Patients with cardiac syndrome X (CSX)—typical chest pain and electrocardiographic changes suggestive of myocardial ischemia despite normal coronary arteriograms—represent a diagnostic and therapeutic riddle. CSX is not associated with an increased mortality or an increased risk of cardiovascular events, but it often severely impairs quality of life and represents a substantial cost burden to the healthcare system. This syndrome of chest pain with normal coronary arteries encompasses a variety of pathogenic subgroups and is predominantly seen in postmenopausal women. Lack of understanding of the syndrome by the cardiovascular physician not infrequently results in discounting the clinical problem. Treatment remains elusive, but management strategies can improve the patient’s quality of life and reduce the financial burden imposed on health services.

**Case Report:** A 55-year-old white female pharmacist underwent diagnostic coronary arteriography for the assessment of typical exertional chest pain, which had started 18 months previously and had gradually become more frequent and severe despite treatment with oral and sublingual nitrates and atenolol (50 mg daily). Central chest pain and dyspnea occurred at rest and with emotional stress and responded rather poorly to sublingual nitrate administration. ECG exercise stress test was positive (Figure 1), and transient perfusion defects were found on thallium-201 dipyridamole testing (Figure 2). She had long-lasting excruciating chest pain after dipyridamole infusion. Risk factors included a family history of coronary artery disease, a low-density lipoprotein-cholesterol level of 4.2 mmol/L, a high-density lipoprotein-cholesterol level 0.9 mmol/L, menopausal status, a previous history of smoking, body-mass index of 28 kg/m², and raised high-sensitivity C-reactive protein levels (3.8 mg/L). Coronary arteries and left ventricular function were completely normal. Coronary intravascular ultrasound showed no significant subangiographic disease. After reassurance by her cardiologist, all cardiac medications were discontinued. Symptoms continued to deteriorate over the ensuing months, however, to the point that she was unable to work and required help with her supermarket shopping and household tasks. She was referred to our CSX clinic for treatment.

**Clinical Results:** Symptoms improved significantly over an 8-month period and the patient was able to return to work. Improvements were observed in body mass index (23 kg/m²), high-density lipoprotein-cho-

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Background
Although patients with typical exertional chest pain and positive exercise tests usually have obstructive coronary artery disease, particularly when risk factors are present, approximately 20% of these patients have normal coronary arteriograms. These individuals are considered to have CSX, for which there is no universally accepted definition. Most cardiologists agree that, in addition to typical chest pain and ECG changes (or other evidence of a cardiac involvement such as myocardial perfusion abnormalities), the coronary angiogram should be completely normal. Even this stringent angiographic criterion has limitations, as coronary arteriography provides no information regarding early atherosclerotic events within the arterial wall.

Patients with systemic hypertension, left ventricular hypertrophy, and diabetes mellitus are excluded from CSX, as it is assumed that the cause for their angina is known. Consideration whether or not such exclusions are justifiable is beyond the scope of this manuscript. Patients with coronary artery spasm and those with objectively documented extracardiac causes for the pain (such as chest wall syndrome, psychological disturbances, and esophageal spasm) are also excluded.

Despite intense investigation over the past 30 years regarding the pathogenesis of CSX, many fundamental questions remain unanswered. Among these, the following feature prominently: (1) Is the chest pain cardiac in origin?; (2) Is it caused by myocardial ischemia?; (3) Are other mechanisms involved?; and (4) What are the respective roles of microvascular dysfunction and reduced pain threshold?

Pathogenesis
Coronary Microvascular Dysfunction (Microvascular Angina)
Microvascular angina (reduced coronary microvascular dilatory responses and increased coronary resistance) has been consistently found in CSX patients and suggested as a cause for regional myocardial blood flow abnormalities and heterogeneous myocardial perfusion. Endothelial dysfunction, with reduced bioavailability of endogenous NO and increased plasma levels of endothelin-1 (ET-1), may explain the abnormal behavior of the coronary microvasculature in CSX. Transient myocardial perfusion defects have been reported in areas supplied by...
Myocardial Ischemia

From the initial description of CSX, it has been speculated that myocardial ischemia could be its pathogenic mechanism. However, this mechanism has proven elusive, as ischemia is objectively documented in only a minority (approximately 25%) of patients. Evidence of myocardial ischemia in these patients derives from myocardial perfusion studies, from investigations using metabolic markers such as myocardial lactate and isoprostane production, and from coronary sinus blood oxygen and pH changes. Studies using myocardial-perfusion MRI and 31-Phosphorus nuclear magnetic resonance have provided fresh evidence for myocardial ischemia in CSX patients. Because many authors question the role of myocardial ischemia in CSX based on its good prognosis, the poor response to nitrates in many cases, the normal results of stress echocardiography, and the absence of objective markers of ischemia in many CSX patients, non-ischemic mechanisms have been proposed to explain the occurrence of CSX, including autonomic nervous system dysfunction and increased pain perception. Negative findings regarding ischemia, however, may be due to dilution of study groups by subjects with non-cardiac chest pain and to poor sensitivity of diagnostic techniques.

Abnormal Pain Perception

Increased pain perception is common in patients with CSX, but the reason remains elusive. Potassium and adenosine release, as well as abnormalities in the central modulation of pain perception, have been suggested to play a role. Greater and more extensive cortical activation, particularly of the right insula, suggesting abnormal handling of afferent stimuli by the central nervous system is seen in CSX patients as compared with controls. CSX patients may thus have an ineffective thalamic gate that would allow inadequate cortical activation by afferent stimuli from the heart, resulting in increased pain perception.
nomic nervous system imbalance with increased adrenergic activity and impaired parasympathetic tone could explain both increased pain sensitivity and endothelial dysfunction. Possible interactions between pain threshold and microvascular dysfunction in CSX are presented in Figure 4.

**Psychiatric Morbidity**

CSX patients have high rates of psychiatric morbidity; approximately 30% have a treatable psychiatric disorder and another 30% have psychological problems, factors that probably contribute to the continuing symptoms characteristic of the condition. Psychiatric morbidity varies in different series depending on the referral sources of these patients and may, particularly in anxiety disorders, be secondary to inappropriate reassurance about often disabling cardiovascular symptoms, uncertainty as to the nature of the condition, and failure of conventional treatments to improve quality of life.

**Prognosis and Management**

With the exception of patients who present with left bundle branch block and subjects with microvascular angina secondary to serious systemic diseases (such as amyloidosis or myeloma), prognosis is good regarding survival and left ventricular function in patients with CSX. Quality of life, however, is poor in a large proportion of CSX patients.

Treatment is a challenging and often frustrating exercise for both patients and physicians. Kaski and Valenzuela Garcia have reviewed treatment options available for CSX, and American Heart Association/American College of Cardiology treatment guidelines are available for management of CSX in the context of the acute coronary syndrome. Successful management usually depends on identifying the prevailing pathogenic mechanism and tailoring the intervention to the individual patient. Advice on lifestyle changes and risk factor management—in particular aggressive lipid lowering therapy with statins—should be considered vital components of any therapeutic strategy. A multidisciplinary approach is required in most cases. Figure 5 depicts an algorithm used in our institution for the management of CSX patients. Briefly, antianginal medications such as calcium antagonists and β-adrenergic blockers are useful in patients with documented myocardial ischemia or abnormal myocardial perfusion. Sublingual nitrates are effective in 50% of CSX patients. Little evidence is available in relation to the efficacy of nicorandil, α-adrenergic blockers, trimetazidine, and angiotensin-converting enzyme inhibitors in this setting.

**Analgesic Intervention**

Analgesic intervention with imipramine, an antidepressant with analgesic properties, and with aminophylline, an antagonist of adenosine receptors, has been shown to improve symptoms in patients with chest pain and normal coronary arteriograms. Transcutaneous electrical nerve stimulation and spinal cord stimulation can offer good pain control. As with other interventions in CSX, studies in larger numbers of patients are lacking.

**Hormone Therapy**

Hormone therapy improves chest pain and endothelial function in women with CSX. Estrogens antagonize the effects of ET-1 and dilate the coronary vasculature. Controlled clinical trials have suggested, however, that the risk of developing cardiovascular disease and breast cancer increases in women taking hormone therapy (HT). Thus, although HT has potential cardiovascular benefits, it can also cause harm. The US Preventative Services Task Force has suggested that routine postmenopausal HT should not be advised for the prevention of chronic conditions, and women should take an active part in decisions regarding HT. These recommendations apply also to CSX patients. However, HT may be useful in specific cases where a direct relationship exists between estrogen deficiency and CSX symptoms.

**Psychological Intervention**

Psychological intervention may be beneficial for a substantial number of patients, whether or not organic factors are involved. Studies support the role of a structured cognitive behavioral approach to the management of CSX patients with non-ischemic chest pain, and this treatment is more likely to be effective if it is begun early after diagnosis.

**Physical Training**

As a result of physical deconditioning and low pain threshold, CSX patients have an impaired exercise capacity. Physical training improves pain threshold and endothelial function and
delays the onset of exertional pain in patients with typical chest pain and normal coronary arteries. 25

Summary and Final Considerations
Controversy surrounds the pathogenesis and management of CSX patients. Although the majority of these patients has non-ischemic mechanisms and increased pain sensitivity, only a minority has documented myocardial ischemia. Identification of the prevailing mechanism is important for rational management. A multidisciplinary approach and a genuine, sympathetic appreciation by the physician of the devastating effect of CSX on the patient’s quality of life usually have a positive therapeutic impact.

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Pathophysiology and Management of Patients With Chest Pain and Normal Coronary Arteriograms (Cardiac Syndrome X)
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