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HYPERTENSION MANAGEMENT

SUMMARY

Hypertension is commonly encountered in the surgical patient. Although most commonly related to inadequate pain control, a variety of other etiologies for either systolic or diastolic hypertension may be seen. This guideline aims to provide an overview of the available agents as well as guidance on drug selection and dosing for the treatment of hypertension.

RECOMMENDATIONS

- **Level 1**
 - **Vasodilator infusions should be titrated to mean arterial pressure (MAP) rather than systolic or diastolic blood pressure.**
 - **Antihypertensive medications should be administered to patients with hypertensive emergencies (extreme elevations in blood pressure (SBP \geq 180 mmHg or DBP \geq 110 mmHg) and evidence of end-organ dysfunction).**
 - **For hypertensive emergencies, the goal is to lower the MAP 20-25% in the first 60 minutes.**
- **Level 2**
 - **Underlying causes of perioperative hypertension (including pain, anxiety, agitation, or hypoxia) should be ruled out before administration of antihypertensive agents.**
 - **Esmolol is the drug of choice for patients with acute aortic dissection.**
 - **Empiric perioperative beta-blockade should only be administered to patients taking a beta-blocker prior to hospital admission.**
- **Level 3**
 - **Labetalol is the antihypertensive of choice for patients with a history of cocaine abuse.**
 - **Labetalol or nicardipine are the first line agents for intracranial hemorrhage-associated hypertension.**
 - **Labetalol is recommended for initial treatment of patients with acute perioperative hypertension and no prior history of hypertension.**

INTRODUCTION

Hypertension (HTN) is defined as a systolic blood pressure (SBP) \geq 140 mmHg or a diastolic blood pressure (DBP) $>$ 90 mmHg (1). A hypertensive crisis may refer to either "hypertensive emergencies" or "hypertensive urgencies" (1,2). Hypertensive emergencies are defined as severe elevations of SBP \geq 180 mmHg and/or DBP \geq 110 mmHg plus the presence of end-organ dysfunction (such as neurologic changes, intracranial hemorrhage, myocardial ischemia, aortic dissection, eclampsia, etcetera) requiring immediate reduction in blood pressure (1-3). In contrast, hypertensive urgencies have no associated end-organ dysfunction and require reduction over hours to days (1-3).

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

The acute management of isolated systolic, isolated diastolic or combined systolic and diastolic hypertension differs. Generally, diastolic hypertension is more clinically important and should be treated first. The primary determinants of SBP are left ventricular contractility, stroke volume, and great vessel compliance. The primary determinants of DBP are systemic vascular resistance (SVR), peripheral run-off, and diastolic time interval (heart rate). Coronary perfusion pressure is determined by the difference between DBP and pulmonary artery occlusion pressure (PAOP) (4).

Patients with a history of uncontrolled hypertension shift their cerebral and renal perfusion autoregulation to function at the higher blood pressure levels. Consequently, too rapid a decrease in blood pressure may result in hypoperfusion of the brain and the kidneys (3). Treatment of hypertension may also affect coronary perfusion pressure and over aggressive reductions in blood pressure, especially DBP, may result in the development of myocardial ischemia (4,5).

Vasodilator infusions should be titrated to MAP as the dynamic response artifacts of intra-arterial pressure monitoring systems least affect this parameter (6). The goal of therapy during a hypertensive emergency is to lower the MAP 20-25% in the first 60 minutes with an ultimate goal of achieving a SBP < 160 mmHg and DBP 100-110 mmHg over the next 2-6 hours (2).

Within the surgical population, there are two major principles of therapy for the management of hypertension (3):

1. Patients with a history of hypertension should be continued on their home antihypertensive therapy as soon as possible after admission to the hospital to minimize the development of rebound hypertension.
2. Acute hypertension in the postoperative period, in the absence of prior history, is almost always related to pain, anxiety, agitation, or abnormalities of gas exchange or pH.

ANTIHYPERTENSIVE MEDICATION REVIEW

Angiotensin Converting Enzyme (ACE) Inhibitors: captopril, enalapril, lisinopril, and others

ACE inhibitors block the conversion of angiotensin I to angiotensin II. Angiotensin II is a potent vasoconstrictor and stimulator of aldosterone secretion. ACE inhibitors also block the degradation of bradykinin and stimulate the synthesis of other vasodilating substances including prostaglandin E2 and prostacyclin. The major hemodynamic effect of ACE inhibitors is decreased SVR due to increased compliance of large arteries. Enalaprilat, prodrug of enalapril, is the only ACE inhibitor available for intravenous administration. Adverse effects associated with the ACE inhibitors include dry cough, the development of angioedema, and a decline in renal function in patients with renal artery stenosis due to loss of the afferent-efferent pressure gradient with the blockade of angiotensin II (7-10).

Beta-Blockers: labetalol, metoprolol, and others

There are a number of different proposed mechanisms for the antihypertensive effects of the beta-blocker class. First, beta-blockers lower cardiac output through negative chronotropic and inotropic effects on the heart. Second, non-selective beta-blocker agents, such as propranolol, exert action at both beta-1 and beta-2 receptors – activity at peripheral beta-2 receptors results in peripheral vasodilatation. Third, mixed agents such as labetalol, provide alpha-1, beta-1, and beta-2 blockade with both alpha-1 and beta-2 blockade leading to peripheral vasodilatation. Of all the beta-blockers, labetalol exerts the greatest effects on blood pressure due to the alpha-1 antagonism. Major adverse events associated with beta-blocker administration include bradycardia and AV conduction abnormalities (7-9).

Calcium Channel Blockers (CCBs): amlodipine, clevidipine, nicardipine, diltiazem, and others

Calcium channel blockers cause relaxation of cardiac and smooth muscle by blocking voltage sensitive calcium channels thereby reducing the entry of extracellular calcium into the cells. Vascular smooth muscle relaxation leads to vasodilatation and a reduction in blood pressure. CCBs are classified as dihydropyridines and non-dihydropyridines. Dihydropyridines produce more peripheral vasodilatation compared to the non-dihydropyridines (including verapamil and diltiazem) which preferentially slow atrio-ventricular conduction. Clevidipine, the newest dihydropyridine CCB, is an arterial-selective vasodilator with subsequent systemic, pulmonary, and coronary vasodilatation (13). It has been primarily studied in

the pre- and post-cardiac surgery population. Nicardipine, another dihydropyridine CCB, has both arterial and venous vasodilatory properties, including cerebrovascular smooth muscle. Unlike clevidipine, nicardipine also has an oral formulation which facilitates conversion from the continuous infusion (8-13).

Central Alpha-2 Agonist: clonidine

Clonidine stimulates alpha 2 adrenergic receptors in the brain leading to a reduction in sympathetic outflow from the vasomotor center and an associated increase in vagal tone. As a consequence of the reduced sympathetic activity and some enhancement of parasympathetic activity, heart rate, CO, SVR and renin are decreased. In addition, baroreceptor reflexes are blunted. Adverse effects include sodium and fluid retention, rebound hypertension with abrupt withdrawal, sedation, and dry mouth (8,9).

Direct Vasodilators: sodium nitroprusside (SNP) and nitroglycerin (NTG)

Both SNP and NTG have direct effects on both venous and arterial smooth muscle resulting in smooth muscle relaxation and vasodilatation. While SNP exerts this effect equally, NTG has a greater effect on venous tone. Hemodynamic effects include afterload reduction (decreased SVR) and increased cardiac output (CO) in the presence of adequate preload. Preload reduction occurs due to a decrease in venous tone and reduced aortic and left ventricular impedance. It is important to remember that SNP is metabolized to cyanide and thiocyanate. Hepatic and/or renal failure can lead to accumulation of these breakdown products and the development of cyanide toxicity (2,8,9).

Dopaminergic (D1) Agonist: fenoldopam

Fenoldopam is a post-synaptic dopaminergic (D1) agonist leading to vasodilatation of peripheral arteries, renal and mesenteric vasculature. Fenoldopam lowers systemic blood pressure and peripheral vascular resistance while maintaining renal perfusion. Fenoldopam may raise intraocular pressure and intracranial pressure and should be avoided in patients with glaucoma or elevated intracranial pressure (2,7).

Peripheral Vasodilators: hydralazine and minoxidil

Similar to SNP, minoxidil causes venous and arterial smooth muscle relaxation. Hydralazine, however, is a direct arterial vasodilator and affects DBP more than SBP. Both minoxidil and hydralazine cause a decrease in SVR and subsequent reflexive tachycardia which frequently requires concomitant beta-blocker administration (2,7,14).

Peripheral Alpha-1 Blockers: doxazosin, prazosin, and terazosin

Peripheral alpha-1 blockade leads to arterial and venous vasodilatation resulting in decreased SVR and reflex tachycardia. Adverse effects include sodium and fluid retention as well as vivid dreams and depression. Additionally, these drugs exert a so-called "first-dose phenomenon" characterized by transient dizziness or faintness, palpitations, and syncope within one to three hours after the first dose. Adverse events associated with these agents can be minimized by dosing at bedtime (7,8).

LITERATURE REVIEW

There have been numerous studies conducted with the various anti-hypertensive agents. The type of agent chosen depends on a number of patient factors including age, race, pregnancy status, volume status, and the presence of end-organ disease or compromise (1). There is limited data for many of the uses of antihypertensives in the ICU. This guideline attempts to provide recommendations for some of the more common surgical critical care indications.

In 1999, Perez et al. reviewed the use of esmolol and sodium nitroprusside at their institution for heart rate (HR) and blood pressure (BP) control during transport of patients with acute aortic dissections. They conducted two separate retrospective reviews (n=119 for the first study and n-151 in the second study). Both studies found a higher percentage of patients achieved target BP and HR treated by a standardized protocol than without it (15). [Class II]

The POISE study group conducted a prospective, randomized trial comparing the effects of extended-release metoprolol 100mg po with placebo on 30-day risk of major cardiovascular events in patients undergoing non-cardiac surgery. They enrolled 8,351 patients in the trial (4,174 in the metoprolol group

and 4,177 in the placebo group). The primary outcome was the composite of cardiovascular death, non-fatal myocardial infarction (MI), and non-fatal cardiac arrest at 30 days after enrollment. The authors did identify a statistically significant decrease in overall cardiovascular events ($p = 0.0399$), this was due largely to significantly few MIs ($p = 0.0017$) in the metoprolol group. However, patients in the metoprolol group had significantly more strokes, there was a higher rate of mortality and more episodes of sepsis in the metoprolol group compared to placebo ($p < 0.05$). The authors identified clinically significant hypotension as the major risk factor for the development of stroke or death (16). [Class I]

The following table, adapted from Rhoney D, et.al, provides a select list of recommended agents based on indication (2, 7-14).

Table 1. Antihypertensive Drug Selection Recommendations.[†]

Disease State	Preferred Agent(s)	Comments
Acute aortic dissection	Esmolol	Beta-blocker is 1 st line Concomitant vasodilator therapy may be needed if SBP > 120
Acute intracerebral hemorrhage	Labetalol, Nicardipine	Use labetalol for patients with concomitant tachycardia Use nicardipine as 1 st line for spontaneous SAH
Acute myocardial infarction	Esmolol, Labetalol, Metoprolol*, Nitroglycerin	Consider nicardipine or nitroglycerin for patients with HR < 70
Diastolic hypertension	ACEI, Hydralazine, Nitroglycerin	Avoid rapid reduction as may cause cardiac ischemia
Perioperative hypertension	Clevidipine [‡] , Esmolol, Labetalol, Nicardipine, Nitroprusside	Utilize home-medications first Address other causes prior to starting therapy
Sympathetic crisis OR Catecholamine toxicity	Clevidipine [‡] , Fenoldopam, Nicardipine, Phentolamine	May require concomitant beta-blocker therapy

[†]Medications are listed in no specific order.

*Intravenous metoprolol does provide some antihypertensive activity; however, it will primarily slow the heart rate and decrease cardiac O₂ consumption

[‡]Clevidipine is currently non-formulary at Orlando Health.

Table 2. Intravenous Antihypertensive Agents (2, 7-14).

Drug	Mechanism of Action	Intermittent Dose	Continuous Infusion Dose	Maximum Dose	Onset	Duration	Comments
Clevidipine[‡] (Cleviprex™)	Dihydropyridine CCB → arterial vasodilator	N/A	1-2 mg/h Titrate: 1-2 mg/h increments	21 mg/h x 24h	2-4 minutes	5-15 minutes after infusion stopped	20% lipid emulsion Dedicated IV access required
Enalaprilat (Vasotec® IV)	ACE inhibitor	0.625-5mg IV q6	N/A	5 mg IV q6	60 minutes	4-6 hours	Caution in renal impairment
Esmolol (Brevibloc®)	Beta-1 blocker	N/A	50 mcg/kg/min Titrate: 25-50 mcg/kg/min increments	300 mcg/kg/min	1-2 minutes	10-30 minutes after infusion stopped	Central line (avoid extravasation)
Hydralazine	Direct arteriole vasodilatation	10-40mg IV q4	N/A	N/A	5-20 minutes	1-4 hours	May give q1h Reflex tachycardia Caution in TBI patients
Labetalol (Trandate®)	Alpha-1 blocker (primary) Beta-1 blocker Beta-2 blocker	10-40mg IV q4	2 mg/min Titrate: 0.5-1 mg/min increments	4 mg/min	2-5 minutes	2.5-8 hours	Primarily antihypertensive Use for cocaine-induced hypertension
Metoprolol (Lopressor®)	Beta-1 blocker	1.25-5 mg IV q6	N/A	10 mg IV q4	10-20 minutes	4-6 hours	Use for HR control not BP management
Nicardipine (Cardene® IV)	Dihydropyridine CCB → arterial vasodilator	N/A	5 mg/h Titrate: 2.5-5 mg/h increments	15 mg/h	5-15 minutes	4-6 hours	Consider in the neurosurgery patient
Nitroglycerin	Direct venous vasodilator	N/A	5 mcg/min Titrate: 5 mcg/min increments	200 mcg/min	2-5 min	5-10 min	Frequent headache, flushing
Nitroprusside (Nitropress®)	Direct arterial vasodilator	N/A	0.3-0.5 mcg/kg/min Titrate: 0.5 mcg/kg/min increments	10 mcg/kg/min	Within seconds	1-2 hours	Cyanide metabolite Avoid in renal insufficiency/failure

[‡]Clevidipine is currently non-formulary at Orlando Health.

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