Postprandial Hypotension: Epidemiology, Pathophysiology, and Clinical Management
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Objective: To show the clinical relevance of postprandial hypotension and to review its pathophysiology and management.
Data Sources: Articles on postprandial hypotension were identified through MEDLINE and bibliographies of relevant articles.
Study Selection: All articles and case reports describing meal-related hypotension in the elderly and in patients with autonomic failure.
Data Synthesis: Postprandial hypotension, defined as a decrease in systolic blood pressure of 20 mm Hg or more, may result in syncope, falls, dizziness, weakness, angina pectoris, and stroke. Postprandial hypotension is distinct from and probably more common than orthostatic hypotension. Because meal-related hypotension is particularly common in older hypertensive patients, it has important implications for the evaluation and management of hypertension. The mechanism of postprandial hypotension is not fully understood. Possible contributors include inadequate sympathetic nervous system compensation for meal-induced splanchnic blood pooling; impairments in baroreflex function; inadequate postprandial increases in cardiac output; and impaired peripheral vasoconstriction, insulin-induced vasodilation, and release of vasodilatory gastrointestinal peptides. Although caffeine is often recommended as treatment for postprandial hypotension, available data do not support its use. Octreotide, a somatostatin analog, has been shown to be effective, but it is expensive and must be given parenterally.
Conclusion: All physicians caring for elderly patients should be aware of the hypotensive effects of food intake and should consider postprandial hypotension in the evaluation of syncope, falls, dizziness, and other cerebral ischemic symptoms.

Postprandial hypotension was first recognized as a clinical problem in 1977 in a patient with Parkinson disease (1). However, the hypotensive effect of meal ingestion has been appreciated for a longer time. In 1935, Gladstone (2) described a hypertensive patient who had had a postprandial decrease in blood pressure from 185/120 mm Hg to 145/80 mm Hg. In 1953, Smirk (3) observed a decrease in blood pressure after patients with autonomic failure ingested food. Robertson and colleagues (4) confirmed these results in patients with chronic autonomic failure and found an average decrease in systolic blood pressure of 49 ± 6 mm Hg after a meal (4). Since Lipsitz and colleagues (5) first described it in nursing home residents a decade ago, postprandial hypotension has become recognized as a common disorder of blood pressure regulation in the elderly (5).

Our current understanding of postprandial hypotension is limited by the lack of a standardized, clinically meaningful definition. Analogous to orthostatic hypotension, postprandial hypotension is commonly defined in the literature as a decrease in systolic blood pressure of 20 mm Hg or more within 2 hours of the start of a meal. Postprandial hypotension also develops when the absolute level of systolic blood pressure after a meal decreases to less than 90 mm Hg and when the systolic blood pressure before a meal is greater than 100 mm Hg. In addition, if a meal-related decrease in systolic blood pressure exceeds the threshold for cerebral autoregulation, patients may become symptomatic when the absolute systolic blood pressure level exceeds 90 mm Hg or when the postprandial systolic blood pressure decreases to less than 20 mm Hg. The frequent absence of symptoms associated with this decrease in blood pressure after meal ingestion makes the value of this definition uncertain. In addition, the morbidity and mortality related to postprandial hypotension are unknown. A potential cumulative effect of multiple hypotensive stresses, such as posture change or administration of medication at the time of meal ingestion, makes assessment of the clinical relevance of individual blood pressure responses to a meal even more difficult. Although it can be exacerbated by posture change, postprandial hypotension is a distinct entity that differs from orthostatic hypotension.

We have reviewed the current knowledge of the epidemiology, clinical symptoms and significance, pathophysiology, and management of postprandial hypotension. We hope to make the practicing physician more aware of this common abnormality in blood pressure regulation and to stimulate new research of its mechanisms and management.

Methods

Through a MEDLINE search, we identified all articles on postprandial hypertension published between 1966 and 1994. We
also used the bibliographies of relevant articles. All articles and case reports describing meal-related hypotension in the elderly and in patients with autonomic failure were included for analysis.

Epidemiology and Associated Conditions

During the past decade, hypotension in response to ingestion of a mixed meal or oral glucose has been shown in healthy elderly persons (6–14); young and elderly persons with hypertension (10, 15–21); elderly patients in nursing homes (5, 22–25); and patients with postprandial syncope (26, 27), autonomic insufficiency (4, 28–36), Parkinson disease (1, 37–39), paraplegia (40), diabetes mellitus (28, 38, 41), cardiovascular disease (42, 43), and renal failure treated with hemodialysis (44, 45). However, the epidemiology of postprandial hypotension has not been thoroughly studied.

Mild, meal-induced decreases in blood pressure are common in healthy older persons (6–11), but the prevalence of these decreases is unknown. The presence of multiple illnesses in elderly persons may further impair cardiovascular adaptation to meal ingestion and result in marked postprandial decreases in blood pressure. Investigations of elderly persons living in nursing homes have shown that nearly all persons experience some decrease in blood pressure (24, 25). In 24% to 36% of these patients, systolic blood pressure decreases more than 20 mm Hg within 75 minutes of eating a meal (24, 25).

It has been difficult to dissociate the effects of physiologic aging on postprandial blood pressure regulation from those of age-associated illnesses. The elevation in blood pressure associated with aging can profoundly influence postprandial blood pressure. In a study of 82 healthy persons aged 19 to 79 years, meal-related reductions in supine systolic and diastolic blood pressure were significantly correlated. However, when the data were corrected for baseline blood pressure, this correlation was no longer seen (46). Older hypertensive persons have greater reductions in blood pressure after ingesting food or oral glucose than do age-matched normotensive persons (7, 9, 10, 17–20). Postprandial decreases in systolic blood pressure ranging from 17 to 25 mm Hg have been found in hypertensive elderly patients older than age 65 years who did not have other overt cardiovascular diseases (9, 10, 17, 18). In these patients, diastolic blood pressure may decrease as much as 15 mm Hg. However, because hypertensive middle-aged and young persons also have postprandial decreases in blood pressure (10, 16), this phenomenon may be primarily caused by blood pressure elevation rather than by aging itself.

Profound postprandial hypotension has been observed in patients with autonomic failure (1, 4, 28–36, 47, 48). The first case report described a 65-year-old man who had dizziness and visual disturbance associated with large decreases in blood pressure after almost every meal (1). Robertson and colleagues (4) found a marked postprandial decrease in sitting systolic blood pressure (range, 22 to 98 mm Hg) in 10 patients with autonomic failure. Hoeldtke and associates (28, 47) studied patients with multiple-system atrophy (the Shy-Drager syndrome) and pure autonomic failure and found that the decrease in the mean sitting postprandial arterial blood pressure ranged from 62 to 83 mm Hg (28, 47). All of these patients had blurred vision and dizziness after the meal (47). Postprandial hypotension is also commonly found in patients with peripheral neuropathy caused by diabetes mellitus or other disorders (28, 33, 38, 41) as well as by Parkinson disease (1, 37–39). Hypotension is a common side effect of antiparkinsonian drugs such as levodopa. In patients with renal failure, symptomatic postprandial hypotension has been seen during hemodialysis (44, 45). This appears to be relevant primarily in uremic patients who have autonomic dysfunction.

Determining the prevalence and clinical implications of postprandial hypotension is complicated not only by different diseases and drugs in the populations studied but also by methodologic inconsistencies among studies. First, the body’s position while the meal is being consumed probably affects food-induced changes in blood pressure. Postprandial hypotension occurs in both the sitting and supine positions. Although the sitting position is more physiologic, orthostatic changes in blood pressure during prolonged sitting might contribute to the postprandial decrease in blood pressure. Second, no studies have addressed the variability of postprandial blood pressure. Previous studies have shown that orthostatic blood pressure measurements in the elderly vary considerably from day to day (49). This could also be true for postprandial hypotension. Third, the nutrient composition of meals affects the magnitude of the decrease in postprandial blood pressure (12, 13, 15, 50). Carbohydrates and, more specifically, glucose have been found to play a significant role (10, 29). However, conflicting data have been reported about the influence of fat or protein on postprandial blood pressure (12, 13, 15, 51, 52). Fourth, postprandial hypotension depends on the temperature of the meal (53). After cold glucose solutions are ingested, blood pressure remains unchanged, whereas glucose solutions served warm or at room temperature cause a decrease in blood pressure. Finally, the time at which blood pressure is measured after a meal may influence the detection of this phenomenon. Postprandial hypotension can be found at all meal times (14) and is almost immediately apparent after a meal. Blood pressure usually reaches a nadir within 30 to 60 minutes. In nursing home residents, the systolic blood pressure nadir occurred as early as 15 minutes after the meal in 13% to 17% of the patients and as late as 75 minutes after the meal in 11% to 13% of the patients (24, 25).

Clinical Symptoms and Significance

In elderly persons or patients with autonomic failure, postprandial reductions in blood pressure may result in syncope, falls, angina pectoris, weakness, dizziness, nausea, lightheadedness, or black spots in the visual field (1, 5, 22, 24–26, 29, 39, 46) (Table 1). In addition, case reports have described elderly patients with large postprandial reductions in blood pressure who developed angina pectoris or transient ischemic attacks that resolved as blood pressure returned to normal (24, 54). However, data on the frequency of postprandial hypotension and its potential symptoms are scarce. In one recent study, half of a group of patients with unexplained syncope had postprandial hypotension (27).

The cerebral symptoms probably depend on the extent to which cerebral perfusion is compromised. Accumula-
tion of age- and disease-related conditions that threaten cerebral blood flow or reduce oxygen content in the blood may bring cerebral oxygen delivery near the threshold needed to maintain consciousness (55). Therefore, even small changes in blood pressure may reduce cerebral oxygen delivery to below the critical threshold and thus result in ischemic symptoms. The potential for postprandial cerebral ischemia may be greater in elderly persons with hypertension because cerebral blood flow decreases with both aging and hypertension (56–58). Hypertension not only enhances the postprandial decrease in blood pressure (7, 10, 22) but also shifts the threshold for cerebral autoregulation to higher levels (58). In contrast, patients with autonomic failure can sometimes tolerate a standing systolic blood pressure as low as 70 mm Hg because of a shift in autoregulation to lower levels of blood pressure (59). This shift in autoregulation may be the result of prolonged exposure to low blood pressure.

Data on the effect of postprandial hypotension on cerebral blood flow are limited. Krajewski and colleagues (60) studied elderly institutionalized patients with postprandial hypotension and did not find a change in the blood flow velocity of the middle cerebral artery. However, they found an unexpected increase in the resistance of the intracerebral circulation after these patients ate a meal. This change may further increase the risk for cerebral ischemia.

Several studies have shown that postprandial hypotension is common in patients who fall and have syncope (22, 26, 27). Recent studies showed that blood pressure after meals was most reduced in elderly persons who had fallen compared with those who had not fallen (22, 25). Hoeldtke and colleagues (28) described patients with autonomic failure who could not stand or walk after a meal because of meal-induced hypotension (28). Although syncope in the elderly has been associated with postprandial hypotension, this association is rarely considered in the evaluation of syncope (5, 25, 26). Elderly patients in nursing homes with a history of syncope have been found to have average postprandial decreases in systolic blood pressure of 24 to 31 mm Hg compared with decreases of 14 to 17 mm Hg in elderly patients without such a history (24, 25). In a prospective study of the causes of syncope in an elderly nursing home population, 8% of syncopal episodes were associated with a postprandial reduction in blood pressure (61). In a recent study, 50% of elderly patients with unexplained syncope occurring within 2 hours of a meal had postprandial hypotension (27).

As noted above, meal-related reduction in blood pressure is even more common in elderly patients with cardiovascular disease and hypertension. Furthermore, older hypertensive patients frequently use cardiovascular medications that have hypotensive effects. These medications are often given at meal-time, thereby potentially exacerbating the postprandial decrease in blood pressure. Postprandial hypotension thus has important implications in the evaluation and management of hypertension in elderly patients. Because of meal-related fluctuations in blood pressure in older hypertensive patients, it is more difficult to establish a meaningful baseline blood pressure. In addition, meal-induced hypotension may cause the blood pressure to return to normal for a limited time without treatment. Therefore, blood pressure should be examined before and after meals before hypertension is diagnosed or the effect of treatment is judged.

Elderly persons or patients with autonomic failure who have postprandial hypotension also frequently have orthostatic hypotension (26, 29, 34, 36). Moreover, both of these phenomena are often observed in elderly hypertensive patients (21). However, both postprandial and orthostatic hypotension do not always occur in the same patients. We recently found that none of the patients with unexplained syncope had orthostatic hypotension but that half had postprandial hypotension (27). In addition, preliminary studies in patients in nursing homes show that postprandial hypotension occurs more often than orthostatic hypotension. These phenomena are rarely seen together in the same patients.

### Pathophysiology of Postprandial Hypotension

The mechanism of postprandial hypotension is not fully understood, but several hypotheses have been proposed. It is likely that different mechanisms are associated with different clinical conditions. Postprandial hypotension may be considered a physiologic process associated with age-related changes in blood pressure regulation or with a pathologic process related to specific diseases that impairs the autonomic control of blood pressure. The normal cardiovascular responses to meal ingestion and the potential mechanisms of postprandial hypotension are reviewed below.

### Normal Cardiovascular Responses to Meal Ingestion

Splanchnic blood pooling after a meal reduces systemic vascular resistance (62, 63). Despite an associated postprandial reduction in the return of blood to the heart, meal ingestion in young persons is followed by a slight increase in systolic blood pressure because of an increase in heart rate and cardiac output (30, 62–66). Sympathetic nervous system activity increases after meals, as shown by increases in heart rate, plasma norepinephrine levels (10, 19, 67, 68), and sympathetic nerve activity of muscle recorded by microneurography (69). Plasma renin activity also increases after meal ingestion in healthy young persons (63, 70, 71).

Healthy elderly persons also have postprandial increases in heart rate, plasma norepinephrine, cardiac output, and forearm vascular resistance, which compensate for splanchnic blood pooling and result in a stable blood pressure after meal ingestion (6–11, 30, 51).

### Table 1. Clinical Symptoms Associated with Postprandial Hypotension

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<tr>
<th>Symptom</th>
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<tr>
<td>Dizziness</td>
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<td>Syncope</td>
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<td>Transient ischemic attacks</td>
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<td>Nausea</td>
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<td>Disturbed speech</td>
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<td>Vision changes</td>
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<td>Angina pectoris</td>
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Data on the effect of postprandial hypotension on cerebral blood flow or reduce oxygen content in the blood may bring cerebral oxygen delivery near the threshold needed to maintain consciousness (55). Therefore, even small changes in blood pressure may reduce cerebral oxygen delivery to below the critical threshold and thus result in ischemic symptoms. The potential for postprandial cerebral ischemia may be greater in elderly persons with hypertension because cerebral blood flow decreases with both aging and hypertension (56–58). Hypertension not only enhances the postprandial decrease in blood pressure (7, 10, 22) but also shifts the threshold for cerebral autoregulation to higher levels (58). In contrast, patients with autonomic failure can sometimes tolerate a standing systolic blood pressure as low as 70 mm Hg because of a shift in autoregulation to lower levels of blood pressure (59). This shift in autoregulation may be the result of prolonged exposure to low blood pressure.

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Healthy elderly persons also have postprandial increases in heart rate, plasma norepinephrine, cardiac output, and forearm vascular resistance, which compensate for splanchnic blood pooling and result in a stable blood pressure after meal ingestion (6–11, 30, 51).
Splanchnic Blood Pooling

Splanchnic blood pooling appears to be an important initial event in the development of postprandial hypotension. However, a recent study (27) does not support the suggestion that excessive splanchnic blood pooling during digestion might be a principal mechanism of postprandial hypotension (32). The response of splanchnic blood volume to meals also depends on the type of food ingested (72, 73). The increase in superior mesenteric arterial blood flow velocity after a high-carbohydrate meal is similar in young and elderly persons, whereas only elderly persons have a postprandial decrease in blood pressure (13, 30). In addition, the blood flow of the superior mesenteric artery after a meal increases to the same extent in patients with autonomic failure and in young volunteers, despite a decrease in mean arterial blood pressure in the former patients (31). A study has shown that bowel blood volume increases by approximately 20% after a meal in both healthy young and old persons but reaches its maximum later in elderly persons than it does in young persons (30).

Heart Rate

The heart rate increases after a meal in healthy young and older persons (6-11, 30, 62, 74). In general, this increase does not differ between young and older persons (6-10), although one study showed that the postprandial increase in heart rate was more pronounced in healthy elderly persons than in young persons (30). Hypertensive elderly persons have a smaller increase in heart rate than do normotensive elderly persons (10, 18, 19), whereas in frail elderly persons and patients with autonomic failure, postprandial hypotension is associated with the absence of a cardioacceleratory response (5, 29, 31, 34-36, 47). Several studies have found an unexpected increase in heart rate after a meal in patients with both pure autonomic failure and multiple-system atrophy (4, 30, 75). In healthy young persons, it has been shown that β-adrenergic blockade with atropine and propranolol does not attenuate the increase in heart rate in response to food ingestion, which suggests that the change in heart rate is independent of the autonomic nervous system and that other factors might be involved (74).

Spectral analysis of the heart rate is a relatively new technique used to study the contributions of baroreflex (low-frequency spectral power) and parasympathetic nervous system (high-frequency spectral power) influences on heart rate variability. Spectral analysis techniques have confirmed that healthy aging is associated with reductions in both baroreflex and vagal modulation of the heart rate, with a relatively greater loss of the parasympathetic component (76). Low-frequency heart-rate power markedly increases in healthy young persons after a meal. Ryan and colleagues (23) studied 13 nursing home residents and found a 27 mm Hg postprandial reduction in the sitting mean arterial blood pressure and little change in low-frequency heart-rate power, which indicates a blunted baroreflex-mediated heart-rate response to meal ingestion.

Impairment of the Sympathetic Nervous System

Postprandial hypotension can be partially explained by an inadequate sympathetic response to meal-induced splanchnic vasodilation. This hypothesis has been corroborated by an inadequate or blunted response of the heart rate, plasma norepinephrine levels, and microneurographic recordings of muscle sympathetic nerve activity to meal ingestion in patients with postprandial hypotension (5, 10, 19, 26, 77).

In hypertensive elderly persons and elderly patients with syncope, the postprandial increase in plasma norepinephrine is equal to or lower than the increases in plasma norepinephrine in normotensive elderly and young persons, despite a greater decrease in blood pressure (10, 26). This is in accordance with the decrease in baroreflex sensitivity associated with aging and blood pressure elevation (19, 78-80). In elderly patients in nursing homes who have a history of postprandial syncope, plasma norepinephrine levels slightly increase and then markedly decrease to baseline levels despite a reduction in postprandial blood pressure (26).

Studies of the sympathetic nerve activity of muscle after a meal are also consistent with an inadequate sympathetic response in patients with postprandial hypotension. In healthy young persons, the sympathetic nerve activity of muscle increases after ingestion of oral glucose but not after receipt of intravenous glucose or ingestion of water (69, 77, 81). The sympathetic nerve response of muscle to the ingestion of glucose or mixed meals tends to be greater than the response after the ingestion of protein or fat. In patients with multiple-system atrophy, the sympathetic nerve activity of muscle did not change after oral glucose ingestion, despite a significant decrease in blood pressure (77).

Cardiovascular Mechanisms

A significant decrease in systemic vascular resistance after a meal has been reported in several studies (30, 31, 36, 48). An important recent finding is the absence of peripheral vasoconstriction despite severe meal-induced hypotension (27, 30). Thus, postprandial hypotension appears to develop when vascular compensation for the shift of blood volume into the splanchnic system is inadequate.

Although normal aging has been associated with blunted β-adrenergic vasodilation, α-adrenergic vasoconstriction appears to remain intact (82). It was recently shown that peripheral vasoconstriction prevents postprandial hypotension in healthy elderly persons (30). The impaired peripheral vasoconstriction in patients with meal-induced hypotension is poorly understood. Hoeldtke and colleagues (33) found that in patients with autonomic failure, forearm vascular resistance could increase after treatment with octreotide and dihydroergotamine. This finding suggests that the absence of a local vasoconstrictor substance such as somatostatin or endothelin is involved.

Impairments in early diastolic ventricular filling associated with aging, hypertension, and ischemic heart disease make the heart more dependent on ventricular preload to generate an adequate cardiac output. In patients with angina pectoris and impaired ventricular diastolic filling, administration of nitrates before a meal may enhance
venous blood pooling, reduce cardiac preload, and aggravate postprandial blood pressure reduction (22).

Humoral Mechanisms

Several gastrointestinal peptides may play a pathogenic role in postprandial hypotension.

Insulin

The effects of carbohydrates on blood pressure are primarily caused by glucose, which stimulates insulin release. Other carbohydrates, such as fructose or xylose, have no or minimal effect on blood pressure and do not stimulate insulin (10, 29). Insulin has therefore been implicated in the pathogenesis of postprandial hypotension. In diabetic patients with autonomic neuropathy, systolic and diastolic blood pressure decrease considerably after insulin is administered, sometimes resulting in syncope (83–87). Epidemiologic evidence for an association between insulin therapy and syncope was found in institutionalized elderly persons (61). In the absence of hypoglycemia, insulin infusions stimulate sympathetic nervous system activity and produce forearm vasodilation (81, 88–94). This finding suggests that a vasodilatory effect of insulin might be responsible for postprandial hypotension. However, all recent studies in the elderly and in patients with autonomic failure did not show a correlation between the increase in plasma insulin levels and the decrease in blood pressure after oral glucose ingestion (10, 18, 26, 95).

The mechanism by which insulin stimulates sympathetic activity and increases blood flow is unknown. One hypothesis suggests a central neural action by insulin (92). The vasodilator effect is presumed mediated by the sympathetic nervous system stimulation of β-adrenoceptors in the vasculature. Indeed, in dogs and young humans, propranolol inhibits the vasodilator response to insulin infusion (88, 96). Other mechanisms include endothelium-dependent relaxation; stimulation of the sodium–potassium pump, which causes hyperpolarization and relaxation; and metabolic vasodilation secondary to the increased oxygen consumption of the skeletal muscle (92).

Finally, it has been suggested that eating may affect blood pressure homeostasis in the elderly through insulin-induced blunting of baroreflex sensitivity (97). However, baroreflex function as established by the phenylephrine and nitroglycerin method is not affected by oral glucose loading in young and elderly persons (19).

Somatostatin

Somatostatin has an inhibitory effect on almost all gastrointestinal hormones and may therefore play a regulatory role in modulating splanchnic circulation. Several vasoactive peptides have been implicated in the pathogenesis of postprandial hypotension, but attempts to identify such peptides have thus far been unsuccessful (15, 29, 34, 52, 53, 75, 95). The potential role of somatostatin in postprandial hypotension has been reviewed elsewhere (98).

Vasoactive Peptides

Vasoactive intestinal polypeptides have been studied because of their well-known vasodilating effect (99, 100). However, plasma levels of this peptide before and after meals or oral glucose loading are unchanged in the elderly and in patients with autonomic failure (15, 28, 29, 32, 34, 52). A role for neurotensin, a possible gastrointestinal vasoactive peptide, remains controversial. Plasma neurotensin levels increase in patients with autonomic failure after a meal or ingestion of glucose, and this change could be inhibited by octreotide (32, 34). Mathias and colleagues (34) found that compared with young, healthy persons, patients with autonomic failure and postprandial hypotension had a greater increase in plasma neurotensin levels after a meal; however, this finding was not confirmed in other studies (28). The same investigators found a similar increase in plasma neurotensin levels after patients ingested both oral glucose and xylose, although blood pressure decreased after ingestion of glucose but not xylose (29). Therefore, a role for neurotensin in postprandial hypotension is not compelling.

Although substance P has been classified as the most powerful vasodilating peptide, a change in the substance P level has not been observed after a meal or glucose ingestion in patients with autonomic failure or in the elderly (29, 53). Levels of other peptides, such as cholecystokinin, gastrin, and motilin, also remain unchanged after a meal (29, 34).

The purinergic system could be involved by the release of vasodilatory adenosine, which thereby induces hypotension. The reported beneficial effect of caffeine in postprandial hypotension could be caused by its antagonistic effect on adenosine receptors. However, as discussed below, the beneficial effect of caffeine is controversial.

Although vasoactive peptides may be involved in the pathophysiologic mechanism of postprandial hypotension, all attempts to identify a primary role for these peptides have been unconvincing. The plasma levels of any peptide must be interpreted with caution because plasma concentrations are affected not only by hormonal release but also by clearance. Aging may affect local release as well as renal or hepatic clearance, thus altering the distribution of these peptides in various body compartments. Clinical studies are currently being done to explore the role of other substances involved in regulating vascular tone, particularly those involved in endothelial-derived vasoactivity.

Intravascular Volume Status

An osmotic shift of fluid into the gut and consequent reduction in intravascular volume may contribute to meal-induced hypotension. Changes in intravascular volume may further reduce diastolic ventricular filling (101). In the absence of a compensatory increase in heart rate (commonly seen in the elderly or in patients with autonomic failure), cardiac output may decrease and hypotension may result.

The importance of preload in the pathogenesis of orthostatic hypotension has been shown in healthy elderly persons who could maintain systolic blood pressure during a head-up tilt test under normal conditions but who experienced significant orthostatic hypotension after a thiazide-induced weight loss (102). The role of intravascular volume is also suggested by the observation that symptomatic postprandial hypotension develops during hemodialysis. Dialysis is frequently accompanied by fluid removal, osmosis-induced intracellular fluid shifts, and
acetate-induced vasodilation that predisposes patients to the development of hypotension (44). The hypotensive effects of meals and dialysis may result in significant decreases in blood pressure.

The hypothesis that an osmotic shift of fluid into the gut and a consequent reduction in intravascular volume contribute to postprandial hypotension is contradicted, however, by studies in elderly persons showing that ingestion of glucose profoundly affects blood pressure, whereas ingestion of an iso-osmotic, isocaloric fructose solution or of osmotic solutions such as fat or protein does not (10, 15).

**Therapeutic Interventions**

Most healthy elderly persons have postprandial decreases in blood pressure, but these changes in blood pressure are usually small and asymptomatic. Any postprandial decrease in systolic blood pressure of 20 mm Hg or more, however, should be considered a potentially dangerous response, and efforts should be made to reduce the risk for the development of such symptoms as postprandial syncope, dizziness, falls, weakness, or stroke. Unfortunately, few rigorous studies have been done on the treatment of symptomatic patients with postprandial hypotension. The results of these studies are summarized below. Our approach to the treatment of postprandial hypotension is described in Table 2.

**Nonpharmacologic Interventions**

There are only empirical data on nonpharmacologic measures for the treatment of postprandial hypotension. Advice about the size of a meal may help. In young persons, a large meal induced a greater decrease in peripheral vascular resistance and mean arterial pressure and a greater increase in cardiac output than did a small meal (103, 104). Because postprandial blood pressure reduction seems to be related to carbohydrates, a low-carbohydrate, high-protein meal might help alleviate postprandial hypotension.

Because orthostatic and postprandial hypotension may have additive hypotensive effects, it is often recommended that symptomatic patients rest in a supine position after meals (51, 54). However, several other studies could not confirm that hypotension was exacerbated by an upright posture after meals (7–9). It has been shown in nursing home residents that ambulating after a meal can completely restore blood pressure (22).

Because dehydration can predispose patients to postprandial hypotension, adequate fluid intake must be assured in susceptible persons. With advancing age, the conservation of renal salt and water decreases, which makes elderly persons vulnerable to hypovolemia (102). Older persons often restrict their salt intake, thereby causing a reduction in circulating blood volume. Hot weather can further reduce the circulating blood volume because of sweating and cutaneous vasodilatation. All these preventable factors might precipitate postprandial hypotension in otherwise healthy elderly persons.

**Pharmacologic Interventions**

**Treatment of Hypertension**

Systolic hypertension impairs blood pressure homeostasis and increases the risk for postprandial hypotension.

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**Table 2. Approach to the Treatment of Postprandial Hypotension**

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<tr>
<td>1</td>
<td>Inform patient about danger associated with meal-induced hypotension, particularly the risk for falling and syncope within 15 to 90 minutes after meals.</td>
</tr>
<tr>
<td>2</td>
<td>Discontinue therapy with any unnecessary medications that lower blood pressure. If the patient has sustained hypertension when blood pressure is measured before and after meals, institute treatment but monitor postprandial blood pressure to avoid hypotension.</td>
</tr>
<tr>
<td>3</td>
<td>Administer hypotensive medications between rather than during meals.</td>
</tr>
<tr>
<td>4</td>
<td>Have patient avoid sitting for prolonged periods or standing still after meals. Check blood pressure after a postprandial walk; if it returns to normal, patient should walk after meals. Otherwise, patient should lie semi-recumbent for 90 minutes after a meal.</td>
</tr>
<tr>
<td>5</td>
<td>Maintain patient’s intravascular volume.</td>
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<tr>
<td>6</td>
<td>Advise liberal salt intake when possible.</td>
</tr>
<tr>
<td>7</td>
<td>Ensure adequate fluid intake.</td>
</tr>
<tr>
<td>8</td>
<td>Discontinue use of diuretics.</td>
</tr>
<tr>
<td>9</td>
<td>Adjust the size and composition of patient’s meals.</td>
</tr>
<tr>
<td>10</td>
<td>Encourage frequent small meals.</td>
</tr>
<tr>
<td>11</td>
<td>Encourage limited carbohydrate content.</td>
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<tr>
<td>12</td>
<td>Advise avoiding meals during hemodialysis.</td>
</tr>
<tr>
<td>13</td>
<td>Advise avoiding alcoholic beverages before and after meals.</td>
</tr>
<tr>
<td>14</td>
<td>Institute therapy with pharmacologic agents.</td>
</tr>
<tr>
<td>15</td>
<td>Caffeine, 250 mg (two cups of coffee), before a meal.</td>
</tr>
<tr>
<td>16</td>
<td>Octreotide, 50 µg subcutaneously, administered 30 minutes before each meal.</td>
</tr>
<tr>
<td>17</td>
<td>Fludrocortisone, 0.1 to 1.0 mg daily.</td>
</tr>
<tr>
<td>18</td>
<td>Indomethacin, 25 to 50 mg orally, three times a day.</td>
</tr>
<tr>
<td>19</td>
<td>a1-Adrenergic agonists such as midodrine, 2.5 to 10.0 mg orally three times a day, or phenylephrine, 60 mg orally every 6 to 12 hours.</td>
</tr>
</tbody>
</table>

One study has shown that treatment of hypertension with a calcium channel blocker such as nitrendipine or hydrochlorothiazide alleviated glucose-induced blood pressure reduction in elderly hypertensive patients (105). More recently, nicardipine treatment reduced the meal-induced decrease in blood pressure in elderly patients with coronary heart disease (106). Therefore, antihypertensive treatment may favorably affect the regulation of postprandial blood pressure. These observations do not imply that symptomatic postprandial hypotension should be treated with the previously mentioned medications. The patients in these studies were asymptomatic and had relatively small reductions in postprandial blood pressure. It is currently unknown whether blood pressure-lowering medications given before or with a meal might aggravate decreases in blood pressure in patients with symptomatic postprandial hypotension. These studies suggest that hypertension can be treated safely in the elderly without an accompanying worsening in postprandial hypotension, but it is sensible to administer hypotensive medications between rather than during meals.

**Caffeine**

Caffeine is often recommended as a simple and effective remedy for patients with symptomatic postprandial hypotension (35, 107). This treatment is particularly appealing because caffeine is relatively nontoxic, inexpen-
sive, convenient, and widely available. A preprandial pressor effect of caffeine that prevents the postprandial blood pressure from decreasing below its baseline value has been found in healthy elderly persons (108). The effect of caffeine on postprandial hypotension has been examined in only a few conflicting studies. Very few of these studies included patients with symptomatic postprandial hypotension. Several studies found that caffeine attenuated the postprandial decrease in blood pressure (35, 38, 107, 109). We recently found, however, that caffeine given orally with a meal does not prevent postprandial hypotension in elderly patients with postprandial syncope (110). Other investigators could not show any beneficial effect of caffeine in patients with autonomic failure or in those with symptomatic postprandial hypotension (54, 111).

Octreotide

The somatostatin analog octreotide has been shown to be effective in preventing the reduction of postprandial blood pressure in hypertensive elderly patients (95, 112) and in patients with autonomic dysfunction (28, 31-34, 47). This approach has not been studied in elderly patients with symptomatic postprandial hypotension. Treatment with octreotide is expensive, requires frequent subcutaneous injections, and may cause diarrhea. Because of the low pH of the solution, treatment is also painful. Therefore, this approach should be limited to the most severely affected symptomatic patients.

The mechanism by which octreotide helps prevent postprandial hypotension has not been fully studied, but it has been suggested that the suppression of vasoactive gastrointestinal hormone secretion or a reduction in splanchnic blood flow may play a role (95). Octreotide has been shown to prevent the increase of splanchnic blood flow induced by a meal and to increase splanchnic vascular resistance in patients with autonomic failure (31, 33). Octreotide increased forearm vascular resistance and cardiac output in fasting patients with autonomic failure (33). The increase in cardiac output after octreotide administration is probably related to an enhanced cardiac filling, although an inotropic effect cannot be excluded. The most likely mechanism for the beneficial effect of octreotide on postprandial hypotension is an increase in splanchnic and forearm vascular resistance.

Other Agents

Other drugs that have been evaluated for treatment of postprandial hypotension include indomethacin (4, 28), diphenhydramine (4), cimetidine (4), dihydroergotamine (33, 52), denopamine (113), midodrine (113), and vasopressin (77), although only a few patients have been studied so far. In six patients with severe autonomic failure, indomethacin attenuated the hypotensive effects of a meal, whereas diphenhydramine and cimetidine did not affect postprandial blood pressure (4). Dihydroergotamine has not prevented postprandial hypotension in patients with autonomic failure (33, 52). A pilot study in patients with autonomic failure showed that a combination of denopamine ({$\beta_1$}-adrenergic agonist) and midodrine ({$\alpha_1$}-adrenergic agonist) attenuated postprandial hypotension, whereas monotherapy with either drug had no beneficial effect (113).

Clinical and Research Implications

Because of its association with aging, hypertension, disorders of autonomic function, medications, and several other medical conditions, postprandial hypotension is commonly detected if it is looked for in medical practice. Recent experience suggests that it might be more common than orthostatic hypotension in the elderly. All physicians treating elderly patients should be aware of the hypotensive effect of food intake and its potentially important clinical association with syncope, falls, dizziness, weakness, lightheadedness, and stroke. Especially in the elderly, the work-up of syncope, falls, dizziness, and cerebral ischemic symptoms should include close attention to the possible relation of these symptoms to meals.

In elderly patients with postprandial hypotension, attention should be paid to the possible association with dehydration, anemia, orthostatic hypotension, medication use, hypertension, and adrenal insufficiency. In addition, clinical features of autonomic failure such as orthostatic hypotension, impotence, visual disturbances, defective sweating, bowel dysfunction, and neurologic symptoms should be sought. If these are present, formal autonomic function testing with heart-rate responses to deep breathing and the Valsalva maneuver, plasma catecholamine responses to posture change, and sweat testing may help identify the site of the lesion (114, 115). Ultrasonography of the carotid artery and ocular plethysmography may help the clinician to identify cerebrovascular lesions that could contribute to the symptomatic expression of postprandial hypotension. Further clinical research efforts are also needed to establish the relation between the treatment of hypertension and postprandial hypotension. Recent data suggest that judicious treatment of hypertension might actually reduce the risk for postprandial hypotension.

An important question is which meal should be used and under what conditions should patients be tested for postprandial hypotension. For studying the pathophysiology of postprandial hypotension, oral glucose solutions are attractive but not representative of meals consumed during normal physiologic conditions. Furthermore, meals with different nutritional compositions may have different effects on blood pressure. For the clinical evaluation of postprandial hypotension, we recommend a standardized mixed meal. We prefer a liquid meal because many patients require different amounts of time to eat a solid meal. In our experience, the test meal given in Table 3 is easily consumed within 10 minutes. It is most practical to give the meal in the morning after an overnight fast. Because the nadir in postprandial blood pressure varies, blood pressure should be monitored for at least 90 minutes after the start of the meal. So that the normal eating situation is simulated as much as possible, we suggest studying patients while they are sitting, although the orthostatic stress of sitting may enhance blood pressure reduction. We recommend that blood pressure and heart rate be measured twice before the test meal after a rest of 20 minutes to reach equilibrium. After the start of the meal, blood pressure and heart rate should be measured every 15 minutes for 90 minutes while the patient remains seated. In selected nonhospitalized patients with classic symptoms, 24-hour blood pressure can be measured with
Table 3. Recommended Composition of Standardized Study Meal

<table>
<thead>
<tr>
<th>Variable</th>
<th>kcal</th>
<th>Protein</th>
<th>Fat</th>
<th>Carbohydrate</th>
<th>Sodium</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 mL of lactose-free 1% whole milk</td>
<td>103</td>
<td>8.3</td>
<td>2.5</td>
<td>11.8</td>
<td>124</td>
<td>391</td>
</tr>
<tr>
<td>55 g of Carnation Instant Breakfast</td>
<td>201</td>
<td>12.3</td>
<td>0.3</td>
<td>37.7</td>
<td>231</td>
<td>569</td>
</tr>
<tr>
<td>30.3 g of Moducal*</td>
<td>115</td>
<td>0</td>
<td>0</td>
<td>28.8</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>419</td>
<td>20.6</td>
<td>2.8</td>
<td>78.3</td>
<td>376</td>
<td>963</td>
</tr>
</tbody>
</table>

* Moducal (Mead Johnson Nutritional, Evansville, Indiana, is a carbohydrate supplement in powder form that is widely used in hospital settings for undernourished patients.

an automatic device. The time of each meal should be carefully documented. In the evaluation of a patient who falls or has syncope after a meal, the circumstances at the time of the event should be reproduced.

Identification of appropriate treatment for symptomatic postprandial hypotension is warranted. Because it is unknown whether the mechanism of postprandial hypotension differs between healthy elderly patients and those with autonomic impairments, potential treatment options need to be explored in different patient populations. Studies of the long-term use of octreotide administered subcutaneously by pump are under way. Administration of this medication by nasal spray will be attractive for many situations. Alternations in meal composition and the use of vasoconstrictor agents to increase systemic vascular resistance should be studied further.

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References

30. Raimbach SJ, Cortelli P, Koerner JS, Bannister R, Bloom SR, Mathias CJ. Prevention of glucose-induced hypotension by the so-


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