Symptomatic Hypotension: ED Stabilization And The Emerging Role Of Sonography

You just performed an easy endotracheal intubation on an elderly woman brought in by EMS. She was alert during transport but arrived diaphoretic and lethargic with a BP of 82/45 mmHg, an irregular pulse at 120, a rectal temperature of 100.8° F, and she was tachypneic at 32 breaths per minute. Surprisingly, her oxygen saturation, which was initially 82%, decreases postintubation to 76%. Portable chest x-ray shows proper ET tube placement, no infiltrates, no pneumothorax, and a normal cardiac silhouette. The patient is anuric. Labs show a creatinine of 2.1, a WBC count of 18,000, a hematocrit of 22%, and elevated lactate and transaminase levels. Heart sounds and breath sounds are normal, the abdomen is soft, and both legs are swollen. The patient is sick and you realize the key to her survival is finding the cause of her hypotensive state...

Before an answer is found, two new patients arrive, both with end-stage renal disease, diabetes mellitus, hypertension, and coronary artery disease. You begin to wonder why you ever took a job with single clinician coverage...

Patient #2 looks worse—ashen and diaphoretic, with a blood pressure of 60/40 mmHg. He is afibrile and has a pulse of 100 in the arm without the AV fistula. He has a history of non compliance with his medications. He describes the sudden onset of non radiating chest pain that has persisted for the past two hours. Three sublingual nitroglycerin tablets given by EMS did not make the chest pain any better and potentially contributed to his hypotension. On lung examination, you hear rales. You order fluids for the hypotension but realize this might be a mistake...

Patient #3 has a blood pressure of 100/60 mmHg and appears to be in no distress. She took her regular morning dose of clonidine and states that her hypotension is “expected.” Her face is cool and she is mildly diaphoretic. The patient is anuric. Labs show a hematocrit of 22%, and elevated lactate and transaminase levels. Heart sounds and breath sounds are normal, the abdomen is soft, and both legs are swollen. The patient is sick and you realize the key to her survival is finding the cause of her hypotensive state...

Upon completion of this article, you should be able to:
1. Identify the common and life-threatening causes of hypotension.
2. Understand the clinical approach to the rapid identification of dangerous causes of hypotension.
3. Explain the emerging role of goal-directed bedside sonography in the rapid non-invasive diagnosis and management of hypotensive patients.
4. Appreciate the importance of early intervention in the management of hypotension, including the role of intravenous fluids, inotropes, and vasopressors.
5. Decide the practical and evidence-based advantages and disadvantages of various point-of-care tests, imaging modalities, and treatments in hypotension.

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There is no clear blood pressure definition of hypotension. Instead, blood pressure must be placed in the context of the patient’s age and current clinical and baseline physiologic states. For example, what appears to be a “normal” blood pressure may actually be a dangerously low blood pressure in the patient who is generally hypertensive. Hypotension is a sign, not a diagnosis, and it is not pathognomonic of any specific condition by itself. It can be found in both acute critical conditions and in chronic steady state conditions. The emergency physician must determine which is present and tailor the aggressiveness of interventions based on the underlying etiology.

In critically ill patients, the first hours of treatment have a direct impact on morbidity and mortality. In these cases, the approach to hypotension is sometimes unstructured, with a focus on “correcting the numbers” while investigating the cause. Less emergent but equally challenging are those patients with low blood pressures who are in a steady state but are not critically ill (e.g., patients with end-stage congestive heart failure). Trying to raise the blood pressure in this group of patients is not generally indicated and may be harmful.

The cases presented at the beginning of this article illustrate the challenge posed by patients with hypotension and demonstrate the need for the emergency physician to accurately narrow the differential diagnosis. Management involves a three pronged approach that simultaneously includes stabilization, diagnostic testing, and therapy. Because the differential diagnosis is so broad, most guidelines are diagnostic and do not provide a systematic approach to managing hypotension. This issue of Emergency Medicine Practice is designed to provide an evidence-based, algorithmic approach to the management of conditions causing hypotension. Specific attention will be given to the role of ultrasound in the clinical decision making involved in caring for these patients.

Terminology

General medical teaching cites normal blood pressure (BP) as 120/80 mmHg as measured over the brachial artery using auscultatory methods. Population studies have shown these numbers to range between 109-137 mmHg for the systolic blood pressure (SBP) and 66-87 mmHg for the diastolic blood pressure (DBP). Another study found BP to range from 116-145 mmHg SBP and 66-84 mmHg DBP in men and 107-137 mmHg SBP and 61-78 mmHg DBP in women. Keep in mind these numbers vary with the patient’s size and ideal body weight.

Mean arterial pressure (MAP) is more reflective of the actual pressure in the arterioles and smaller vessels than the standard blood pressure measurements and may be more helpful in the evaluation of hypotension. MAP calculations are as follows:

\[
\text{MAP} = \frac{2}{3} \text{DBP} + \frac{1}{3} \text{SBP}
\]

The standard definition of hypotension in an adult includes the findings of: a SBP < 90 mmHg, a MAP < 60 mmHg, a decrease of more than 40 mmHg below the person’s baseline, or any combination of the aforementioned parameters. In some studies, the definition of hypotension uses a SBP < 100 mmHg. A healthy adult will have natural variations in blood pressure readings during a routine 24-hour period. A numerical blood pressure reading takes on clinical significance when the MAP is below the patient’s usual regulated pressures for organ perfusion. For example, a blood pressure reading of 140/90 mmHg may provoke symptoms of organ hypoperfusion (such as dizziness and fatigue) if the patient’s chronic blood pressure readings have been consistently much higher. Such a patient should be considered ‘acutely clinically hypotensive.’ Shock can occur with “normal” blood pressure readings.

Refractory hypotension refers to persistently hypotensive readings after the administration of an intravenous crystalloid fluid bolus of 20-40 mL/kg.

Pseudohypotension refers to the underestimation of the patient’s true BP secondary to arterial occlusion or other abnormalities. If the unaffected extremity has adequate perfusion, the true blood pressure reading is noticeably higher than in the affected extremity. Pulse deficits or pseudohypotension can be a strong indicator of aortic side branch occlusions and thus raise the suspicion of a vascular emergency.

Shock refers to a state of organ dysfunction or even organ failure due to inadequate tissue perfusion. Multiple etiologies of shock are described and more than one type may be present in a single patient. The various types of shock are listed below:

- **Cardiogenic** – results from loss of cardiac output
- **Hypovolemic** – results from decreased intravascular volume
- **Obstructive** – results from intrinsic (e.g., pulmonary embolus) or extrinsic (e.g., pericardial tamponade) vascular outflow obstruction
- **Distributive** – results from disruption of vasomotor regulation (e.g., anaphylactic, septic, and neurogenic shock)

Shock is the most feared cause of hypotension; it is not a diagnosis but a final common pathway by which many disease processes produce multi-organ failure.
Orthostatic Hypotension

Standing or sitting with the legs dangling can cause up to 1 L of blood volume to pool in the venous circulation of the legs. The immediate result of lowering intrathoracic blood volume is a reduction in both cardiac output and blood pressure. Through the normal autonomic response, an increase in heart rate by as much as 25 beats/minute and an increase in systemic vascular resistance should keep blood pressure at normal levels. A 5-10 mmHg drop in BP can be seen in normal individuals within three minutes of the position change. This change is clinically insignificant.

The symptomatic lowering of blood pressure upon standing is called postural or orthostatic hypotension. Symptoms are usually due to an impaired autonomic response. Traditionally, orthostatic blood pressure readings and heart rate are measured in the supine patient then repeated with the patient in a standing position. A decrease in the SBP of 20 mmHg or in the DBP of 10 mmHg after standing for three minutes defines orthostatic BP.11 Parameters for abnormal orthostatic increases in heart rate are not yet defined but many have a HR greater than 20-30 beats per minute. Patients with a hypertensive blood pressure when supine can be symptomatically orthostatic with a large enough decrease in BP upon standing.

A similar blood pressure drop associated with eating is called postprandial hypotension.

Volume depletion can compound the symptoms from an abnormal sympathetic neurocirculatory response but can also be an independent factor causing orthostasis. Up to 20% of patients over the age of 65 can have orthostatic hypotension. Of particular note is the patient with Parkinson’s disease who may have primary autonomic dysfunction which can easily be exacerbated by dehydration or polypharmacy.

Determination of orthostasis should be directed by the patient’s clinical presentation. If symptomatic at rest and supine, orthostatic vital signs are not necessary as the patient is already “hypotensive” regardless of the numbers. If history suggests near syncope or similar symptoms with position change prior to ED presentation, orthostasis is already diagnosed and vital signs after treatment may be more helpful.

Critical Appraisal Of The Literature

Literature searches were performed using Ovid MEDLINE and PubMed in the National Library of Medicine for diagnosis and management recommendations as well as updates regarding conditions involving hypotension. In addition, the Cochrane Database of Systemic Reviews was searched for reviews on similar topics. This search provided an enormous number of studies, though few well designed, prospective studies. Another source of information was the National Guideline Clearinghouse™ which provided guidelines for sepsis management and ultrasound-guided central line placement.

Difficulties arose in finding studies specific on the management of undifferentiated hypotension as this topic covers a clinical sign that manifests in many different clinical situations (including sepsis, dehydration, heart disease, trauma, and many other disease states). Sub-topics of fluid management, sepsis management, pressor support, ultrasound applications, Advanced Cardiac Life Support (ACLS), Advanced Trauma Life Support (ATLS), and others were reviewed and combined to produce recommendations for diagnosis and treatment, especially in early stages of hypotension.

Epidemiology

While it is difficult to determine with accuracy the incidences of hypotension in a general population or even in a select population of ED or hospitalized patients, studies have examined data on critically ill patients and effects of hypotension on outcome.

The duration of hypotension after trauma, sepsis, anaphylaxis, and cardiogenic sources are critical determinants of morbidity, prognosis, and survival in these groups of hypotensive patients.3 Jones et al performed a secondary analysis of data accrued from a randomized, controlled trial of rapid versus delayed bedside goal-directed ultrasound of patients with symptomatic, non-traumatic shock. In this study, hypotension was defined as an initial ED systolic blood pressure reading of less than 100 mmHg. Shock was defined by the presence of hypotension with one or more predetermined signs or symptoms. The hospital mortality of the 190 ED shock patients in this study was 15%. Adverse hospital outcomes included organ failure, the need for intensive care admission, and in-hospital mortality. Fifty percent of the patients with a SBP < 80 mmHg had an adverse hospital outcome. Forty percent of the patients with an adverse outcome had blood pressure readings that were consistently below 100 mmHg for more than 60 minutes.13

The one month mortality rate after the onset of...
hypovolemic shock is dependent on the underlying cause and the patient’s co-morbidities. A 2002 study by Moore et al of ED patients with atraumatic hypotension (defined as a SBP < 100 mmHg) showed an in-hospital mortality rate of 18%. In a recently released prospective cohort study by Jones et al, ED patients with a SBP < 80 mmHg had a six-fold increased incidence of in-hospital death. Patients with a SBP < 100 mmHg for more than 60 minutes had nearly three times the incidence of in-hospital death.14 Within one month of the diagnosis of septic shock, the overall mortality rate can be as high as 40%. Mortality for cardiogenic shock can be as high as 60%. Use of the presence of hypotension alone as a predictor of ED patient mortality is incomplete and risks ignoring the importance of the associated clinical context. In certain well-defined disease entities (such as aortic dissection and cardiac failure), hypotension is associated with sicker patients; thus, there are higher mortality rates of 50-80%. Hypotension in patients with end-stage renal disease (ESRD) and/or atherosclerotic cardiovascular disease is also associated with higher mortality rates. Consequently, rapid identification of the etiology of the hypotensive state has a potentially critical impact on the patient’s short and long term clinical outcome.

Hypotension In Trauma

The ATLS protocols support the practice of using hypotension as only a late marker of shock because of its low sensitivity. Prior to 1989, ATLS guidelines taught that the absence or presence of the carotid, femoral, and radial pulses could be correlated to systolic blood pressures. When compared to invasively obtained arterial blood pressure measurements, however, it was discovered that the correlations previously made were overestimations. ATLS no longer teaches pulse and SBP correlations in the context of clinical decision making.

The National Trauma Data Bank (n = 115,830), where hemorrhagic shock was the main cause of hypotension, reports that SBP correlates with serum base deficits (considered to be a marker of circulatory shock). The mean and median SBP decreased to less that 90 mmHg when the base deficits were worse than -20. The Data Bank supports the conclusion that SBP is a late marker for mortality and that, in the setting of hemorrhagic shock, SBP should not be used as a primary decision point in choosing which patient should receive resuscitation efforts. Patients with hypotension and significant base deficits had a mortality rate of 65%.

Pathophysiology

Normal BP results from a balance between the peripheral vascular resistance and the cardiac output (CO), with total blood volume affecting both. Cardiac output is a product of the stroke volume (SV) and the heart rate (HR):

\[
CO = SV \times HR
\]

Hypotension results when either the stroke volume or the heart rate is decreased. In addition, blood volume provides the “substrate” that the resistance vessels "push" against in order to regulate BP. Thus, even maximal vasoconstriction will be ineffective if volume status is inadequate. This key point resurfaces in managing many hypotensive patients.

The peripheral vascular resistance (PVR) is regulated by a variety of mechanisms. Only a small proportion of the blood volume is involved in perfusing tissues at any given time. Most of the total blood volume is contained in the venous system. The veins serve as blood reservoirs that are mobilized by the neuroendocrine system in time of need. Certain organs, such as the heart and brain, are autoregulated. Their perfusion is influenced by metabolic factors and not by the neuroendocrine system. Thus, blood flow is preserved and can actually be enhanced in early volume loss.

Adrenergic receptors are located in organs based on their function in the “fight or flight” response to stress. Non essential organs in acute stress events (such as the gastrointestinal tract) have high concentrations of vasoconstrictive alpha-1 (A1) receptors, while those essential to survival in acute stress (the heart, lung, and skeletal muscles) have high concentrations of vasodilatory beta-2 (B2) receptors. Cardiac beta-1(B1) receptors produce increased chronotropy and inotropy with consequent increased oxygen demand. Dopaminergic receptors are primarily located in the splanchnic and the renal beds.

These receptors are stimulated by mediator release from nerve endings (norepinephrine) and the endocrine system (epinephrine). Mediator release is stimulated by the vasomotor centers located in the medulla and hypothalamus. Inhibitory outputs from cardiac, renal, and blood vessel baroreceptors affect these centers. Pathological drops in blood pressure cause decreased outputs to be sent from the baroreceptors, disinhibiting the vasomotor centers. Sympathetic nervous system output or tone is thus augmented; “vagal tone” is conversely decreased.

In low pressure states, like hypovolemia, there is less baroreceptor stimulation which leads to ADH release. The release of ADH leads to: 1) An increase in water absorption in the distal renal tubules and then an increase in vascular blood volume; and 2) Peripheral vasoconstriction. Other mediators that increase adrenergic tone include carbon dioxide and hydrogen ions.

The kidney plays a role in the regulation of blood pressure through the following mechanisms:

- Glomerular filtration rate (GFR) decreases in hypotension which decreases sodium transit time in the tubules and increases its absorption. In turn, this increases the absorption of water.
- Increased water absorption mediated by ADH in the distal tubule.
Renin release from granular cells of the afferent arteriole stimulated by adrenergic output, macula densa output, and direct action of low blood pressure on the granular cells themselves. Renin catalyzes angiotensinogen to angiotensin-1 in the liver which is converted to angiotensin-2 in the lung by angiotensin converting enzyme (ACE). Angiotensin-2 is a direct vasoconstrictor but also stimulates the renal cortex to release aldosterone, further promoting sodium retention.

- Hypotension causes a decrease in the release of atrial natriuretic peptides which decreases sodium and water loss in the urine.

### Differential Diagnosis

The differential diagnosis of hypotension is vast. Table 1 provides a framework to use when approaching these patients.

### Prehospital Care

The detection of hypotension prompts urgent transport to the nearest or most appropriate ED with concomitant intravenous access and fluid administration if possible. Advance notification places the ED on alert and facilitates expedited care when the patient arrives. Patients should receive oxygen, an oxygen saturation monitor should be put in place, and electrocardiogram (ECG) monitoring begun. If at all possible, a 12-lead ECG should be performed in any hypotensive patient who is at risk for acute coronary syndrome. A cardiac monitor tracing and repeated vital signs should be recorded clearly and exchanged between prehospital and ED personnel.

Jones et al conducted a cross sectional risk assessment study of non-traumatic ambulance transports in the U.S. and Canada.5 Patients experiencing hypotensive episodes (a single reading of less than 100 mmHg) with one or more predetermined symptoms of circulatory insufficiency but whose blood pressure readings were always above 100 mmHg. In the U.S. venue, there were 395 exposures and 395 non-exposures; the in-hospital mortality was 26% for exposures and 8% for non-exposures. In the multi-center Canadian venue, the in-hospital mortality rate was 32% for exposures compared to 11% for non-exposures. This data supports the association of out of hospital hypotension with in-hospital mortality.

One of the highest risk groups of patients with hypotension are those with an acute myocardial infarction. Interestingly, even in this high risk group, one study reported a decrease in mortality from 69% in the control phase to 10% when paramedic level of care was made available.21 Heightened ED readiness cuts vital minutes off of door-to-ECG to needle or balloon times. Medical control should be notified of patients with ischemic ECG findings and consideration should be given to transporting these patients to a center with percutaneous interruption capabilities.

The trauma literature is replete with studies advocating for ambulance notification and activation of the ED and trauma teams in cases of hypotension or uncontrolled hemorrhage. Trauma team activation has been shown to improve outcomes in patients with penetrating trauma. In a retrospective study of 180 patients, Hooker et al showed that 61% of patients with prehospital hypotension (defined in this study as SBP < 100 mmHg) required transfusion versus 11% of patients without a hypotensive reading in the field.22 Franklin et al showed that not only ED hypotension but prehospital hypotension was a bona fide indicator to activate the trauma team.23 More than half of the patients with hypotension required urgent operative hemorrhage control. Another study showed that an isolated prehospital hypotensive reading, even with normal BP readings in the ED, marked the trauma patient for increased mortality and the need for operative intervention for chest and abdominal injuries.24

An interesting area of prehospital diagnostics is the use of portable ultrasound devices to evaluate cardiac output and internal bleeding. Acquired images may be transmitted to the receiving hospital. Garrett et al recently showed the transmission of wireless images to be effective in allowing a hospital-based cardiologist to do a preliminary assessment of left ventricular function and the presence or absence of pericardial effusion.25 Successful transmission of sonographic images occurred 88% of the time. The potential in trauma assessments and abdominal aorta screening in symptomatic patients en route to pertinent tertiary care centers is an area of ongoing research.
ED Evaluation

Hypotension is a predictor of negative outcomes regardless of the underlying etiology. Consequently, it is the emergency physician’s responsibility to quickly identify and treat underlying causes. A large, prospective study of 6303 patients conducted across five hospital wards in Australia identified hypotension (BP < 90 mmHg), a two or more point decrease of the Glasgow Coma Scale, the onset of coma, respiratory rate less than 6 per minute, oxygen saturation < 90%, and bradycardia for more than 30 minutes as predictors of mortality.26 Of these predictors, hypotension and oxygen desaturation were identified as the most common occurrences prior to cardiac arrest, with hypotension being associated with nearly a seven-fold increase in mortality.

In general, patients with hypotension should be placed in the critical area of the ED. Oxygenation should be maximized by placing the patient on 100% oxygen by nonrebreather face mask. Large bore intravenous access should be established, using central access if necessary. An accurate set of vital signs should be obtained and frequently repeated while the history, physical, and diagnostic tests are performed.

The most common causes of hypotension — hypovolemia, cardiogenic shock and sepsis — may overlap. Noninvasive measures should be used early and frequently to assess oxygen debt, cardiac performance, and the overall flow state; see the following discussions. Equally important is the need to monitor the cardiac and flow state response to the therapies initiated. Given the insensitivity of blood pressure to evaluate cardiac output, the correction of blood pressure is not the only goal.27

Vital Signs

Blood pressure is a “vital sign” and must be measured accurately. The standard blood pressure is measured over the brachial artery at the antecubital fossa. Care must be taken in selecting an appropriate size cuff for the patient and to ensure proper positioning of the cuff bladder over the brachial artery. When the cuff pressure drops below the SBP, blood audibly passes with each systole, producing Korotkoff’s sounds. Once pressure drops below the DBP, these sounds disappear because blood can now pass during both systole and diastole.

Blood pressures are often recorded with automated cuffs, and a malpositioned cuff bladder will give a falsely low reading which may lead to mismanagement if it goes unrecognized.6 Any low BP that impacts clinical care should be confirmed with a manual BP measurement. Automated cuff measurements have been tested against manual sphygmomanometer readings and against direct intra-arterial blood pressure measurements. Varied results have been obtained.28,29 In a study by Lehman et al, automated BP readings were compared with central arterial blood pressure recordings in 120 patients.29 There were clinically significant inaccuracies (± 10 mmHg) in 24% of the automated device readings and severe inaccuracies (± 20 mmHg) in 3.2% of the automated device recordings. More recent studies have demonstrated these devices to be of acceptable accuracy when used correctly. Cavalcanti et al studied manual cuff readings compared to automated cuff readings in 92 patients; there was high correlation (within 10 mmHg) in all of the patients.30 Greater inaccuracies have been found with cuffs that are too small, leading to erroneously high BP readings.31-34 Some studies have also examined differences in blood pressure readings with respect to body position, arm position, and relative resting state of the patient.35-38 Unfortunately, these studies are based on monitoring of hypertension and only very loose inferences can be made to the hypotensive patient. The best available evidence suggests that blood pressure measurements be taken with the patient in a recumbent position with the antecubital fossa at the level of the right atrium and that subsequent measurements remain consistent with this position.

Other vital signs will offer clues to the extent and source of hypotension and provide a baseline for monitoring the patient. Heart rate will likely be increased in a hypotensive patient but may be affected by body position, activity prior to measurement, or medications (e.g., beta blockers). Orthostatic vital signs are rarely needed or indicated in the already hypotensive patient. Respiratory rate, rectal temperature, and pulse oximetry are fundamental to the patient’s assessment. Of note, hypoperfusion may interfere with an accurate assessment of oxygen saturation.

Despite the importance of obtaining accurate vital signs, it is important to note that vital signs alone have limitations in identifying shock states. Ander et al examined the use of lactic acid level and continuous central venous oxygen saturation in identifying the disease severity of patients with acute decompensation of severe chronic congestive heart disease (ejection fraction [EF] < 30%).10 The vital signs did not help distinguish the patients with hidden shock states (defined as high lactic acid levels and low central venous oxygen saturations) from those with mildly compensated or stable CHF. The patients in the shock state required more aggressive treatment for CHF with resultant decrease in lactic acid levels and increased central venous oxygen saturation.

History

The evaluation of the patient with hypotension must be comprehensive. Ideally, the patient’s baseline blood pressure must be determined as well as the overall clinical status. Symptoms that indicate a cardiopulmonary cause include but are not limited to prodromal symptoms (such as chest pain, palpitations, and dyspnea). Nausea, vomiting, diarrhea, or
abdominal pain, as well as hematemesis and melena may indicate a gastrointestinal etiology. Fever, cough, or dysuria may point to an infectious etiology. The potential for an allergic reaction must be assessed as well as the pregnancy status of women of childbearing age. A mental health screening will assess for the likelihood of drug overdose as the etiology. See Tables 2 and 3 for possible symptoms and key historical questions.

Searching through medical records for the ‘baseline’ BP and finding multiple low blood pressure readings during prior hospitalizations or ED visits should not lower the concern. These patients were sick enough to need frequent care and hospitalizations. Routine clinic visits are a better source for establishing a baseline.

### Table 2. Potential Symptoms Of Organ Hypoperfusion

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Dizziness</th>
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<tbody>
<tr>
<td>Weakness</td>
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<tr>
<td>Fatigue</td>
<td>Syncope</td>
</tr>
<tr>
<td>Anxiety</td>
<td>Thirst</td>
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<tr>
<td>Sense of doom</td>
<td>Dyspnea</td>
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<tr>
<td>Chest discomfort</td>
<td></td>
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<td>Confusion</td>
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### Table 3. Quick Critical Questions: Key Historical Pointers

<table>
<thead>
<tr>
<th>Events Immediately Preceding</th>
<th>Call for help</th>
<th>EMS evaluation and course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Hypotensive Episodes</td>
<td>Dehydration</td>
<td>GI bleed</td>
</tr>
<tr>
<td>None</td>
<td>Cardiac</td>
<td></td>
</tr>
<tr>
<td>Medication-related</td>
<td></td>
<td></td>
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<tr>
<td>Sepsis</td>
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<tr>
<td>Allergic</td>
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<tr>
<th>Known Medical Diseases</th>
<th>Pulmonary</th>
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<tbody>
<tr>
<td>Cardiac</td>
<td></td>
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<tr>
<td>Renal</td>
<td>Hepatic</td>
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<tr>
<td>Cerebrovascular accident</td>
<td>Pregnancy</td>
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<tr>
<td>Transplant recipients</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>Autoimmune disease</td>
<td>Cancer</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>Cognitively impaired</td>
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<tr>
<th>Medication Exposure</th>
<th>Prescribed</th>
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<tbody>
<tr>
<td>Not prescribed, including herbal medications</td>
<td></td>
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<tr>
<td>Alterations to medication regimen</td>
<td></td>
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<tr>
<td>Medication overdoses (intentional or accidental)</td>
<td></td>
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<tr>
<td>Illicit drugs</td>
<td>EMS or ED administered (e.g., rapid sequence intubation, sedation)</td>
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<table>
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<tr>
<th>Allergy History</th>
<th>Recent or suspected exposure (food, medications, latex, etc.)</th>
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<tr>
<th>Coagulopathic States</th>
<th>Warfarin (after trauma or spontaneous bleeding due to drug toxicity)</th>
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<tbody>
<tr>
<td></td>
<td>Hemophilia A and B</td>
</tr>
<tr>
<td></td>
<td>Thrombocytopenia &lt; 20 K</td>
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<tr>
<td></td>
<td>Platelet dysfunction syndromes: von Willebrand’s disease, uremia, etc.</td>
</tr>
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</table>

### Physical

Due to the broad differential diagnosis, a thorough and comprehensive physical examination is necessary for the evaluation of the hypotensive patient. General nutritional and hydration status should be assessed. During the head and neck examination, signs such as sunken eyes, bitemporal wasting, and moisture of the mucous membranes should be noted. Neck examination can reveal the presence or absence of jugular venous distention (JVD) and gives an early clue to pre-load status. The presence of JVD on a patient with hypotension is a serious finding that must be aggressively investigated. Neck vein distension is usually caused by an impaired return of venous blood to the right side of the heart or by significantly elevated right heart pressures. Conditions that may cause this include pericardial tamponade, constrictive pericarditis, tension pneumothorax, right ventricular infarction, massive pulmonary embolism, and air trapping with mechanical ventilation. Tracheal deviation with dyspnea can point to pneumothorax.

During the chest examination, note the presence or absence of breath sounds, crackles, wheezes, and areas of dullness or tympany to percussion. The heart examination can reveal tachycardia, flow murmurs indicating cardiac hyperactivity, diastolic and systolic murmurs which may indicate valve dysfunction, or muffled heart sounds indicating pericardial effusion. The abdominal examination may reveal abnormal bowel sounds, bruits, ascites, palpable masses, distention, rigidity, and areas of tenderness pointing to pathology that indicates dehydration, sepsis, third spacing, or intra-abdominal bleeding. Extremities may be cool and clammy and exhibit poor capillary refill or peripheral pulses. Edema may indicate third spacing or endocrinopathies such as hypothyroidism or adrenal pathology. A careful skin examination may reveal petechiae, suggesting platelet dysfunction (as seen in a vasculitis) or purpura (as seen in disorders of coagulation).

The neurological examination will be most significant for arousability and abnormal mental status, but other more focal signs may be present as watershed areas in the brain are affected by decreased cerebral perfusion pressure. Rectal and pelvic exams are recommended based on clinical suspicion.

### Diagnostic Tests

#### Complete Blood Count (CBC)

**White Blood Cell Count (WBC)**

The WBC rarely contributes to the acute management of pathologic hypotension. Although high and low WBC counts can suggest infection, they can also merely relate the severity of the insult resulting in hypotension. In 1992, the American College of Chest Physicians (ACCP) and the Society of Critical Care Medicine published guidelines for the interpretation of WBC counts and their clinical significance.
Hypotension and the presence of WBC counts above 12,000 or below 4000 were two of the four clinical findings used to diagnose the presence of this syndrome, and both can be present in non-infectious etiologies (e.g., polytrauma). A single white blood cell count that is within the normal range does not exclude an infection-related cause of hypotension. The presence of extremely high or extremely low white counts can also reflect the presence of hematologic, oncologic, and immune disease. The presence of neutropenia (absolute neutrophil cell count of less than 1000) not only indicates the above, but also the need for empiric antibiotic treatment when fever is present.

**Hemoglobin/Hematocrit (H/H)**
In the setting of suspected hemorrhage, the finding of a low value helps to make the clinician more confident of his or her diagnosis. However, in the setting of massive rapid hemorrhage, the H/H may appear normal even though the patient is in extremis. If clinical suspicion is high, the test needs to be repeated over time. The H/H is also helpful in management decisions in that transfusion becomes a consideration when the hematocrit is less than 30 and you suspect the patient has sepsis or myocardial ischemia.

Red blood cell (RBC) indices that may be helpful include the mean corpuscular volume (MCV), range distribution width (RDW), and reticulocyte count. The MCV is a measure of the average size of red blood cells in the circulation. High or low values reflect nutritional deficiencies, drug effects, or red cell hematopoietic dysfunction. When present, this abnormality does not eliminate the possibility of an acute event; it only suggests the presence of a chronic problem having been present before the acute one. When many cell lines of different sizes are present, the MCV can erroneously be normal; in which case, the RDW becomes helpful. The RDW is a measure of the range of different sizes of RBC’s present in the blood stream; its elevation suggests pathology even in the face of a normal MCV. The reticulocyte count is helpful in determining whether an anemia is hyperproliferative (high count) or hypoproliferative (low count).

**Platelet Count (PLT)**
Platelet count and function must also be assessed in hypotensive patients. Thrombocytosis is rarely of immediate clinical concern in that platelet elevations are commonly seen in many inflammatory or infectious diseases, leading to its nickname among rheumatologists as the poor man’s sedimentation rate. It is also elevated in iron deficient anemia.

Thrombocytopenia is associated with several serious diseases and is an ominous sign when present with hypotension. Thrombocytopenia in the setting of anemia requires evaluation of the peripheral smear to detect whether it is actually low and if schistocytes (peripherally shredded RBC’s) are present; a microangiopathic hemolytic anemia (MAHA) should be suspected in these cases. When MAHA is not due to a consumptive coagulopathy (discussed later), it is due to pathologically activated platelets adhering in the capillary bed with resulting RBC hemolysis and anemia. Toxins elaborated in sepsis and in thrombotic thrombocytopenia purpura (TTP) can cause this.

**Coagulation Profile**
There are three main reasons to send the International Normalised Ratio (INR) with Prothrombin Time (PT) and Partial Thromboplastin Time (PTT) tests.

- To document the presence of a consumptive coagulopathy, use INR/PT and PTT plus D-dimer, fibrin split products, and fibrinogen levels.
- To evaluate coagulation function in the face of anticoagulants such as warfarin (Coumadin®), use the INR/PT.
- To evaluate liver synthetic function (e.g., albumin, vitamin K-dependent clotting factors), use PT.

Disseminated intravascular coagulopathy (DIC) produces MAHA by inappropriate activation of the clotting system. The fibrin produced settles in the capillary beds and destroys RBCs and PLT’s. Afterwards, pathologic activation of the fibrinolytic system produces the purpura, hemorrhage, and PT/PTT abnormalities that are diagnostic of the condition. Other tests (such as fibrin split products, D-dimer, and fibrinogen levels) are sent when the condition is highly suspected even in the face of a normal PT and PTT results.

Increased PT times may be due to:
- Liver disease (Bile duct obstruction, cirrhosis, and hepatitis)
- Disseminated intravascular coagulation
- Vitamin K deficiency
- Warfarin (Coumadin®) therapy
- Factor I, II, V, VII, and X deficiencies

Increased PTT evaluates the intrinsic coagulation system and can be used to:
- Monitor heparin therapy and to aid in detecting classical hemophilia A and B and other congenital factor deficiencies.
- Screen for the presence of hypo or dysfibrinogenemia, disseminated intravascular coagulation, liver failure, and vitamin K deficiency.
- D-dimer is very specific for disseminated intravascular coagulation.

**Serum Chemistry Panel**

**Blood Urea Nitrogen (BUN) And Creatinine (Cr)**
The BUN and Cr provide indicators of renal function. A BUN/Cr ratio of > 1:20 suggests dehydration.

**Electrolytes**
Elevations in serum sodium more accurately reflect...
water balance than actual sodium concentration. Hyponatremia in the absence of diuretics or rare sodium wasting nephropathies reflects the retention of water in excess of sodium, whatever the cause. It can be chronic (such as in the syndrome of inappropriate antidiuretic hormone [SIADH]) or acute (as seen when there is volume loss of 10% or more). Hypernatremia almost always reflects severe dehydrations but with loss of water exceeding salt losses. Potassium elevations reflect either increased or decreased intake or excretion of potassium or sudden release of intracellular potassium from massive tissue damage.

Bicarbonate and chloride are useful mainly in the calculation of the anion gap, which can be used to generate the differential of high anion gap acidosis or non-anion gap acidosis.

Glucose
Serum glucose levels tend to rise in pathologically hypotensive patients secondary to excessive catecholamine levels. Elevated serum glucose has been identified as a prognostic marker in severe illness. Hypoglycemia without a drug-induced cause is ominous and denotes the presence of endocrinopathy or very severe hepatic gluconeogenic dysfunction. It is a preterminal event in end-stage liver disease.

Liver Function Tests (LFT’s)
Transaminases measure hepatocellular integrity. Albumin and PT/PTT reflect the liver’s synthetic function; alkaline phosphatase and bilirubin reflect the liver’s excretory function. It is important to be aware of co-morbidities (e.g., history of hepatitis) when interpreting these tests.

Lactic Acid
Normal values for serum lactic acid are usually below 0.7 mmol/dL. Lactate levels above 2.1 mmol/dL point to severely inadequate multi-organ or extensive single organ system ischemia (e.g., mesenteric ischemia).

It does not matter whether the serum lactate is a venous or an arterial sample. In a study of 48 ED patients, Younger et al showed that venous lactate levels of 1.6 mmol/dL and higher had a 100% sensitivity and an 86% specificity in determining elevated arterial lactate levels. A recent study by Jones et al also determined that venous lactate levels are unaffected whether drawn with or without the use of a tourniquet or sent to the laboratory on or off ice as long as the sample is run within 15 minutes. Rapid lactate clearance is associated with improved mortality rates and clinical improvement.

Lactate levels rise in the early stages of sepsis because of increased glycolysis and later on because of decreased clearance by the liver and the kidneys. Prolonged organ hypoperfusion leads to increasing hypoxia and increased lactate production. Elevated lactate levels suggest poor organ perfusion and alert the clinician of impending organ failure. In a study by Ander et al, vital signs and clinical impression were not able to distinguish patients with stable Killip class IV congestive heart failure (CHF) from those with mild versus acute decompensations; however, lactate levels were able to stratify the patients’ severity of illness.

Electrocardiogram (ECG)
An ECG and cardiac monitoring are fundamental to managing the patient with hypotension. Table 4 lists possible etiologies of hypotension that may be revealed by the ECG.

Radiologic Testing
Plain films (such as the chest x-ray) are useful as screening tools to confirm already suspected diagnoses of pneumonia or free air and to confirm past history (such as heart failure). CT scanning and other

<table>
<thead>
<tr>
<th>Potential ECG Findings Encountered</th>
<th>Diagnoses Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduction delays, varying degrees of atrio-ventricular blockade, sinus rate abnormalities, ventricular arrhythmias, supraventricular arrhythmias, pacemaker function and malfunction</td>
<td>Arrhythmias (primary electrophysiologic cause)</td>
</tr>
<tr>
<td>ST segment elevation morphology (may be similar to non-ischemic causes of ST elevation such as benign early repolarization), ST segment depression, T wave depressions</td>
<td>Acute myocardial infarction or ischemia stigmata</td>
</tr>
<tr>
<td>ST elevations with PR segment depression (relative to T-P segment)</td>
<td>Pericarditis (consider effusion or myocardial dysfunction)</td>
</tr>
<tr>
<td>Low voltage QRS complexes, electrical alternans</td>
<td>Tamponade</td>
</tr>
<tr>
<td>Atrial enlargement: suggests chronic pressure and/or volume overload</td>
<td>Cardiac valve dysfunction</td>
</tr>
<tr>
<td>Bradycardia or AV in the setting of hypotension due to use/overuse of AV nodal blocking agents, terminal R wave in tricyclic antidepressant overdose, sinus tachycardia or tachyarythmia</td>
<td>Drug toxicity/exposure</td>
</tr>
<tr>
<td>Wide QRS complexes becoming sinusoidal</td>
<td>Hyperkalemia</td>
</tr>
</tbody>
</table>

Table 4: Diagnoses In Hypotension That May Be Found On ECG
studies are warranted based on the disease process in question. See “Bedside Sonography” on page 15 for a discussion of ultrasound in the evaluation of the hypotensive patient.

Emergency Department Management

The severity of hypotension is not solely based on the depth of the numerical reading. The presence of signs and symptoms of organ hypoperfusion and the number of organs affected are critical features that should be recognized early by the treating physician. Despite our desire to make the correct final diagnosis and initiate definitive treatment, there are situations where the time consumed waiting for that diagnosis would present a danger to the patient’s outcome. Thus, aggressive treatment of the hypotension must occur in tandem with its diagnostic work-up. Beyond the recognition of symptomatic hypotension, there is the issue of adequacy of treatment. In the Shoemaker study cited previously, 76% of patients had mean arterial pressures below 80 mmHg after admission.12 Twenty-four percent of patients that were admitted were normotensive but subsequently had recurrence of hypotension. Treatment of the patients was considered suboptimal in most instances because:

• The underlying disease entity associated with the hypotension was not yet identified
• The underlying disease was erroneously attributed to another etiology
• The resuscitation efforts were late or not sufficiently aggressive

Certain basic steps in the treatment of the symptomatic hypotensive patient are required and are outlined in Figure 1.

Fluids

The mainstay of early treatment of hypotension remains intravenous fluid management. Decreased vascular tone can arise from a myriad of factors, but the initial attempt at correction should be to increase intravascular volume in the majority of cases, with exceptions typically stemming from cardiac decompensation (such as in left heart failure). Intravenous challenges of at least 1-1.5 liters or 20-40 mL/kg48-50 should be given as a bolus and the response monitored. The “Surviving Sepsis” protocol recommends “aggressive” use of IV fluids without a specific volume, highlighting the fact that each patient requires individualized therapy.51 Adequacy of hydration can be assessed subjectively with approximation of CVP via extent of JVD (measured at 8-12 cm above the right atrium) or objectively with a central venous pressure. The caveat to this guideline is that CVP goals are not always clearly defined. In the Early Goal-Directed Therapy (EGDT) article by Rivers et al, the CVP target of 8-12 mmHg for patients in sepsis was not prospectively evaluated. Most patients in both the control and treatment groups reached CVP readings that were higher than the target range. Preload assessment is offered by CVP readings and does not speak accurately to adequate or optimal perfusion of organs in all patients with sepsis. Patients with invasively measured CVP readings of more than 8 mmHg may still have signs or direct evidence of hypoperfusion. Sepsis patients with CVP readings that are within the ‘target range’ used in the often quoted EGDT study may still be hypoperfused and responsive to fluids; they should not be deprived of fluid repletion.

The fluid of choice remains an isotonic crystalloid solution (normal saline or ringer’s lactate).48 Though once in vogue, current evidence does not support the routine use of colloidal solutions (albumin or het-astarch) in acute resuscitation.49,52-54 Although a plethora of literature exists regarding the use of hypertonic saline in the management of the trauma or burn patient, advantages over normal saline in the management of the medical patient have not been demonstrated. In a meta-analysis of 14 trials of 956 trauma and burn patients and those undergoing surgery, it was unclear that any benefits existed with the administration of hypertonic saline.55

Trauma

In bleeding patients with blunt trauma, there is recent evidence that suggests lower volumes of crystalloid should be used to prevent overdilution of blood and coagulation factors.56,57 While tamponade of the bleeding may occur in a closed space, there is a fear that bleeding may increase later if overdilution occurs. Although the data is not conclusive, packed red blood cells and fresh frozen plasma should be considered early in the patient’s treatment in these cases.

In penetrating trauma, terms like “permissive hypotension” or “hypotensive resuscitation” have recently been advocated.58-62 In essence, numerically low blood pressures (approximately 70-80 mmHg systolic) are preferred during early resuscitation of these patients so as not “pop the clot” prior to surgical intervention. Whether this is due to pure intravascular pressure or to dilution of clotting factors, a preference for lower intravascular fluid infusion is established. Care should be taken, however, since target BP’s are not an accurate measure of end-organ perfusion and any signs of such should still be treated aggressively. Additionally, timely transfer to the operating room for definitive treatment is needed in these cases as compensatory mechanisms may have an effect on the patient’s clinical status and could collapse with delays in treatment.

Pressors

If fluid resuscitation fails to correct hypotension, pressors become a consideration. The hemodynamic effects of these agents come from their different affinity for the various endogenous catecholamine receptors. Drug action can also vary from patient to
Figure 1. Algorithm for the Assessment and Treatment of Hypotension

**Initial Stabilization** of the patient includes airway support if necessary, immediate treatment of obvious causes of hypotension (e.g., frank bleeding, trauma, etc.), and ACLS protocols for arrhythmias or arrest. Otherwise, some key physical exam findings (i.e., JVD and lung sounds) can help direct further diagnosis and management of hypotension in this patient.

**Diagnoses to Consider:**
- Hypovolemia
- Distributive shock
- Spinal
- Anaphylactic
- Pneumonia/ pneumonitis

**Vasopressor Support:** Any large vein is acceptable for emergency administration of these drugs, but central venous access is preferred to decrease risk of extravasation. *Bedside sonography can improve procedure success and reduce patient discomfort* with use here. (Class I)

**Lung Sounds—Clear or Wet?**

- **Absent**
- **Present**

**Diagnoses to Consider:**
- Acute lung injury (ALI)
- Cardiogenic shock
- Hemorrhagic shock
- Hypovolemic shock
- Obstructive etiology

**Lung Sounds—Clear or Wet?**

- **Clear**
- **Wet**

**Inotropic Support of Cardiac Function:**

- Dopamine 0.5–1 mcg/kg/min, titrate to 40mcg/kg/min max.
- Norepinephrine 0.125–1 mcg/kg/min starting dose (12 mcg/min max) and titrate to desired BP. Can titrate down to 2.4 mcg/min when BP goal achieved. (Class I)
- Epinephrine 1-4 mcg/min. (Class I)

**Inotropic cardiac support is desired as dopamine has greater chronotropic and arrhythmogenic potential** than norepinephrine. “Renal dose” dopamine (i.e., strictly used for “preserving renal function”) is no longer recommended (5 mcg/kg/min).

**Inotropic** and **vasopressor** agents to be considered if severe tachycardia with other pressors (Class IIb).

**Inotropic Support of Cardiac Function:**

- Dobutamine 0.5–1 mcg/kg/min, titrate to 40mcg/kg/min max. Maintenance dose typically 2.5–20 mcg/kg/min. Has the greatest chronotropic activity than norepinephrine. “Renal dose” dopamine (i.e., strictly used for “preserving renal function”) is no longer recommended (5 mcg/kg/min).
- Milrinone 0.75 mg/kg bolus over 2-3 minutes. May have least risk of peripheral vasodilation.
- Dobutamine 50 mcg/kg bolus over 10 minutes then maintenance dose of 0.375-0.75 mcg/kg/min. (Class IIb)

**Inotropic (i.e., strictly used for “preserving renal function”) is no longer recommended (5 mcg/kg/min).**

**Dobutamine** 0.5–1 mcg/kg/min, titrate to 40mcg/kg/min max. Maintenance dose typically 2.5–20 mcg/kg/min. Has the greatest arrhythmogenic potential as it is an adrenergic agent. (Class I)

**Phosphodiesterase (PDE) inhibitor—** theoretically less peripheral vasodilation. *May have least risk of peripheral vasodilation.*

**Phosphodiesterase (PDE) inhibitor—**

- Milrinone 50 mcg/kg bolus over 10 minutes then maintenance dose of 0.375-0.75 mcg/kg/min. (Class IIb) Newest PDE inhibitor in the USA. May have least risk of peripheral vasodilation.

**Dobutamine** 0.5–1 mcg/kg/min, titrate to 40mcg/kg/min max.

**Phosphodiesterase (PDE) inhibitor—**

- Milrinone 50 mcg/kg bolus over 10 minutes then maintenance dose of 0.375-0.75 mcg/kg/min. (Class IIb) Newest PDE inhibitor in the USA. May have least risk of peripheral vasodilation.

**Consider OBSTRUCTIVE etiology and treat accordingly:** The use of bedside sonography is particularly useful in diagnosis.

- Tension pneumothorax (Class IIa)
- Massive pulmonary embolus (Class IIb)
- Cardiac tamponade (Class I)
- Inferior wall MI with right ventricular infarct (Class I)
- Post-infarction hypotension due to high intrathoracic pressures and decreased venous return

See back page for Class of Evidence Definitions.
patient, and various doses of the same medication can have different actions. The physician must be vigilant in monitoring patients on these agents. Improvement in overall organ perfusion (as determined by clinical improvement in symptoms, urine output, central venous pressure, lactate clearance, and tissue oxygen saturation) should be the primary goal of therapy rather than merely raising the blood pressure. The receptor affinities and actions of these drugs on the various hemodynamic parameters are listed in Table 5.

Current critical care and sepsis treatment guidelines recommend the use of norepinephrine or dopamine as first line vasopressor agents, with a slight bias towards norepinephrine so as to avoid unwanted sinus tachycardia and arrhythmias. If the hypotension is associated with relative bradycardia or primarily a cardiac etiology, then dopamine may be the preferred pressor. Dobutamine may be added if cardiac support is necessary (e.g., inotropic support) but may worsen peripheral vascular tone and hypotension. If further support is needed in the setting of cardiogenic shock, the use of an intra-aortic balloon pump may be necessary.

Continuous vasopressin infusion is gaining support as an adjunct to other pressor agents specifically in sepsis. A relative vasopressin deficiency has been shown to exist in septic patients, although this phenomenon may not actually be present until 24-48 hours into the clinical course. Malay et al conducted a double blinded, placebo-controlled study of 10 septic shock patients receiving either low dose vasopressin or placebo in addition to standard use of fluid and other vasopressors and inotropes. The patients in the vasopressin arm of the study had increases in cardiac index and MAP which allowed for the discontinuation of the other vasopressors and inotropes in that order. The MAP, cardiac index, and SVR were not statistically affected in the placebo group. Two of the five patients in the placebo arm of the study died before 24 hours, but all the patients in the vasopressin arm survived beyond 24 hours and were able to maintain MAP above 70 mmHg solely on vasopressin infusions. Landry et al studied 19 patients with vasodilatory septic shock and 12 patients with cardiogenic shock. In 10 of the patients with low SVR shock states, the mean blood pressure increased from 92/52 to 146/66 mmHg.

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Table 5. Drugs By Adrenergic Receptor Type: Indications, Advantages, And Disadvantages

<table>
<thead>
<tr>
<th>Pressor</th>
<th>Indications</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Dopamine    | • Dopamine is FDA indicated for all forms of shock and for treatment of decreased cardiac output  
• Poor cardiac function with poor perfusion  
• Post arrest hypotension/myocardial stunning | • Effective at multiple receptors  
• Graded, dose-dependent receptor activity (not all or nothing)  
• Titrate to patient specific responses and hemodynamic monitoring | • “Dopaminergic” doses may improve urine output but do not improve renal function and generally are not helpful in addressing hypotension  
• May be arrhythmogenic at higher “alpha” doses  
• High doses may compromise urine output (consider using with dobutamine) |
| Norepinephrine | • Septic shock due to low SVR  
• Can be used in anaphylactic shock | Excellent at increasing systemic vascular resistance (SVR) | Increased risk of dysrhythmias and myocardial ischemia; increased oxygen consumption; may decrease intestinal perfusion and increase lactate levels |
| Phenylephrine | FDA indicated for use in hypotension | Good choice if tachycardia/arrhythmia limiting use | No effect on cardiac output |
| Dobutamine  | • FDA indicated for decreased cardiac output and CHF  
• Best if used when there are signs/symptoms of shock without severe hypotension (< 90 mmHg) | • Inotropic agent: increases cardiac output  
• Good for congestive heart failure without hypotension | Can decrease SVR; may provoke hypotension. Potential solution: add dopamine or epinephrine to increase SVR OR consider switching to another class of inotropic agents, such as phosphodiesterase inhibitor (e.g., inamrinone and milrinone) |
| Epinephrine | • FDA indicated for use in anaphylactic shock  
• Intravenous form is FDA indicated for cardiac arrest | Does not require volume resuscitation prior to use (for the purely anaphylactic cause of shock) | Increased risk of dysrhythmias and myocardial ischemia |
| Vasopressin | Consider in septic shock refractory to volume expansion and first line catecholamines | May decrease amount of other vasopressors needed | • Not a first line agent  
• Delayed onset of action  
• Its use in septic shock and for cardiac arrest are off-label |
SVR increased from 644 to 1187. Six patients receiving low dose vasopressin infusion alone had a return to hypotension upon vasopressin withdrawal and an improvement to normotensive state when vasopressin was restarted. When a vasopressin infusion of 0.04 U/min was added to the shock treatment, reactivity to other pressor agents was enhanced; the authors concluded that the replenishment of vasopressin allows for the discontinuation of other pressors. Acute use of vasopressin in the ED is still controversial but can be considered.

Phenylephrine is also a peripherally acting vasopressor but there is limited support for its use and it is not considered a first line agent. Epinephrine has a reputation for potentially worsening vital organ perfusion and is not a first line agent, though it does remain the drug of choice in the treatment of anaphylaxis. An abstract recently presented by Annane at the Society of Critical Care Medicine’s 36th Critical Care Congress compared epinephrine to norepinephrine for the treatment of hypotension. In contrast to traditional thinking, no significant differences were found in beneficial outcomes or adverse events after 28 days. So-called “renal dose” dopamine is no longer recommended as it has been shown to be ineffective in improving renal function, and improvements in urine output are likely due to higher flow states and not to specific renal bed effects.

Other Adjunctive Treatments

Other pharmacologic agents for use in sepsis include stress dose steroids and activated protein C. Both are recommended in current sepsis protocols. Consultation and cooperation with critical care medicine will facilitate the use of these agents.

Adrenal insufficiency is found in more than half of patients in septic shock. Adrenal insufficiency is defined as non-response to the 250 microgram corticotropin test (cortisol increase of less than 9 micrograms/deciliter). Cortisol maintains vascular sensitivity to catecholamines and helps blunt the endotoxin effect on the heart.

Only a few decades ago, high dose steroid administration was commonly given to patients with septic shock. Now, low dose steroids are thought to increase arterial pressures and decrease the duration of shock. However, most randomized, controlled trials do not point to any decrease in mortality rates of septic shock patients receiving stress dose steroids. That being said, no harm has been brought to light either. The low dose of glucocorticoids that is recommended by sepsis treatment guidelines is 300 mg of hydrocortisone. In a study by Kortgen et al, there was a significantly improved mortality rate when a sepsis bundle that employed an even lower dose of steroids (hydrocortisone 150 mg) was used. At the current time, based on the best available evidence, hydrocortisone 150-300 mg is indicated in patients in presumed septic shock that remain hypotensive despite adequate fluid and vasopressor administration. In the ED, using dexamethasone instead of hydrocortisone offers the advantage of not interfering with corticotropin stimulation testing after admission.

The role of activated protein C (APC) (Xigris®) in the treatment of septic shock is controversial. This compound has antithrombotic, profibrinolytic, and anti-inflammatory properties. A multi-center, randomized, placebo-controlled trial of more than 1600 patients showed that patients with septic shock who underwent treatment with APC had a relative reduction in the risk of death, but a statistically significant increased risk of bleeding. APC has been FDA approved for treatment in patients with severe sepsis, defined as an APACHE II score ≥ 25 or with refractory organ/multi-organ dysfunction. (APACHE score calculator: http://www.icumedicus.com/icu_scores/apacheIV.php [Last accessed June 9, 2007])

Special Situations In ED Management

Anaphylaxis

Anaphylaxis is a true pure distributive shock with mediators causing end capillary damage and subsequent leakage of fluid into the extravascular space. These mediators are responsible for the uncontrolled, uncoordinated vasodilatation seen in anaphylaxis. A patient in cardiovascular collapse from truly life-threatening anaphylaxis can sequester the equivalent of 50% of their effective blood volume into their extravascular space within minutes of onset. Treatment of an allergic reaction usually involves the use of histamine blocking agents and steroids, but in the setting of anaphylactic shock, the early administration of epinephrine (1:1000 dilution 1 mg/mL) is necessary. Intramuscular injections (0.2-0.5 mL) of this solution into the thigh every five minutes as needed is the preferred route, but it can also be given subcutaneously. If circulatory collapse persists, an epinephrine infusion at 1-4 mcg/min should be started. If IV access is unavailable or delayed and the patient is in extremis, epinephrine may also be administered via the endotracheal tube with a dose two to three times greater than the IV dose (1:10,000 solution). If the initial response to epinephrine is transient, repeat bolus dosing may be necessary or the described IV drip at 1-4 mcg/min can be started.

Cardiogenic Shock

Cardiogenic shock occurs acutely when the myocardium suddenly loses 40% of its function in the previously normal heart or when the already diseased heart loses a lesser percentage over time. Clinical criteria for the diagnosis of cardiogenic shock include:

- Systolic blood pressure < 90 mmHg (higher if chronically hypertensive)
- A urine output < 0.5 cc/kg/hr
- Evidence of end organ dysfunction manifesting
Airway And Post-Intubation Considerations

Early intubation in a critically ill patient is a mainstay of ED practice. While providing airway protection, respiratory support, and blood oxygenation, this practice can have deleterious effects on peripheral blood pressures through medication administration and side-effects of positive pressure ventilation. Previously normotensive patients who are intubated may subsequently develop hypotension.

One large urban ED study associated subsequent hypotension with 29% of 84 patients requiring medical intubation. Though mortality was not increased, 13% of these patients required vasopressors and one patient experienced cardiac arrest. Specific associations were not found to correlate with medications, but hypercarbic COPD and hypoxemic respiratory failure showed statistical correlations. These sobering statistics put the onus on ED physicians to be vigilant for the occurrence of post-intubation hypotension and to take appropriate steps to prevent it.

Wide acceptance of rapid sequence intubation (RSI) protocols in the ED have greatly facilitated safe and successful airway management. The danger in the hypotensive patient is the possible arbitrary use of medications, as this may worsen the patient’s hemodynamic status. For example, induction with benzodiazepines, propofol, or barbiturates can contribute to hypotension and are not recommended in this patient population. Two useful induction agents are etomidate and ketamine. Etomidate produces a strong sedative-hypnotic effect but its effects on cardiac and other hemodynamic parameters are less significant than with many other agents. Unfortunately, etomidate suppresses cortisol release which may have significant repercussions in critically ill patients.

Ketamine presents a very good option in these patients. As a dissociative anesthetic agent, the depressant effects of other RSI medications are avoided while its adrenergic activity may help in BP support. Though current recommendations for intubation support the use of etomidate plus succinylcholine, a trial directly comparing the morbidity associated with the use of etomidate versus ketamine is underway.

The post-intubation management is critically important in resuscitating the hypotensive patient. Patients who are marginally compensated may precipitously crash during this period. This is because intubation can further compromise preload due to high intrathoracic pressures associated with mechanical positive pressure ventilation. Positive end-expiratory pressure (PEEP) can further increase intrathoracic pressure, and in patients with obstructive pulmonary disease, “auto-PEEP” can climb to dangerously high levels. If air-trapping becomes an issue, allowing the lungs to decompress by temporarily disconnecting the ventilator can result in a dramatic improvement in blood pressure. Be aware that similar pathophysiology may occur even in non-invasive ventilatory modalities such as continuous positive airway pressure and bilevel non-invasive ventilation.

Endocrinopathies

Endocrinopathies can have a profound effect both on the rapid onset of hypotension and in its treatment once it occurs. Thyroxine and cortisol play important roles in regulating the body’s basal metabolic rate. At
the vascular level in the hypotensive patient, this manifests as a failure of vascular smooth muscle to respond to sudden stresses, producing early cardiovascular collapse. The problem continues during therapy as these patients show impaired responses to therapeutic interventions such as fluids and catecholamine infusion. Therapy focuses on vigilance in suspecting an underlying endocrinopathy, which prompts the ordering of diagnostic tests (e.g., cortisol and thyroid function tests) and/or instituting early replacement therapy. Treatment of severe hypothyroidism (myxedema coma) not only includes giving thyroid hormone but also stress dose glucocorticoids. Beware of the patient on chronic steroid therapy or who is adrenally suppressed. Exogenous administration of stress dose steroids is imperative in these cases. As mentioned earlier, septic patients may be relatively adrenally insufficient and should also receive stress dose steroids.

**Bedside Sonography Use In The Emergency Department**

The concept of the “golden hour” is built on strong evidence that the rapid identification of life-threatening conditions and early initiation of time-sensitive and specific treatments are critical to the patient’s clinical outcome.4-5,13,14,23,51,86-98 This section explores the emerging role of ultrasound in diagnosing and managing patients with hypotension.

**Ultrasound In Hypotension Protocol**

Ultrasound has been used by physicians to detect low intravascular volume states, to evaluate cardiac function, to evaluate the aorta, and to detect peritoneal and pleural free fluid accumulations. In one study, an average of six minutes (+/- two minutes) was needed to perform a bundle of goal-directed ultrasound applications to determine unexplained hypotension.99 Indeed, the utilization of ultrasound is becoming more widespread and is being extended to code response teams in the hospital or to prehospital teams performing ACLS care.100

Differentiating whether hypotension with or without pulmonary edema findings is caused by a cardiac (pump) or non-cardiac (non pump) problem is one of the first major steps toward a careful tailoring of the medical treatment during a resuscitation. The invasive method of pulmonary artery catheter (PAC) placement and monitoring was compared to information obtained by performing noninvasive cardiac sonography in a 1994 study by Kaul et al.101 Forty-nine consecutive patients presenting with hypotension and/or pulmonary edema were evaluated. Early transthoracic cardiac sonography data was compared with that of pulmonary catheter readings obtained within two hours of each other. Two to three blinded observers were used for each study. Complete agreement between PAC and cardiac sonography information was found in 36 (86%) of the 42 patients. There was complete agreement in patients with hypotension alone and 90% of the 20 patients with pulmonary edema alone. The time taken for pulmonary artery catheter placement was 63 +/- 45 minutes compared to 19 +/- 7 minutes for comprehensive two-dimensional echocardiography.

Studies in hypotensive patients support the diagnostic role of ultrasonographic evaluation of the inferior vena cava (IVC) as an indicator of volume status. A prospective study of 50 patients by Adler et al identified hypovolemia, unrecognized right heart failure, and high volume states based on the longitudinal views of the IVC using ultrasound.102 By looking at the anteroposterior diameter of the IVC and the respiratory variation in size, one could reliably estimate central venous pressure. Another study evaluated the correlation between sonographically-measured proximal IVC diameters, the respirophasic variations of the IVC size (caval index), and the central venous pressures (CVP) that were measured invasively. This study showed a definite correlation between caval index and central venous pressure.103 An IVC respiratory collapse of more than 50% represents a caval index above 0.5. Eighty-nine percent of patients with a caval index above 0.5 had RA pressure readings above 10 mmHg. Eighty-six percent of patients with a caval index below 50% had RA pressure readings less than 10 mmHg (Figure 2).
abnormalities/disease had greater average IVC diameters and much less respiratory collapsibility than the normal subjects or the ones with cardiac disease without right heart involvement. Even though 30 patients were in atrial fibrillation, the authors found no correlation between IVC size and dynamics and the sex, body surface area, age, and cardiac rhythm of the patients. The size of the IVC was helpful in the further stratification of CVP measurements. The combination of small size and greater collapse confirmed a low CVP. The combination of an IVC diameter above 2.5 cm and a very low caval index (barely any respiratory variation) is termed IVC plethora. In this study, plethora of the IVC was associated with CVP readings over 15 mmHg (Figure 3, 4, and 5).

Elevated right atrial pressures, determined by invasive methods, are associated with a poor prognosis in patients with pulmonary hypertension, congestive heart failure, congenital heart disease, and heart transplantation. Sonographic findings of IVC plethora were also associated with poor survival in a study of 4385 stable male patients in an outpatient setting. It was determined to be an important prognostic finding in the one-year survival rate of patients but less so for the 90-day survival rate. This was independent of the ventricular function, a history of heart failure, other illnesses, and pulmonary artery pressure readings. The prognostic impact of IVC plethora in the unstable patient with hypotension remains to be determined. IVC plethora should spur a rapid search for a cause of the elevated RAP in the hypotensive patient.

In addition to using sonographic IVC diameter as an estimate of central venous pressure, the presence of IVC plethora should prompt physicians to consider patient factors that might cause right-sided pressure to be underestimated. IVC diameter and collapsibility should be measured at the level of the diaphragm (proximal IVC) and at the right atrial junction (distal IVC). These two measurements are relatively easy to make, and their ratio is suggestive of central venous pressure as it correlates with intra-abdominal pressure. The caval index is the ratio of the diameter at the level of the right atrial junction to the proximal IVC and is believed to provide a more accurate estimate of CVP than IVC diameter alone (Figure 3, 4, and 5).

Table 6. Estimation Of Left Ventricular Ejection Fraction

<table>
<thead>
<tr>
<th>Cardiac Ultrasound</th>
<th>Clinical Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well filled hyperdynamic heart</td>
<td>Distributive shock: sepsis, anaphylaxis</td>
</tr>
<tr>
<td>Well filled hypodynamic heart</td>
<td>Cardiogenic shock: sepsis, metabolic/ischemic, toxidrome</td>
</tr>
<tr>
<td>Barely filled hyperdynamic heart</td>
<td>Hypovolemia: hemorrhage, dehydration</td>
</tr>
</tbody>
</table>

Figure 5. Cardiac Features Of Hypovolemia: Subcostal Four Chamber View

There is a small pericardial effusion (arrows), but the clinically significant sonographic finding is that the heart chambers are difficult to distinguish because the endocardial surfaces are very close together. This is due to severe hypovolemia. The heart was able to become hyperdynamic but the poor filling volumes lead to a very low cardiac output. Fluid loss may be evident by history clues or physical signs, but further goal-directed sonography can be used to determine if there were any significant internal fluid accumulations in the thoracic, peritoneal, or pericardial spaces or potential sources of cardiovascular hypovolemia (such as finding an abdominal aortic aneurysm or a ruptured ectopic tubal pregnancy). In this case, the patient had severe gastrointestinal bleeding compounded by warfarin toxicity.
a determinant of volemic status, it has also been shown to assist in gauging response to therapy. Barbier et al conducted a prospective study of 23 mechanically ventilated patients with sepsis-related circulatory failure in an ICU setting. The presence of respiratory variations in IVC diameter at baseline and after fluid boluses demonstrated that IVC distensibility could dichotomize fluid responders and fluid non-responders with a 90% sensitivity and a 90% specificity.

The visual estimation of LVEF can be reported qualitatively and quantitatively as increased, normal, or decreased (mildly, moderately, or severely).

(Table 6). Estimation of LVEF in the ED has been shown to be useful in a number of studies.

Pericardial effusion detection is best performed by echocardiography as it provides dynamic real-time information on myocardial motion and physiology. Most pericardial effusions are not loculated. The rate of fluid accumulation, the size of the fluid buildup, and the compliance of the pericardial sac will all determine when intra-pericardial pressure (IPP) exceeds the right atrial wall pressure. Rapid pericardial fluid accumulations will lead to tamponade at a lower fluid volume (e.g., stab wounds) than slow accumulations over months (e.g., uremic effusions). When the IPP exceeds the RAP, it will provoke RA wall invagination or, even worse, right ventricular wall collapse during diastole (tamponade physiology) (Figure 6 and 7).

In summary, some of the Class I recommendations for echocardiography by the American College of Cardiology/American Heart Association Task Force on Practice Guidelines for the Clinical Application of Echocardiography apply to the patient being cared for in the ED, see Table 7. These indications include, but are not limited to:

- Patients with unexplained hypotension
- Patients with dyspnea and clinical signs of elevated central venous pressure when a cardiac etiology is possible or when a central venous pressure reading cannot be obtained or interpreted with confidence, especially when cardiac disease is suspected clinically
- Patients with suspected effusion, tamponade, and/or constrictive physiology
- The assessment of LV size and function with suspected cardiomyopathy or the suspicion of heart failure

**Applied ED Bedside Ultrasonography**

**Abdominal Aortic Aneurysm (AAA)**

When hypotension is present in preoperative patients with ruptured AAA, there is usually high mortality. Suspicion for AAA is heightened when the presenting symptoms include sudden abdominal pain and

**Table 7. Key Clinical Questions Addressed by Sonography in the Severely Hypotensive Patient**

<table>
<thead>
<tr>
<th>Sonographic Clinical Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is a pericardial effusion present?</td>
<td>Yes or No</td>
</tr>
<tr>
<td>If yes, is it with tamponade?</td>
<td>Yes or No</td>
</tr>
<tr>
<td>What is the RV size?</td>
<td>Normal or dilated</td>
</tr>
<tr>
<td>What is the LV function?</td>
<td>Hyperdynamic/normal/ moderately weak/ very weak</td>
</tr>
<tr>
<td>What is the LV size?</td>
<td>Dilated/normal/small</td>
</tr>
<tr>
<td>Is there IVC collapse?</td>
<td>Yes or No</td>
</tr>
<tr>
<td>Is there an AAA?</td>
<td>Yes or No</td>
</tr>
<tr>
<td>Is there free intraperitoneal fluid?</td>
<td>Yes or No</td>
</tr>
</tbody>
</table>
radiation to the back, syncope, or other signs of clinical shock. The presence of an aortic aneurysm is reliably detected sonographically (Figure 8 and 9). Indeterminate studies are possible due to interference by bowel gas. The sonographer can apply firm, steady pressure to the abdomen to displace bowel gas so that the posterior lying aorta can be seen. The presence of aortic rupture or leak is not determined by ultrasound except if the rupture occurs into the peritoneal cavity, releasing free fluid. Most episodes of abdominal rupture occur into the retroperitoneum; this may contain and curtail the rate of blood leakage. Bedside ultrasound does not detect the site of rupture.

Aortic Dissections

The most lethal area of aortic dissection is the thoracic aorta. Involvement in the ascending thoracic aorta can extend through the adventitial layer with rapid accumulations of blood into the pericardial sac with early tamponade. Aortic root dilation can lead to severe aortic insufficiency. Dissections involving the abdominal aorta or the proximal iliac arteries are easier to detect. Intimal flaps are seen as echogenic lines that move independent of the aortic wall pulsations (Figure 10).

The thoracic aorta (TA) presents a difficult challenge in performing a thorough sonographic evaluation. The presence of lungs, ribs, and the naturally varying anterior-posterior create impediments to performing complete studies. The parasternal transthoracic approach offers a very limited view of a portion of the descending aorta; the left ventricular outflow tract views provide clues of the most proximal 1-2 cm portion of the ascending TA; the apical two-chamber view may provide a longitudinal view of a small portion of the descending TA; the suprasternal views show the aortic arch. Transesophageal echocardiography is the preferred modality for imaging the thoracic aorta.

Pulmonary Embolism: Role Limited To Massive Pulmonary Embolism (MPE)

In the patient with shock, bedside transthoracic echocardiography evaluation is used to determine if there are signs of acute right heart strain; the most likely causes are massive pulmonary embolism or right ventricle infarction. Right ventricular cavity dilation is the right heart’s initial compensation.
to severe pulmonary artery occlusion. The right ventricle is distended and also hypokinetic. The apex of the inner normal right ventricle is usually sharp, but with acute RV strain, it will become blunted. The right ventricle is usually 60% of the diameter of the left ventricle when measured in diastole. When the RV diameter to LV diameter ratio approaches or exceeds 1.0, the diagnostic certainty of acute RV strain is increased. The McConnell sign (hypomotility of RV free wall with apical sparing) has been used as a relatively unique sonographic feature of significant PE (Figure 11).

The buildup of right ventricular pressures may exceed that of the left ventricle, provoking a bulge of the septal wall into the LV cavity. True pressure overload is distinguished from RV volume overload by evaluating the septal distortion during systole and diastole. In RV volume overload, the septal wall is flattened during diastole, but the greater LV systolic pressure returns the septal wall to its normal appearance. In RV pressure overload, the intraventricular septal wall may be flattened or pushed into the LV during diastole. During systole, the intraventricular septum remains flattened or deviated into the LV. High RV wall stress eventually compromises coronary blood flow to the inner RV myocardium and endocardium. The RV myocardial ischemic insults further compromise the already weakened RV output. Diastolic filling of the left ventricle is reduced by the leftward bulge of the ventricular septal wall. The reduced volume of already poorly oxygenated blood leads to poor perfusion and oxygen delivery to multiple organs.

RV dysfunction by cardiac ultrasound is not specific for PE in that it can also be found in primary pulmonary hypertension, RV infarction, acute exacerbations of COPD, and in certain cardiomyopathies. In addition, RV dysfunction has been reported by cardiac ultrasound in 40% of patients with PE but no significant hemodynamic stability. Twenty percent of cases of diagnostically confirmed PE have normal echocardiographic findings. Sonographic RV dilation and hypokinesis in a patient that is unstable suggests PE and drives the need for definitive study. Performing bedside ultrasound can be difficult in patients with obesity, hyperinflated lung states, and those who are immobile and on mechanical ventilator support.

The hypotension that results in pulmonary embolus is usually responsive to preload increases and the use of vasopressors to augment coronary perfusion of the myocardium. The best treatment occurs with a reduction of the pulmonary artery pressure.
occlusion by inherent thrombolysis, prevention of further thromboembolic events with heparin, and — most effectively — the use of thrombolytic agents or pulmonary thromboendarterectomy.

**Vascular Access**

Well designed, randomized, controlled trials have compared ultrasound-guided vascular cannulation to the traditional anatomic landmark based vascular access. Vascular access is particularly more difficult in the patient with hypotension or cardiac arrest. Arterial pulsations may already be too faint to provide guidance. In addition, the anatomic relationships of the femoral and neck vessels may vary thus compounding the potential for errors. Prolonged and multiple attempts, the development of complications, and failure to attain access will delay the administration of time-sensitive medications and fluids. Ultrasound-guided peripheral vascular access may be better and safer than central venous cannulation, especially in patients with coagulopathies where vessel compression may be critically important (Figure 12 and 13).

**Controversies / Cutting Edge**

**Hemodynamic Monitoring**

The resuscitation literature points towards early aggressive management as being key to altering outcomes in patients with pathologic hypotension. This awareness has resulted in increased pressure to initiate therapy in the ED and provide close monitoring. Static hemodynamic reports do not accurately predict the patient’s responsiveness to fluid administration or their actual clinical improvement. For example, while most patients with sepsis are discovered to be in a hyperdynamic state, this may be an early compensatory response. The patient with septic shock with a hyperdynamic LV on bedside ultrasound can have LV dysfunction several hours later, especially if the patient has pre-existing cardiac disease. RV dysfunction can also be present in as many as one-third of patients with sepsis. Continuous monitoring of RV function is extremely helpful for the assessment of cardiac and respiratory function and in response to treatments and interventions.

Measurement of cardiac filling pressures and pulmonary artery occlusion pressures are generally used in more intensive care settings and require highly invasive procedures (e.g., central venous pressure readings and right heart catheterization). With normal CVP readings between 6-12 cm H2O, low or high readings can help differentiate between hypovolemic states, cardiac failure, obstructive etiologies, and/or hypervolemic states.

Right heart catheterization (RHC) and pulmonary artery catheters (PAC) are more complicated and are used for occlusive pressure measurements. Further data can be obtained with this modality, especially when determining if pump failure primarily involves the left heart (e.g., decompensated CHF) or the right heart (e.g., right ventricular MI or other obstructive pathology). A meta-analysis of several randomized, controlled trials showed that early (prophylactic) use of PAC-directed therapy aimed at tissue perfusion resulted in a marked improvement in patient outcome. Other RCT studies in the meta-analysis, however, showed that there were no outcome improvements when PAC-directed therapy was used in ICU patients after organ failure and sepsis had set in. This was corroborated in other studies. In a prospective cohort study of 5735 critically ill patients, there was no patient group in which RHC demonstrated improved patient outcome. However, RHC was associated with increased mortality, length of stay, cost of care, and resource utilization. In a busy ED, the practicality of using invasive monitoring is severely limited by patient flow, inordinate amount of procedure time, and staffing issues; thus, it is not recommended.

Fortunately, some noninvasive techniques show promise; as they become more readily available, these techniques will allow the emergency physician to more easily deliver goal-oriented treatment. Bioimpedance monitors for cardiac output, transcutaneous oximetry, and capnometry for tissue perfusion in conjunction with pulse oximetry and blood pressure measurement have been shown to be accurate when compared to the same information typically obtained through a right heart catheter. sky.

Shoemaker et al studied the use of noninvasive methods in 151 severely injured patients using the continuous monitoring of certain cardiac pulmonary exchange and tissue perfusion parameters. Cardiac index and tissue oxygenation measured in this manner were significantly higher and well above “optimal” levels (as defined in the study) in survivors as compared to non-survivors. Further support for the more expansive and earlier use of non-invasive hemodynamic monitoring was provided by a study of 680 critically ill patients. New bioimpedance methods for estimating cardiac output combined with arterial BP, pulse oximetry, and transcutaneous PO2 and PCO2 were equivalent to thermodilution invasive data. The bioimpedance monitor was able to detect low flow states and poor tissue oxygenation early. Lower tissue oxygenation and higher tissue CO2 levels were significantly more prevalent in the non-survivors.

Limitations of the thoracic bioimpedance instruments may include improper lead positioning, motion artifacts due to tremors, restless patient movements, and patient disease-related conditions like pulmonary edema, pleural effusions, valvular disease, and arrhythmias. With proper implementation of these instruments, however, better outcomes can be accomplished through earlier diagnosis and treatment of individuals at risk for developing hypotension and shock before late effects on the vital signs are seen. As
this technology becomes more widespread, additional training in this monitoring will be necessary for emergency physicians, nurses, and other health providers in the ED.

**Algorithmic Treatment Of Hypotension And Shock**

With accurate monitoring of hemodynamic parameters and tissue perfusion, algorithms can be developed to directly address sub-clinical signs of poor tissue perfusion. The use of algorithms in managing hypotension is not a new concept. In 1983, a retrospective study of fluid resuscitation in 603 patients with hypotension was identified. This was a case series of patients with hypotension who were resuscitated with either a fluid administration algorithm or on the individual physician’s preferences. A chart review showed that even with this specific clinical guideline, compliance with the algorithm was suboptimal. There were significant delays in the start of fluid challenges and many steps in the algorithm were not followed. There were 114 deaths (19% mortality) in the study group. Significant comorbidities were present in 265 (44%) of the hypotensive patients. Forty-four patients in this subgroup developed severe shock-related organ dysfunction. These patients had a higher mortality rate, more severe hypotension (lower mean arterial pressures), and more challenging and prolonged resuscitations. They also seemed to have noticeably more delayed starts to the resuscitation efforts after hypotension was recognized. The authors

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**Risk Management Pitfalls For Hypotension**

1. **Assuming that an ashen, lethargic patient is not hypotensive because he has a good blood pressure of 120/80 mmHg.**
   
   Treating the number rather than the patient can cause you to miss the hypotensive state. Treat the patient; this patient is hypotensive. The BP is well below baseline and he looks terrible for now. It might get worse. Cardiac dysfunction and tissue ischemia can persist despite normalization of BP, heart rate, and CVP.

2. **Inadequate workup of the underlying etiology.**
   
   Establishing adequate urine output with fluid boluses won’t stop bleeding from a gastric ulcer or ruptured aorta. Giving antibiotics for a fever won’t be effective if a gangrenous gallbladder remains undiagnosed.

3. **Inadequate fluid loading.**
   
   Look for low CVP signs, evaluate urine output, and monitor cardiac output response to fluid administration. Tissue perfusion is your goal and cardiac output is usually the key to achieving this. A hyperdynamic heart is attempting to compensate for a low ventricular volume.

4. **Delaying ventilator assistance.**
   
   Improved ventilation and oxygen delivery to the lungs and ultimately the organs puts less demand on the heart and reduces the oxygen debt.

5. **Overaggressive resuscitation without factoring in the wishes of the patient of family.**
   
   A respectful and cost-effective treatment plan may hinge on getting these important pieces of information.

6. **Discontinuing monitoring after a “good blood pressure” is reached.**

   The BP is a single and imperfect parameter in assessing the patient’s volume and circulatory state. Multiple tools may be necessary to assess tissue perfusion and changes in cardiac output. In some patients, there is an improvement in the blood pressure, a normalized pulse rate, and no more postural dizziness after fluid administration for self-limited diarrheal illness. Another patient may have an improvement in the BP to 120/80 but still feel weak and short of breath because the LVEF is 20%, or the pericardial effusion remains undiagnosed, or the tissue oxygen debt state remains unpaid.

7. **Allowing slow tests to guide management.**
   
   Do not wait for the creatinine and D-dimer to come back before getting the CT; do not wait for the CXR to see if the mediastinum is wide or if the heart is large.

8. **Discounting the possibility of orthostatic hypotension as the primary etiology in the elderly patient with supine hypertensive readings.**

9. **Ignoring the role and use of bedside sonography in hypotension resuscitation.**
   
   The rote use of fluid then vasopressors and inotropic agents may not help and can worsen some clinical processes. Hypotension is not a disease or even a syndrome to be fixed. It is a sign that something is going wrong. You just have to figure it out quickly and carefully. Goal-directed sonography accurately addresses many dangerous and time sensitive clinical questions.

10. **Not re-evaluating hemodynamic profiles.**
    
    RV, LV function, and preload status can change even when you do the right things.
concluded that in circumstances where there were less deviations (or more compliance) from the fluid resuscitation guideline, the resuscitation efforts were shorter and there were fewer shock-related problems. Improved clinical outcomes included lowered mortality, shorter intensive care unit (ICU) length of stay (LOS), and less total time spent in the hospital. The patients with severe comorbid conditions were more likely to succumb to death and complications. In various other studies, better outcomes in terms of duration of hypotension, ICU and hospital stays, and overall mortality were also achieved with the use of algorithms.\textsuperscript{50,127-129}

**Recombinant Factor VIIa**

There has been recent study of the use of rFactor VIIa to control bleeding during surgery. Of particular note to emergency physicians is its use in bleeding trauma patients. This medication is used to induce clotting specifically at the bleeding site and has particular use in blunt trauma and intracerebral hemorrhage, two entities that are not so rare in an ED setting. Current usage is recommended only in refractory bleeding and most case reports show its use as a “last-ditch” effort to control bleeding.\textsuperscript{130-133} Because of its pro-coagulant properties and the relative lack of completed randomized, controlled trials in its use, it can only be recommended with a Class III designation until further information is received.\textsuperscript{134} There is no significant literature to support its use in medically bleeding patients and it may actually be contraindicated because of the typical multi-system disease in these patients.

**Cost- And Time-Effective Strategies In The Workup Of Unexplained Hypotension**

1. Keep bedside ultrasound available to answer focused questions on global heart function and volume status. Signs of vascular catastrophes, massive pulmonary embolism, and tension pneumothorax can also be sought without interrupting resuscitation efforts.
   - Don’t use the CXR to rule out aortic dissection, pericardial effusion/tamponade, or cardiomyopathy based on a mere silhouette.
   - Don’t wait for the CT and the serum creatinine to determine if a high suspicion AAA is present or absent.

**Key Points For Hypotension**

1. It is necessary to use/acquire the bedside tools that noninvasively and accurately assess cardiac output, CVP, and tissue oxygenation as part of the resuscitation in the hypotensive patient. Ultrasonography is the ideal modality—it only takes a few minutes to get crucial accurate information on heart function and major vascular integrity. It also allows safer and quick access for medication administration and guidance of invasive procedures.

2. Consider it a ‘red flag’ when patients have pre-hospital episodes of hypotension.

3. Improving multi-organ tissue oxygenation is your main goal. Monitor for signs of oxygen debt: hypoxia, metabolic acidosis, transcutaneous oxygen deficits, and elevated lactate levels. The hemoglobin level may need supplementation if inadequate.

4. Patients with hypotension do not usually fit exclusively in one category of etiology of hypotension or shock. Therefore, the treatment is multi-pronged.

5. Time is of the essence. Hypotension is a late finding and fixing it does not mean you corrected the state of organ dysfunction that set in.

6. Repeat hemodynamic profiles regularly and in response to changes, especially deteriorations, and after major therapeutic interventions are put into effect (including fluid boluses).

7. Finding the source of hemorrhage or infection is the first management step:
   - a. Thoracic: consider chest tube, endobronchial tamponade, interventional radiology involvement for vessel identification, embolization, etc., and surgical intervention if lobectomy is indicated.
   - b. Gastrointestinal: consider endoscopic variceal tamponade.
   - c. Consider surgery for aortic rupture, splenic rupture, and massive colonic bleeding.
   - d. Reverse bleeding tendencies.

8. Oxygen delivery in the critically ill patient with hypotension often requires intubation. Use medications such as etomidate and fentanyl that do not cause hemodynamic deterioration. Consider ketamine for SBP improvement. Carefully administer induction agents (consider lowering the dose) in any patient with a tenuous hemodynamic profile.
2. Assess cardiac dynamics and CVP estimates before, during, and after fluid and catecholamine support. Well designed studies support the use of goal-directed echocardiography in the hypotensive ED patient.

3. Use crystalloid solutions for fluid resuscitation. No outcome improvements are in the current literature that justify the use of more expensive colloidal solutions in the USA. Goals may include: CVP improvement, cardiac index improvement, adequate urine output, and lactate clearance.

4. Organ hypoperfusion can be occult; aggressively seek to get clues using noninvasive monitoring such as tissue oxygen saturation, central venous oximetry, and lactate levels.

5. Use hypotension as a threshold point, not as a goal. Address multiple factors that may impact hypotension and, more importantly, organ hypoperfusion.

**Disposition**

Because of the high morbidity and mortality associated with hypotension regardless of etiology, there should be a low threshold for admission. Ultrasound may be a useful tool in directing the disposition. The Focused Assessment of Sonography in Trauma (FAST) application allows the direct triage of hypotensive trauma patients with positive FAST findings to therapeutic laparotomy without the use of CT imaging.135

In the new age of ED over-overcrowding (not a typo) the solution to high patient acuity and volume should not prolong critical care in the ED. Step down units and expanding ICU’s help redirect resources and EM expertise to the next patient demanding answers for their unexplained hypotension. The Acute Physiology and Chronic Health Evaluation (APACHE) II, the Simplified Acute Physiology Score (SAPS), and the Hypotension Score were all created as prognosticators of patient outcome or severity of disease and have the potential to guide ICU care.136

**Case Conclusion**

The first patient had deepening hypoxia (despite proper endotracheal intubation) and was given antibiotics because of the fever and the elevated serum leukocyte count. No obvious infectious source was evident. Bedside cardiac ultrasound showed no pericardial effusion but did reveal increased left ventricular function, a distended thin walled right ventricle, and leftward septal wall deviation. The IVC was distended and showed poor respiratory motion. There was no obvious IVC or intracardiac mass or clot. The blood pressure was refractory to 2 L of IV crystalloids, and after discussion with the critical care team, pulmonary embolism was considered to be the likely cause of the acute right heart strain. TEE confirmed the finding of pulmonary artery thrombus, and thrombolytic agents were given.

The second patient had rales and fluid administration that led to more shortness of breath and yet another endotracheal intubation. Furosemide did not help and the dialysis center did not respond. The ECG was unimpressive and the patient, who was paralyzed and sedated, remained hypotensive and tachycardiac. You considered inotropic or vasopressor support but then remembered that the new ultrasound was delivered yesterday. The abdominal aorta appeared to be no more than 2 cm in diameter but you noticed an intimal flap. The heart also had a small pericardial effusion and an intimal flap next to the aortic valve. The patient was taken to the OR where he survived a thoracic aorta repair.

The third patient also had rales. The heart was enlarged on CXR. The lungs were mildly congested. Ultrasound showed a small pericardial fluid and barely any myocardial activity overall with an ejection fraction of 10% at most. The IVC was thick and stayed the same after the patient took in a quick and deep breath. She was quickly put on dobutamine and fell asleep an hour later for the first time in weeks. A repeat echo showed an EF of 20% and the patient appeared remarkably better—you left the shift exhausted but a confirmed believer in the value of bedside ultrasound.

**Summary**

In an age when we are held to a higher standard of being “Better, Faster, and Sure,” the sheer volume, increasing complexity, and higher acuity of ED patients make the management of patients more challenging than ever before. The early recognition of clinical hypotension, the rapid initiation of goal-directed resuscitation, and the early use of accurate diagnostic tools remain the cornerstone to reducing morbidity and mortality of hypotensive patients. Rapid identification of clinical hypotension should be followed by the rapid and confident diagnosis of the primary and contributory etiologies. The correction of the primary disorders must occur in parallel to the diagnostic workup to avoid adverse patient outcomes—a rather tall order for the EM physician. Using the tools that are available to us early, before further deterioration of the critically ill patient, puts us one step closer to achieving that goal.

**References**

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available.


CME Questions

1. The most definitive test in ruling out pulmonary embolism as the cause of a patient’s hypotension and dyspnea is:
   a. Bedside echocardiography
   b. D-dimer
   c. Chest x-ray
   d. Contrast-enhanced CT of the thorax
   e. Lower extremity venous compression ultrasound

2. Which of the following diagnostic tools suggests primary cardiogenic causes of the hypotension?
   a. Brain natriuretic peptide elevations
   b. WBC count elevations
   c. Lactate level of 1.0
   d. Urinary output of less than 10 cc/hr

3. What factors interact to produce a normal blood pressure?
   a. Stroke volume and heart rate
   b. Systemic vascular resistance
   c. Peripheral vascular vasoreceptors and central nervous system vasomotor centers
   d. The patient’s volume status
   e. All of the above

4. Besides a systolic BP < 90 mmHg, which factor is the most common occurrence prior to cardiac arrest in hospitalized patients?
   a. Dyspnea
   b. Oxygen saturation < 90%
   c. Bradycardia for more than 30 minutes
   d. A decrease in GCS

5. In a patient presenting with hypotension and clear lungs without jugular venous distension, the most likely diagnosis is:
   a. Acute hemorrhage
   b. Cardiogenic shock
   c. Massive pulmonary embolism
   d. Cardiac tamponade

6. What is true about the use of vasopressor agents?
   a. Norepinephrine is the drug of choice for anaphylaxis
   b. Dopamine is the drug of choice for sepsis
   c. Phenylephrine is primarily an alpha agonist
   d. Dobutamine is indicated for those patients with an initial systolic blood pressure < 70 mmHg

7. Which of the following statements about bedside goal-directed ultrasound is true?
   a. It allows the differentiation of the causes of obstructive hypotension
   b. It allows for rapid assessment of ventricular function, wall motion, and valvular abnormalities
   c. It can be used to facilitate vascular access
   d. It is rapid, cost effective, and doesn’t require the patient to leave the ED
   e. All of the above

8. Some factors contributing to hypotension in patients intubated and ventilated in the ED include:
   a. Initiation of intubation with inadequate IV access
   b. Failure to consider metabolic derangements likely present at the time of intubation
   c. The use of medications likely to cause hypotension for intubation and sedation
   d. The inappropriate use of ventilatory modalities (such as PEEP) that lower blood pressure
   e. All of the above
9. Which of the following diagnoses must be considered in a hypotensive patient with dyspnea and jugular venous distention?
   a. Tension pneumothorax
   b. Acute pulmonary edema
   c. Pericardial tamponade
   d. Right ventricular infarction
   e. Pulmonary embolism
   f. All of the above

10. First line pressor agents in the treatment of various causes of shock include all of the following EXCEPT:
   a. Norepinephrine use in the setting of pneumonia, good left ventricular systolic function, and hypotension refractory volume resuscitation
   b. Dobutamine use in a patient with severely depressed left ventricular function and a blood pressure of 80/40 mmHg
   c. Epinephrine use in a patient with anaphylactic shock
   d. Phosphodiesterase inhibitor use in the patient with hypotension with pulmonary edema and poor cardiac systolic function
   e. Vasopressin use in the dehydrated patient with suspected urosepsis

Class Of Evidence Definitions
Class I: Conditions for which there is evidence for and/or general agreement that the procedure or treatment is useful and effective
Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment
Class IIa: The weight of evidence or opinion is in favor of the procedure or treatment
Class IIb: Usefulness/efficacy is less well established by evidence or opinion
Class III: Conditions for which there is evidence and/or general agreement that the procedure or treatment is not useful/effective and in some cases may be harmful

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