Hypertension in the intensive care unit
Michel Slama\textsuperscript{a,b} and Santhi Samy Modeliar\textsuperscript{b}

**Purpose of review**
The severity of hypertensive crises is determined by the presence of target organ damage rather than the level of blood pressure. Hypertensive urgencies with no signs of organ dysfunction can therefore be distinguished from hypertensive emergencies in which the presence of severe end-organ damage requires prompt therapy. Hypertensive emergencies include acute aortic dissection, hypertensive encephalopathy, acute myocardial ischaemia, severe pulmonary oedema, eclampsia, and acute renal failure.

**Recent developments**
Malignant hypertension is a severe form of hypertensive emergency demanding special consideration because of the risks of permanent blindness and renal failure. Catecholamine excess and postoperative hypertension may also sometimes require urgent treatment. The management of patients with hypertensive emergencies must be ensured in an intensive care unit, and must include the parenteral administration of antihypertensive drugs and accurate blood pressure monitoring.

**Summary**
Except for acute aortic dissection, the recommended goals of treatment are a reduction of mean arterial pressure by no more than 20\% during the first few hours, because an abrupt fall in blood pressure in patients with preexisting hypertension may induce severe ischaemic injury in major organs as a result of the chronic adaptation of autoregulation mechanisms. Hypertension in the context of acute stroke should be treated only rarely and cautiously because of the presence of impaired autoregulation.

**Keywords**
antihypertensive therapy, hypertensive crisis, hypertensive emergency, hypertensive encephalopathy, hypertensive urgency, malignant hypertension

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**Introduction**
Severe hypertension is a common clinical problem in the intensive care unit (ICU). The Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure recently classified hypertension according to the degree of blood pressure elevation. Stage 1 patients have systolic blood pressure (SBP) of 140–159 mmHg or diastolic blood pressure (DBP) of 90–99 mmHg. Stage 2 patients have SBP of 160–179 mmHg or DBP of 100–109 mmHg, whereas stage 3 corresponds to SBP of 180 mmHg or greater or DBP of 110 mmHg or greater. Stage 3 hypertension has also been called severe hypertension or accelerated hypertension [1].

Although various terms have been applied to severe hypertension, such as hypertensive crises, emergencies, or urgencies, they are all characterized by acute elevations in blood pressure that may be associated with end-organ damage.

Various clinical situations should be distinguished [2]: hypertensive urgency, in which severe hypertension is isolated without any end-organ damage; most authorities have defined hypertensive emergencies as a sudden increase in SBP and DBP associated with `acute end-organ damage` (i.e. cardiovascular, renal, central nervous system) that requires immediate management. Situations that qualify as hypertensive emergencies include hypertensive encephalopathy, acute left ventricular failure, acute aortic dissection, pheochromocytoma crisis, interaction between tyramine-containing foods or drugs and monoamine oxidase inhibitors, eclampsia, drug-induced hypertension and possibly intracranial haemorrhage; malignant hypertension is characterized by elevated blood pressure accompanied by encephalopathy or acute nephropathy. This term has, however, been removed from international blood pressure control guidelines, and this condition is best referred to as a hypertensive emergency (Fig. 1).

**Epidemiology: pathophysiology**
Before the advent of antihypertensive therapy, hypertensive emergencies occurred in up to 7\% of the hypertensive population. At the present time, approximately 1\% of patients with hypertension develop a hypertensive crisis at some point during their lives. The epidemiology of hypertensive urgency or hypertensive emergency in medical ICUs has not been clearly defined, but appears to be frequent [3]. Elevated blood pressure may be related to pain, discontinuation of anaesthetic drugs and the...
recovery period, discontinuation of antihypertensive drugs, urinary bladder distension, hypercapnia, acidosis, hypoglycaemia, psychogenic noise or light stress, and any nursing care (venous or arterial puncture, patient mobilization, tape change, tracheal tube mobilization; Table 1). Limited information is available concerning the postoperative setting. Postoperative hypertension has been reported to occur in 4–35% of patients shortly after the surgical procedure [4–6]. Like other forms of accelerated hypertension, patients with postoperative hypertensive crisis usually have a history of poorly controlled hypertension. Coronary artery bypass graft surgery, operations requiring clamping of the aorta and carotid artery surgery are frequently followed by hypertensive crisis during the immediate postoperative period [7]. The risk of postoperative hypertensive crisis is partly related to adrenergic stimulation occurring before, during and after the operation in both previously hypertensive and non-hypertensive patients [4]. The other identified aetiologial factors are renin–angiotensin system disorders, baroreceptor dysfunction [8] or the interruption of centrally acting antihypertensive therapy [9]. Blood pressure elevation, even minor, can compromise the integrity of vascular sutures. Illicit drug use has also been reported to be a major risk factor for the development of hypertensive emergency [10,11].

Pregnancy-related hypertension (pre-eclampsia) is a form of hypertension that deserves special mention. Pre-eclampsia occurs in approximately 7% of all pregnancies, but the incidence varies according to the patient population, as 70% of patients with pre-eclampsia are nulliparous whereas only 30% are parous [12–14]. Renal failure appears to be the more frequent cause of malignant hypertension (80% of cases). Malignant hypertension can occur in patients with or without a history of hypertension. As a result of therapeutic progress, the prognosis of patients with malignant hypertension is now very similar to that of patients with uncomplicated primary hypertension [15]. The pathophysiology of malignant hypertension has not been fully elucidated. The onset of malignant hypertension appears to depend on an acute elevation of blood pressure related to sudden vasoconstriction, mainly via activation of the renin–angiotensin–aldosterone system [16]. Angiotensin II is

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**Figure 1 Acute hypertensive crisis classification**

**Table 1 Aetiology of blood pressure elevation**

<table>
<thead>
<tr>
<th>Aetiology of blood pressure elevation in a well-known hypertensive patient</th>
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<tbody>
<tr>
<td>Renovascular hypertension</td>
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<tr>
<td>Renal parenchyma lesion</td>
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<tr>
<td>Scleroderma, vasculitis, Collagene disease</td>
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<tr>
<td>Ingestion of cocaine, amphetamine, LSD</td>
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<tr>
<td>Interruption of an antihypertensive treatment</td>
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<tr>
<td>Pre-eclampsia and eclampsia</td>
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<tr>
<td>Phaeochromocytoma</td>
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<tr>
<td>Glomerulonephritis</td>
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<tr>
<td>Cranial traumatism</td>
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<td>Renin-secreting tumour</td>
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HTA, arterial hypertension.
responsible for direct cytotoxic effects on vascular endothelium, partly by activation of genes coding for proinflammatory cytokines or by activation of the transcription of nuclear factor kappa B. When hypertension is severe and prolonged, compensatory mechanisms, such as the endothelial release of vasodilator substances such as nitric oxide, are no longer sufficient and endothelial dysfunction may be observed. Mechanisms such as the activation of proinflammatory mediators induced by the mechanical distortion of blood vessels, an increase in endothelial calcium, the release of endothelin or overexpression of adhesion molecules, participate in endothelial dysfunction. These various molecular events increase endothelial permeability, inhibit local fibrinolytic activity and activate the clotting cascade, resulting in the perpetuation of local inflammation, the formation of arteriolar microthromboses and the loss of normal autoregulation mechanisms. This leads to a risk of local vasostenosis and ischaemia creating a vicious cycle that must be controlled by treatment.

**Clinical manifestations of hypertensive crises**

First, blood pressure must be measured correctly. The auscultatory method of blood pressure measurement using a properly calibrated and validated instrument should be used. The patient’s arm should be placed level with the heart. An appropriate-sized cuff (cuff encircling at least 80% of the arm) should be used to ensure accurate measurements. In the ICU, blood pressure measurements should be repeated 5–10 min after the first measurement.

**Hypertensive urgency**

Triggering factors or events must be identified: the interruption of treatment comprising a centrally acting antihypertensive drug can be the cause of the hypertensive crisis (rebound effect); other triggering factors are also possible: anxiety, pain, urinary retention, hypercapnia, acidosis, hypoglycaemia, the use of cocaine or medications reducing the efficacy of antihypertensive treatment (non-steroidal anti-inflammatory drugs, gastric preparations). Control of the triggering factor allows the restoration of normal blood pressure [9,17].

**Malignant hypertension**

In malignant hypertension [18], the patient is admitted to the ICU for pulmonary oedema, myocardial ischaemia or neurological signs (Table 2). Blood pressure is high (usually DBP > 130 mmHg) and is associated with severe hypertensive retinopathy (haemorrhages, exudates or even papilloedema). Clinical interview reveals recent alteration of the general status, weight loss and intense thirst related to hypovolaemia secondary to polyuria induced by increased sodium excretion. The patient must be managed in the ICU, where treatment with intravenous vasodilators often associated with fluid resuscitation will be rapidly instituted. The prognosis is determined by the development of malignant renal nephroangiosclerosis, characterized histologically by fibrinoid necrosis predominantly involving afferent arterioles and interlobular arteries. Acute renal failure, facilitated by hypovolaemia, is often associated with thrombotic microangiopathy comprising thrombocytopaenia and haemolytic anaemia with schizocytosis and negative Coombs’ test. Renal function can initially deteriorate during treatment, but subsequently improves when the blood pressure control is maintained [19]. Patients requiring haemodialysis may sometimes recover sufficient renal function after several months of treatment to allow the discontinuation of dialysis.

**Hypertensive emergencies**

The following are examples of hypertensive emergencies [20]:

**Hypertensive encephalopathy**

Hypertensive encephalopathy presents clinically with a sudden elevation of blood pressure, increasingly severe headache, nausea, vomiting and visual disorders. The patient can rapidly become confused, with impaired consciousness. Localized or generalized seizures may be the first or the most prominent clinical features [21]. These symptoms usually appear progressively over 24–48 h, which distinguishes hypertensive encephalopathy from intracranial haemorrhage. The symptoms of encephalopathy resolve when blood pressure is lowered, but, in the absence of treatment, encephalopathy can progress to coma that can be rapidly fatal. Hypertensive encephalopathy can occur with or without proteinuria or retinopathy. A normal ocular fundus examination therefore does not exclude a diagnosis of hypertensive encephalopathy. A brain computed tomography scan can exclude intracerebral haemorrhage. The electroencephalogram may show loss of the predominant posterior alpha rhythm, generalized slowing of the electrical activity, as well as posterior epileptic discharges. Hypertensive encephalopathy can occur in a patient with chronic, often essential hypertension, and may be accompanied by features of malignant hypertension, but it can also occur in previously healthy patients who develop a sudden increase in blood pressure. Hypertensive encephalopathy

<table>
<thead>
<tr>
<th>Table 2 Malignant hypertension aetiology</th>
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<tr>
<td>Essential arterial hypertension</td>
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<tr>
<td>Renal parenchyma lesion</td>
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<tr>
<td>Renovascular hypertension</td>
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<tr>
<td>Endocrinial disease: phaeochromocytoma, Conn’s syndrome, Cushing’s disease</td>
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<tr>
<td>Drugs and medicine: cocaine, discontinuation of antihypertensive drugs, erythropoietin, cyclosporine therapy, non-specific monoamine oxidase inhibitors, amphetamine</td>
</tr>
<tr>
<td>Aorta coarctation</td>
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<td>Eclampsia and pre-eclampsia</td>
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may therefore be observed in a context of acute glomerular nephropathy, eclampsia, thrombocytopenic thrombotic purpura, pheochromocytoma, or treatment with immunosuppressive drugs [22], erythropoietin or cyclosporin. Hypertensive encephalopathy is secondary to cerebral hyperperfusion, inducing endothelial dysfunction with increased microvascular permeability predisposing to cerebral oedema [16]. Magnetic resonance imaging has demonstrated posterior, predominantly parieto-occipital, leukoencephalopathy that is potentially reversible after rapid and effective treatment. Autopsy studies have demonstrated cerebral oedema and arterio-alveolar lesions in the form of fibrinoid necrosis and fibrin thrombi associated with micro-infarctions [23]. The characteristic events of hypertensive encephalopathy occur when the mechanisms of cerebral autoregulation are no longer able to compensate. Under normal conditions, cerebral autoregulation maintains a constant cerebral blood flow for mean arterial pressure (MAP) variations between 70 and 150 mmHg. The brain can compensate for blood pressure elevations within these limits by activating vasoconstriction mechanisms, which limit hyperperfusion. In hypertensive subjects, the autoregulation thresholds are higher so that cerebral blood flow is maintained constant for a MAP between 120 and 180 mmHg, thereby protecting the hypertensive subject’s brain from high blood pressure. Vasodilatation and cerebral oedema occur when these autoregulation mechanisms fail. Non-hypertensive subjects can develop hypertensive encephalopathy for lower blood pressure values than chronic hypertensive patients with higher autoregulation thresholds.

**Acute aortic dissection**

This diagnosis should be considered in any patient complaining of chest pain, back pain or abdominal pain, associated with high blood pressure. Clinical examination may reveal asymmetric pulses or blood pressure, avascular murmur, an aortic incompetence murmur, or signs of cerebral or limb ischaemia. Chest X-ray can sometimes suggest the diagnosis by revealing widening of the mediastinum, but the two reference examinations are chest computed tomography angiography and transoesophageal echocardiography [24]. Aortography is only performed when the images provided by these two modalities are difficult to interpret [25]. Magnetic resonance imaging is a very useful diagnostic modality, but is generally not readily available in the emergency setting.

**Acute coronary ischaemia: angina and myocardial infarction**

Myocardial ischaemia may be accompanied by a hypertensive crisis. This blood pressure elevation is largely related to the stress of pain. A reflex mechanism initiated in the ischaemic left ventricle has also been suggested [26]. The increased impedance to systolic ejection represented by the sudden elevation of SBP results in increased myocardial stress and a subsequent increase in myocardial oxygen consumption, which tends to accentuate ischaemia.

**Acute pulmonary oedema**

An episode of acute heart failure with acute pulmonary oedema can be accompanied by a hypertensive crisis, which obviously constitutes a causative or aggravating factor for acute pulmonary oedema because of the considerably increased impedance to left ventricular ejection.

**Pre-eclampsia and eclampsia**

Hypertension of pregnancy is defined as SBP greater than 140 mmHg or DBP greater than 90 mmHg. It is considered to be severe for DBP greater than 110 mmHg. Hypertension may be present before pregnancy or may appear after the twentieth week of pregnancy (hypertension of hypertension).

Pre-eclampsia (approximately 3% of pregnancies) [13] is defined by the combination of hypertension (pre-existing or hypertension of hypertension) and proteinuria (> 300 mg/day). Oedema is also frequently present. In the context of the HELLP syndrome (haemolysis elevated liver enzyme and low platelets), hypertension may also be associated with abnormal liver function tests and platelet counts. Predisposing factors for pre-eclampsia are primiparity, very young or very old maternal age, family predisposition, twin pregnancies, molar pregnancy, diabetes, lupus and essential hypertension. The pathophysiology of pre-eclampsia is poorly elucidated. Defective placental implantation of the trophoblast appears to induce an elevation of placental vascular resistance, followed by local immunological abnormalities responsible for endothelial dysfunction and disseminated intravascular coagulation. This leads to failure of the cardiovascular adaptive mechanisms, characteristic of normal pregnancy, resulting in an increase of systemic vascular resistance.

Severe pre-eclampsia can lead to eclampsia, associated with visual disorders, generalized seizures, oliguria and sometimes congestive heart failure or stroke. Seizures are often preceded by precursor signs: headache, abdominal pain, brisk deep tendon reflexes and haemoconcentration. Eclampsia can be fatal to the mother in the absence of treatment.

**Renal failure**

Acute renal failure is both a cause and a consequence of hypertension. Diseases such as acute glomerulonephritis, vasculitis or renal artery stenosis can be responsible for both acute renal failure and hypertension. Severe hypertensive crises can lead to acute renal failure, therefore corresponding to the definition of hypertensive emergency, or may worsen pre-existing renal failure.
Hypertension is the main cardiovascular complication of chronic renal failure. In this setting, high blood pressure is caused by increased extracellular volume and vasoconstriction secondary to activation of the renin–angiotensin system. Haemodialysis patients, particularly those receiving erythropoietin, are often hypertensive. Renal transplant recipients can present with hypertension resulting from various causes: graft renal artery stenosis, renin secretion by the native kidney, corticosteroid and cyclosporin therapy [22].

Catecholamine excess
Causes of catecholamine excess include phaeochromocytoma, autonomic nervous system dysfunction, such as Guillain–Barré syndrome, sudden withdrawal of centrally acting antihypertensive drugs and overdoses with certain medications or other substances. Treatment with non-specific monoamine oxidase inhibitors associated with the ingestion of tyramine-rich foods (fermented cheese, beers, chicken liver, avocado, banana, chocolate, etc.) can also lead to catecholamine excess.

These hypertensive crises can simply consist of an acute rise in blood pressure or may be accompanied by end-organ damage requiring rapid treatment.

Phaeochromocytoma can induce severe hypertension, usually paroxysmal, but sometimes permanent. The paroxysmal episode is usually accompanied by the classic triad: pulsatile headache, sweating and palpitations. The associated presence of orthostatic hypotension is highly suggestive. Hypertensive crises are often provoked by certain events (abdominal palpation, emotion, sudden change of position, foods containing tyramine, etc.). In addition to the risks related to any form of hypertensive crisis, catecholamine excess is associated with a risk of sudden death from cardiac arrhythmias or cardiovascular collapse as a result of adrenergic shock. Urinary metanephrine assay is a very reliable test to confirm the diagnosis.

Postoperative hypertensive crisis
A postoperative hypertensive crisis occurs in 5–75% of patients during the early postoperative period (approximately 2–6 hours after surgery) [4].

Stroke
Strokes [21,27], regardless of their aetiology, are almost systematically accompanied by an elevation of blood pressure by at least 10%, as ischaemic and haemorrhagic stroke both modify autoregulation mechanisms via vasoactive substances released from the site of injury. Cerebral perfusion of the penumbra zones (adjacent to the lesion) then becomes directly dependent on blood pressure. The blood pressure elevation observed during the acute phase of stroke could be a reflex physiological response designed to maintain adequate cerebral perfusion, and hypertension has never been demonstrated to have a negative impact on the course of ischaemic stroke. Furthermore, even in the absence of antihypertensive therapy, blood pressure gradually decreases spontaneously over a period of 10 days after the stroke. This type of stroke is mainly observed in previously hypertensive patients who, even when they are already being treated, have high upper and lower autoregulation thresholds, probably ensuring protection of their brain against the effects of chronic hypertension. The fact that these patients have a high probability of atheromatous stenoses of blood vessels supplying the brain further increases the risk of cerebral hypoperfusion in response to antihypertensive therapy.

Therapeutic management
The following provide details of therapeutic management strategies for hypertensive crises and hypertensive emergencies.

Hypertensive crisis
Note that an acute hypertensive crisis with no signs of end-organ damage does not require immediate treatment [28]. The rest and control of predisposing factors usually allow blood pressure values to return to normal. Re-evaluation of long-term treatment should subsequently be considered in a known hypertensive patient. In an individual with no known history of hypertension, oral antihypertensive therapy may be initiated after resolution of the acute episode if the presence of true hypertension is confirmed and after performing an assessment of the aetiology and complications of hypertension and the cardiovascular risk factors. In the rare cases in which high blood pressure values (SBP > 210 mmHg or DBP > 120 mmHg) persist despite the rest and control of predisposing factors; some authors recommend the urgent initiation of oral antihypertensive therapy, even in the absence of any end-organ damage [29].

Hypertensive emergencies
A hypertensive crisis associated with signs of end-organ damage constitutes a therapeutic emergency [30]. However, extreme caution is advised when treating a hypertensive crisis in the context of stroke.

Hypertensive emergencies should be treated in an ICU, allowing simultaneous control of the various factors predisposing to high blood pressure (anxiety, pain, hypoxia, hypercapnia, hypoglycaemia, etc.) and intravenous antihypertensive therapy. Intra-arterial blood pressure monitoring may also be required when using certain antihypertensive drugs.

The objective of treatment is not to achieve immediate correction of blood pressure, but rather to lower blood
pressure to a certain level of security, as sudden blood pressure reduction is often more dangerous than hypertension itself, particularly in patients whose autoregulation mechanisms are already adapted to chronic hypertension, or in those with risk factors for arteriosclerosis or in elderly patients, as an excessively rapid reduction of blood pressure can induce serious ischaemic accidents, such as cortical blindness, hemiplegia, myocardial infarction, acute renal failure, etc. Consequently, when treating a hypertensive emergency, most experts recommend that MAP should not be lowered by more than 20% over a period of several minutes to several hours. In particular cases, however, such as aortic dissection, when MAP must be lowered by more than 20%, very close neurological monitoring is essential to detect the first signs of cerebral hypoperfusion, such as nausea, headache, confusion, psychomotor slowing or agitation. Antihypertensive therapy must be effective within 1 h, except in the case of aortic dissection, in which blood pressure control must be achieved within 10 min.

The drugs proposed for the treatment of a hypertensive emergency must satisfy a number of criteria: be able to be used by intravenous injection, rapid onset of action, and easily titrated with a short half-life allowing more flexible use. The use of these drugs is sometimes limited by their adverse effects. The sublingual administration of antihypertensive drugs, once very popular, is now formally contraindicated, as it can induce severe hypotensive episodes that are difficult to control [18]. In the presence of concomitant hypovolaemia (malignant hypertension), plasma expansion may be necessary, especially as the use of a vasodilator drug with venous vasodilator effects can decrease ventricular filling leading to severe collapse, emphasizing the need for haemodynamic monitoring when initiating treatment [18]. When blood pressure is controlled, intravenous therapy can be replaced by oral therapy.

Drugs
The following is a list of drugs proposed for the treatment of a hypertensive emergency [28,32,33*]:

Nicardipine
Nicardipine is a calcium antagonist belonging to the dihydropyridine family. It is an arterial vasodilator with no negative inotropic activity. As a result of its rapid onset of action, its ease of use (dosage independent of body weight) and its demonstrated efficacy, nicardipine has become the first-line treatment for hypertensive emergencies. Its marketing authorization allows it to be used in the following situations: all hypertensive emergencies, perioperative hypertension, and controlled hypotension during anaesthesia. Its adverse effects are related to reflex tachycardia, requiring particular caution in patients with coronary heart disease or presenting with a risk of gastrointestinal bleeding.

Urapidil
Urapidil [34,35] is a peripheral α1 postsynaptic receptor antagonist as well as a central 5-hydroxytryptamine 1A receptor agonist. Its vasodilatory action is not accompanied by reflex tachycardia or any significant modification of the renin–angiotensin system. Urapidil decreases both cardiac preload and afterload and also induces selective pulmonary and renal vasodilatation. Urapidil has a good safety profile and its only single contraindication is aortic stenosis. Its current indications are hypertensive emergencies and perioperative hypertension.

Labetalol
Labetalol is an alpha and beta blocker with a recognized value in the majority of hypertensive emergencies except for acute heart failure. It has the advantage of maintaining cardiac output and cerebral and coronary blood flow, and is associated with good clinical safety, provided the usual contraindications of beta-blockers are observed.

Sodium nitroprusside
Sodium nitroprusside [36] is an arterial and venous vasodilator inducing a simultaneous reduction in cardiac preload and afterload, making it particularly useful in the treatment of hypertensive crisis accompanied by heart failure. Its advantages are its rapid action and its short half-life.

It possesses a number of disadvantages, however: by increasing intracranial pressure, it decreases the cerebral flow rate; by inducing a coronary steal phenomenon, it can induce a significant reduction in coronary perfusion. This effect probably explains why nitroprusside, administered several hours after myocardial infarction complicated by heart failure, was associated with increased mortality in a randomized placebo-controlled trial. The other adverse effects described with nitroprusside are ototoxicity and an increased intrapulmonary shunt. The main limitation to the use of nitroprusside is its toxicity, as nitroprusside is metabolized into cyanide, which is then converted in the liver into thiocyanate, a metabolite eliminated by the kidney and one hundred times less toxic than cyanide. In patients with renal or hepatic insufficiency, there is therefore a high risk of cyanide poisoning, which, by interfering with cellular respiration, can lead to the development of irreversible neurological lesions and, in extreme cases, cardiac arrest. Blood thiocyanate assays are not sufficiently sensitive to detect the early signs of toxicity. Continuous infusion of hydroxocobalamin can prevent or treat nitroprusside toxicity.

Nitroprusside, a reference antihypertensive drug for a long time, is now less widely used as first-line treatment.
because of its adverse effects and the availability of medicinal products that are easier to use. It can still be used, however, in very severe hypertensive emergencies, especially hypertensive encephalopathy and in the presence of heart failure.

Nitrate: nitroglycerin and isosorbide dinitrate
Nitrate are mixed vasodilators with predominantly venous effects decreasing cardiac preload. They induce reflex tachycardia and decrease cardiac output. They are indicated in myocardial ischaemia.

Furosemide and bumetanide
These loop diuretics are only indicated in the presence of signs of circulatory overload, particularly pulmonary oedema. Their major adverse effect is hypokalaemia.

Esmolol
Esmolol [37,38] is a cardioselective beta-blocker with a rapid onset of action (1 min) and a brief duration of action (10–20 min). Its advantages include a rate-slowing effect on supraventricular tachycardias and its metabolism, which is independent of liver and kidney function. It is useful for the treatment of perioperative hypertensive crises, but it is not recommended in the case of catecholamine excess, as persistent alpha stimulation induces vasoconstriction leading to the accentuation of hypertension.

Antihypertensive drugs no longer used in hypertensive emergencies
Hydralazine injection has been withdrawn from the market. Phentolamine, clonidine, diazoxide and nifedipine (by sublingual administration) are no longer part of the treatment options for hypertensive emergency.

Other available agents
Fenoldopam is a DA1 dopaminergic agonist inducing vasodilatation and sodium excretion without a1 or b1 activation. It can be used in all hypertensive emergencies, particularly in patients with renal insufficiency. Enalaprilat, a parenteral angiotensin-converting enzyme inhibitor, is particularly indicated in the case of heart failure.

Particular indications
Particular indications for treatments in the following emergencies are given.

Hypertensive encephalopathy
For all of the reasons indicated above, MAP must not be lowered by more than 20% during the first hour, with a target DBP of 100–110 mmHg.

Aortic dissection
Aortic dissection [39] is associated with a high mortality rate, and must therefore be managed as an extreme emergency in the ICU. The objective of medical treatment is to achieve an SBP lower than 100–110 mmHg rapidly, not just to lower blood pressure, but also to reduce the force of pulsatile flow on the aortic wall to limit the extension of the intimal tear. When the diagnosis is strongly suspected, a lowering of blood pressure may be justified even before confirmation of the diagnosis. Although type A aortic dissections (involving the ascending aorta) require a surgical opinion, type B aortic dissections (dissection arising after the origin of the left subclavian artery) can often be treated medically. Labetalol alone or a combination of a beta-blocker (esmolol, labetalol) and a vasodilator (nicardipine, urapidil, or even sodium nitroprusside) are indicated in this context.

Myocardial infarction
The treatment of myocardial infarction comprises the use of beta-blockers except when they are contraindicated. In case of a hypertensive crisis not controlled by beta-blockers, the use of nitrates is justified. Morphine is an effective adjuvant treatment. Pure vasodilators are not indicated. Thrombolysis can be performed once SBP has been decreased to less than 180 mmHg, but DBP must be maintained above 80 mmHg to avoid compromising coronary perfusion.

Cardiogenic acute pulmonary oedema
The first-line treatment of acute pulmonary oedema is based on nitrates and loop diuretics depending on the patient’s hydration status. If these treatments are not sufficiently effective, urapidil, nicardipine or even nitroprusside can be used.

Pre-eclampsia and eclampsia
A woman with pre-eclampsia should be admitted to hospital to determine the indication for the induction of labour when she is close to term [13]. Watchful waiting with very close maternal and foetal monitoring is now the standard management before 37 weeks of amenorrhoea. Delivery is usually essential, regardless of the gestational age, when severe hypertension persists for more than 48 h despite treatment or in the case of decreased platelet count, elevation of transaminases, renal failure, signs of foetal distress or precursor signs of eclampsia.

In the case of eclampsia, antihypertensive treatment is indicated for SBP greater than 180 mmHg, DBP greater than 110 mmHg or when hypertension is life-threatening to the mother. However, DBP should be maintained above 90 mmHg to ensure uteroplacental perfusion. The drugs recommended in this setting are labetolol, urapidil or nicardipine. The hypotensive effects of calcium antagonists can, however, be dangerously potentiated by magnesium sulphate [14], a treatment that has been demonstrated to be more effective than phenytoin or diazepam to prevent or treat seizures of eclampsia.
Foetal extraction is indicated as soon as blood pressure has been stabilized.

Phaeochromocytoma and catecholamine excess
The first-line treatments for catecholamine excess are urapidil and nicardpine, but nitroprusside is also a possible alternative. Pure beta-blockers are contraindicated in catecholamine excess because of the risk of paradoxical hypertension secondary to increased vasoconstriction. Cocaine can induce coronary vasoconstriction, justifying the use of nitrates. Nicardpine can be used in severe hypertensive crises, but beta-blockers are contraindicated. Benzodiazepines are a frequently effective adjuvant therapy.

Postoperative hypertensive crisis
Intraoperative and postoperative hypertension is essentially caused by adrenergic mechanisms. Various agents can be used: nicardpine, sodium nitroprusside, urapidil, esmolol or labetalol. Nicardpine, although widely used, can be responsible for perioperative bleeding.

Stroke
The physiological blood pressure equilibrium should not be modified in the case of stroke in order to avoid inducing a supplementary iatrogenic ischaemic stroke. A SBP between 180 and 190 mmHg and a DBP between 100 and 120 mmHg are therefore perfectly acceptable [40,41]. Antihypertensive therapy, with progressive and controlled blood pressure reduction by not more than 25% of the initial level, is only indicated when stroke is associated with aortic dissection, myocardial ischaemia or DBP greater than 120 mmHg. The drugs recommended in this situation are labetalol and urapidil. In the case of intracerebral haemorrhage, which almost always induces an elevation of intracranial pressure and an alteration of the autoregulation system [23] in zones surrounding the lesion, reflex elevation of systemic blood pressure maintains cerebral perfusion pressure, which is equal to the difference between MAP and intracranial pressure. It appears more logical, in this situation, to reduce intracranial pressure medically, or even surgically, rather than directly decrease systemic blood pressure in order to restore satisfactory cerebral perfusion. It has also been demonstrated that a rapid reduction of blood pressure increases the mortality rate of cerebral haemorrhage. Subarachnoid haemorrhage is associated with a risk of intracerebral haemorrhage or acute hydrocephalus when SBP is greater than 160 mmHg or when MAP is greater than 110 mmHg. If one of these complications is already present, a reduction in MAP can be deleterious for the reasons indicated above. In the absence of such complications, stroke does not induce any additional alteration of cerebral autoregulation. However, antihypertensive therapy must be very carefully controlled, as there is a considerable risk of vasospasm after the first 48 h. Blood pressure should be controlled in a specialized unit, guided by transcranial Doppler. Nimodipine, a dihydropyridine antihypertensive drug that prevents vasospasm, would be useful in this setting.

Conclusion
Severe hypertension is frequent in the ICU. In contrast, an emergency defined as visceral failure associated with hypertension is rare. In these cases both organ failure and hypertension should be treated.

References and recommended reading
Papers of particular interest, published within the annual period of review, have been highlighted as:
• of special interest
•• of outstanding interest
Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 407).

8 A study suggesting that the haemodynamic effects of the three drugs are similar within the first 30 min, and that after 30 min, diltiazem affords better myocardial performance and more effective control of hypertension.