervention may develop fevers because of venous thromboembolic disease (see Chapter 77). Some procedures may have a side effect of low-grade fever within the first 24 hours (e.g., bronchoscopy). Some disease processes themselves result in fever. Examples include hemorrhage into any body compartment, strokes (see Chapter 71), myocardial infarction (Chapter 50), aortic dissection (see Chapter 51), malignancy, and allograft rejection in transplant patients.

Withdrawal from drugs such as alcohol can also be associated with fever. Additional symptoms in the context of alcohol withdrawal syndrome (AWS) include tremors, diaphoresis, nausea, vomiting, tachycardia, hypertension, and hallucinations (Chapter 31). Similarly, withdrawal from corticosteroids can precipitate adrenal insufficiency, which can present with fever and hypotension, resembling sepsis. Ultimately, although there are a variety of noninfectious etiologies for fever, infection must *always* be ruled out.

DIAGNOSTIC ALGORITHM

The diagnostic evaluation of fever and leukocytosis should be systematic and timely (Figure 13.E2). The initial step should be a review of the list of current medications for potential offending agents. A careful physical exam should be performed with particular attention to the skin (e.g., pressure ulcers, erythema, or induration), extremities (for asymmetry or tenderness), mental status, and vital signs. Sites of all indwelling lines and catheters should also be assessed.

Laboratory evaluation should include two sets of blood cultures, urinalysis, and sputum culture, if there has been a change in sputum production or respiratory status. Preferably, the blood cultures should be obtained by fresh needle stick from two different sites to increase the likelihood that a positive culture represents infection rather than contamination or line colonization. If the patient has a new onset of diarrhea or abdominal pain or a new onset of extreme leukocytosis, a stool sample should be sent to the lab to be examined for *C. difficile* toxin (Chapter 38).

Routine studies should include CXR and sampling of any fluid collections as appropriate (e.g., ascites). As described previously, a lumbar puncture (LP) should be performed only in special circumstances. Other tests that may provide further information if the initial evaluation is unrevealing have been discussed throughout this chapter.

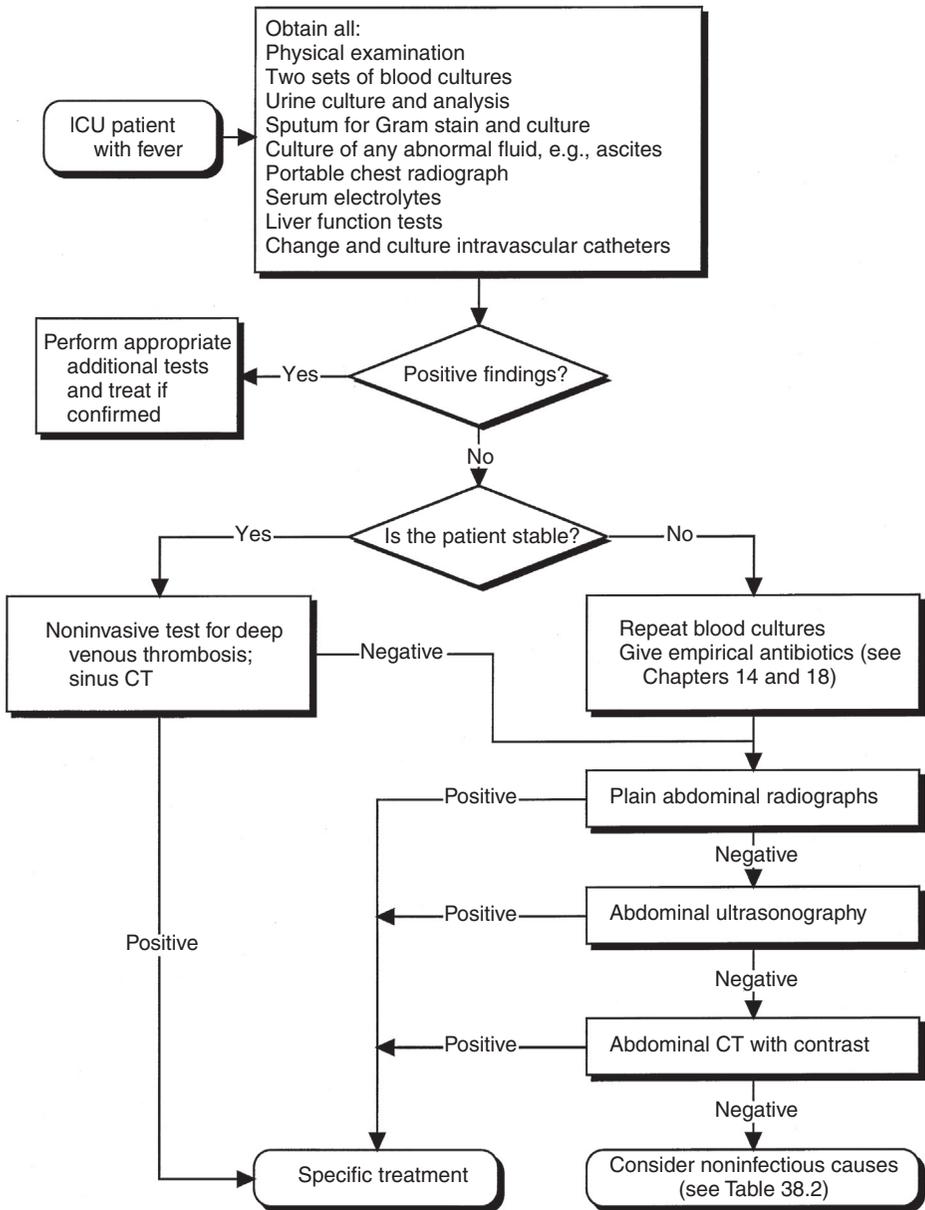


Figure 13.E2 Schematic flow diagram to evaluate fever in ICU patients.

MANAGEMENT

Management of fever and leukocytosis should first be directed at reversing the underlying process. Any offending medications should be stopped, if possible, to eliminate the possibility of drug fevers. Additionally, it is appropriate to remove any catheters or tubes that are no longer clinically indicated as soon as possible. Removal of vascular access devices in critically ill patients

can be difficult given their dependence on specific therapies that require central venous access and continuous hemodynamic monitoring. One option when fevers are suspected to be due to a BSI is to remove the catheter and observe a “line holiday” of up to 3 days prior to reinsertion. If this is not feasible, as is often the case, a new line is placed via a fresh needle stick. Alternatively, the catheter can remain in place, if the patient is stable, while waiting for the blood culture results.

The decision to treat fevers is somewhat controversial, as the fever itself may play a beneficial role in combating disease. However, it is generally accepted that for temperatures $> 39^{\circ}\text{C}$ (102°F), fever reduction is appropriate. The antipyretic of choice is generally acetaminophen. Aspirin and other nonsteroidal anti-inflammatory medications are less desirable because of the impairment of platelet function and risk of bleeding and renal dysfunction. Acetaminophen should be used with caution in patients with chronic liver disease or acute liver injury. In lieu of medication therapy, external cooling is another approach. However, it is less effective than antipyretic therapy.

Lastly, supportive care is an important part of the treatment of the febrile patient. Fever results in increases in metabolic rate, oxygen consumption, heart rate, respiratory rate, and insensible water loss. Administration of IV fluids and nutrition to combat insensible losses and support these increased demands is essential to maintain normal patient physiology and homeostasis in the ICU.

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