Cardiac autonomic neuropathy is a serious complication among diabetic patients. It occurs in both type 1 and type 2 diabetes, and its progression results in poor prognosis and increased mortality. During its course, parasympathetic and sympathetic nerve fibers of the cardiovascular system are damaged, resulting in potentially serious cardiac complications and even death. Poor glycemic control is believed to play a pivotal role in the pathogenesis of cardiac autonomic neuropathy. Its underlying etiology is not well understood; however, several potential pathologic mechanisms have been identified.

Several clinical manifestations of cardiac autonomic neuropathy have been reported, including resting tachycardia, exercise intolerance, loss of heart rate variability, orthostatic hypotension, prolonged QT interval, silent ischemia, and sudden death. Diabetic patients exhibiting these signs and symptoms are at greater risk of anesthesia-related complications. A series of noninvasive autonomic tests were developed for the diagnosis of cardiac autonomic neuropathy, improving the management of diabetic patients requiring general anesthesia.

These patients often experience cardiovascular events that may increase perioperative morbidity and mortality. The presence of cardiac autonomic neuropathy alters the hemodynamic response to induction and tracheal intubation during general anesthesia, resulting in intraoperative hypotension. A thorough preoperative assessment and vigilant monitoring perioperatively ensure successful anesthesia management.

**Keywords:** Anesthesia, cardiac autonomic neuropathy, diabetic autonomic neuropathy, diabetes mellitus.

Diabetic autonomic neuropathy is a complication of type 1 and type 2 diabetes. It affects multiple organ systems throughout the body, causing impairment of the gastrointestinal, genitourinary, and cardiovascular systems. Cardiac autonomic neuropathy (CAN) is the most serious and clinically significant form of diabetic autonomic neuropathy. It has been extensively studied over the years but remains the least understood complication of diabetes mellitus. The prevalence of CAN in diabetic patients varies greatly, from as low as 7.7% in people with recently diagnosed type 1 diabetes to as high as 90% in diabetic patients waiting for pancreas transplants. It can present itself early in its progression; however, many patients remain asymptomatic during the initial course, making a diagnosis extremely difficult.

Synthesis of the literature reveals that both poor glycemic control and duration of diabetes play substantial roles in the development and progression of CAN. Patients in whom diabetes has not been well controlled for many years are more likely to have progressive cardiac abnormalities. Moreover, CAN has also been reported to coexist in patients with diabetic retinopathy, peripheral neuropathies, diabetic nephropathy, and other diabetic complications. The prognosis is said to be poor and mortality risk greatly increased once CAN develops; however, new research reveals that improved glycemic control can potentially slow the progression of CAN in patients with type 1 and type 2 diabetes.

Cardiac autonomic neuropathy has been of particular interest to anesthesia professionals over the years because of its direct effect on the development of potential cardiovascular complications during general anesthesia. A thorough understanding of the pathophysiology process and its clinical manifestations are of clinical importance for optimal anesthetic management of diabetic patients with CAN. In this article we review the literature pertaining to this topic.

**Pathophysiology**

Despite intensive research, the precise etiology and pathologic mechanisms of diabetic autonomic neuropathy remain unclear. It is, however, well established in the literature that both the parasympathetic and sympathetic divisions of the autonomic nervous system suffer progressive nerve fiber loss during the course of this disease. The insult to the sensory and motor nerve fibers that innervate the major organs in the human body results in considerable widespread autonomic dysfunction. Cardiac autonomic neuropathy is said to be the most serious and
**1. Increase polyol pathway influx**
Activation of the polyol pathway leads to the accumulation of sorbitol in the nerves, leading to reactive oxygen species (free radicals), and activity of protein kinase C and activity of Na-K-ATPase activity causing direct nerve damage and a neuronal blood flow.

**2. Oxidative stress**
Induced oxidative stress leads to accumulation of oxygen free radicals causing vascular endothelial damage and dysfunction of Schwann cells, as well as nitric oxide (a potent vasodilator).

**3. Activation of protein kinase C**
Hyperglycemia → second messenger diacylglycerol → activates protein kinase C → leading to a series of pathologic consequences such as nitric oxide → vasoconstriction and nerve blood flow → vascular damage.

**4. Accumulation of advanced glycation end product formation**
Intracellular hyperglycemia appears to be the initiating factor in the formation of advanced glycation end product → causing angiotensin II (vasoconstrictor) and free fatty acid synthesis → activation of protein kinase C → endothelial damage.

**5. Endoneuronal ischemia and hypoxia**
Endoneuronal hypoxia appears to be caused by resistance in vascular system and nerve blood flow. Hypoxia leads to further damage to capillaries and eventually causes axonal transport dysfunction.

**6. Destruction of nerve growth factors and axonal transport**
Nerve growth factors are found in target organs innervated by sympathetic nervous system. Regulation of cardiac sensory nerves appear to be dependent on nerve growth factors. Hyperglycemia ↓ production of nerve growth factors for endothelial and neuronal cells → leading to degeneration of nerves.

**7. Disorder of fatty acid metabolism**
Deficiency in essential fatty acids: accumulation of linoleic acid and linolenic acid changes the cell membrane → neuronal blood flow.

**8. Immunologic mechanism**
Progressive changes in immune system may also be implicated. Autoimmune damage has been noted in earlier research.

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**Table 1. Proposed Pathologic Mechanisms of Diabetic Autonomic Neuropathy**
Abbreviations: →, leads to; ↑, increased; ↓, decreased or decreases; Na-K-ATPase, sodium-potassium-adenosine triphosphatase.

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fatal complication of diabetic autonomic dysfunction. The parasympathetic and sympathetic nerve fibers are vital to the innervation of the cardiovascular system such as control of heart rate, blood pressure, and cardiac contractility, as they provide the body’s homeostasis. Therefore, disturbances in the integrity of the cardiovascular system results in potentially serious cardiac complications in diabetic patients with CAN.

Recent research studies have proposed several mechanisms that may be implicated in the pathology of diabetic autonomic neuropathy (Table 1). Poor glycemic control appears to play a central role in several of these pathologic processes, but the degree of involvement and interrelationship among them all is not well understood. These proposed mechanisms are somewhat complex, and a comprehensive review is beyond the scope of this research article.

**Clinical Manifestations**
Synthesis of the literature reveals that loss of parasympathetic and sympathetic cardiac innervation may lead to several cardiac manifestations in diabetic patients. Many patients remain asymptomatic during the progression of CAN, whereas others are severely affected. It is still not well known whether patients with type 1 and type 2 diabetes experience the same degree of autonomic impairment, as there is a lack of evidence in the current literature. A brief discussion of cardiovascular manifestations follows.

- **Resting Tachycardia.** Resting tachycardia is commonly observed in diabetic patients with autonomic nervous system dysfunction. A resting heart rate of 90/min to 130/min is a known manifestation of CAN. In a recent study, resting heart rate was evaluated in type 1 diabetic patients with CAN. The results of this study revealed that diabetic patients with CAN experienced a significantly higher resting heart rate, 94/min, compared with diabetic patients without CAN, who exhibited a resting heart rate of only 79/min. This suggests that an increase in sympathetic activity may occur because of damage to parasympathetic nerve fibers. It is believed to occur before sympathetic impairment observed in CAN. According to the literature, dysfunction of the parasympathetic nerve system normally precedes sympathetic dysfunction in the progression of CAN. Resting tachycardia is usually seen as a late sign of parasympathetic nerve damage.

- **Exercise Intolerance.** Recent studies have shown that cardiac autonomic dysfunction can greatly impair the cardiovascular compensatory response to moderate exercise. As CAN progresses, both parasympathetic and sympathetic nervous systems are impaired, and as a result, heart rate, blood pressure, and cardiac output are simply unable to increase in response to exercise. A patient’s capacity to tolerate moderate exercise or stress is therefore limited, and the patient may experience symptoms of weakness, fatigue, and syncope.

- **Loss of Heart Rate Variability With Deep Breathing.**
Normally heart rate should increase by more than 15/min in response to deep breathing. In diabetic patients with CAN, however, the heart rate is mainly fixed and will usually increase less than 10/min.\textsuperscript{19} Heart rate variability, as seen on the electrocardiogram (ECG) as the R-R interval, is controlled by the autonomic nervous system and is dependent on parasympathetic activity.\textsuperscript{1} With the onset of cardiac autonomic nerve dysfunction, lack of heart rate variability with deep breathing is often seen. It is often one of the first and most commonly occurring symptoms in diabetic patients with CAN.\textsuperscript{3} A recent meta-analysis demonstrated a significant relationship between lack of heart rate variability and increased risk of silent myocardial ischemia and mortality in these patients.\textsuperscript{1} It has also been associated with intraoperative hypotension in diabetic patients with CAN during general anesthesia.\textsuperscript{20}

- **Orthostatic Hypotension.** The literature defines orthostatic hypotension as a decrease in systolic blood pressure of greater than 30 mm Hg or a decrease in diastolic blood pressure of greater than 10 mm Hg.\textsuperscript{2} Normally blood pressure decreases slightly with postural change, from supine to standing. This response is primarily regulated by the efferent sympathetic nerve fibers.\textsuperscript{6} Autonomic nerve dysfunction impairs the body’s ability to control blood pressure, causing substantial orthostatic hypotension in diabetic patients with CAN.\textsuperscript{6,21} Patients can experience symptoms such as weakness, fainting, dizziness, visual impairment, and syncope.\textsuperscript{2} The underlying disturbance is the lack of vasoconstriction as a result of sympathetic dysfunction and a decrease in norepinephrine release when changing from a supine to standing position.\textsuperscript{6,21}

A study, as recent as 2009, demonstrated that type 1 and type 2 diabetic patients experienced a significant decrease in orthostatic systolic blood pressure (88.9%) with advanced progression of CAN.\textsuperscript{22} Results were similar for both types of diabetes.\textsuperscript{22} Orthostatic hypotension is usually seen as a late complication and is usually indicative of a poor prognosis in diabetic patients with CAN.\textsuperscript{2} Many of these patients, however, appear to remain asymptomatic, even with a significant fall in blood pressure.\textsuperscript{6}

- **Silent Myocardial Ischemia or Infarct.** A meta-analysis of 12 cross-sectional studies showed a statistically significant relationship between CAN and painless ischemia in diabetic patients with CAN.\textsuperscript{1} The presence of afferent autonomic nerve dysfunction appears to decrease the sensitivity to myocardial ischemia by altering pain transmission, thus preventing prompt recognition of myocardial ischemia or infarct.\textsuperscript{1,2,19} Marchant and colleagues\textsuperscript{23} evaluated 22 diabetic patients and 30 nondiabetic patients during a treadmill stress test. All study subjects experienced ischemia during the test. Sixteen of them did not experience angina, and 10 of them were diabetic patients. It was later revealed that diabetic patients with silent ischemia had evidence of significant autonomic nerve dysfunction compared with symptomatic patients. This important finding suggests that CAN may cause silent ischemia in patients with diabetes.\textsuperscript{23} The underlying mechanisms of silent myocardial ischemia are complex and still not well understood by many researchers.\textsuperscript{2}

- **QT Abnormalities.** The QT interval on ECG indicates the duration of ventricular myocardial depolarization and repolarization.\textsuperscript{24} A QTc value greater than 440 ms is considered prolonged, according to the literature.\textsuperscript{10} Several research studies have found a direct relationship between CAN and prolonged QT interval in patients with diabetes mellitus who have autonomic dysfunction.\textsuperscript{10,15,16,25} As a result, these patients are predisposed to potential fatal ventricular arrhythmias such as torsades de pointes and sudden death.\textsuperscript{2} The underlying mechanism responsible for prolonged QT in these patients remains poorly understood. Some studies suggest that alterations in cardiac sympathetic innervation may possibly cause prolongation of the QT interval.\textsuperscript{2,19,26}

- **Intraoperative Cardiovascular Instability.** Diabetic patients with evidence of CAN are at higher risk of intraoperative cardiovascular instability and sudden cardiac death.\textsuperscript{6,14} Vasoconstriction and tachycardia are primary autonomic responses to vasodilating effects of general anesthesia. In patients with CAN, however, those compensatory mechanisms are altered, predisposing these patients to bradycardia, hypotension, and cardiac arrest during the perioperative period.\textsuperscript{6,14} Intraoperative cardiovascular instability experienced by these patients will be discussed further in the “Anesthetic Considerations” section of this article.

- **Hypertension.** Hypertension was also noted in the literature as a possible symptom of CAN. Boulton and colleagues\textsuperscript{19} explain that an increase in sympathetic activity may result as a consequence of parasympathetic nerve dysfunction, causing an increase in blood pressure. A recent study, however, was unable to prove a significant relationship between CAN and hypertension.\textsuperscript{25} There seems to be a lack of evidence in recent literature to substantiate a correlation. Further studies are needed to establish hypertension as a manifestation of CAN.

- **Sudden Death Syndrome.** There is a high risk of sudden death in diabetic patients with CAN, according to recent research. Silent ischemia and prolonged QT interval are possible explanations for sudden deaths in these diabetic patients.\textsuperscript{2,19,26}

All of these cardiac manifestations may be seen during the development and progression of CAN. They collectively contribute to a poor prognosis and a greater mortality risk among these patients.\textsuperscript{8}

**Cardiac Autonomic Neuropathy Testing**

There has been much research over the years on autonomic neuropathy testing in diabetic patients, but much debate remains as to which current method or methods
are best suited for the diagnosis of autonomic neuropathy. Detection of CAN in type 1 and type 2 diabetic patients is of great interest to anesthesia providers because of its potential clinical impact during general anesthesia. Given that CAN may be life-threatening and increase the risk of mortality of diabetic patients during surgery, its detection provides valuable information to the clinical assessment of these patients.1

The literature reports that clinical observation and physical examination alone are not effective in helping detect cardiac autonomic dysfunction in its early stages; therefore, standard autonomic testing should be used for the diagnosis of CAN.1,13 A series of cardiovascular reflex tests known as Ewing’s battery of tests has been extensively used in scientific research for the diagnosis of CAN over the last 3 decades.10,29 These noninvasive tests have been described as simple bedside tests that are effectively reliable with a sensitivity and specificity greater than 90%.10,13 Ewing’s autonomic tests will now be discussed briefly.

- **Heart Rate Response to Deep Breathing.** Heart rate variation with breathing is dependent on parasympathetic nerve activity. Patients in a supine position breathe deeply at a rate of 6/min, which produces a maximum heart rate variation. Electrocardiography is used to evaluate the heart rate. A difference in heart rate of greater than 15/min is considered normal, whereas less than 10/min is abnormal and indicative of cardiac parasympathetic dysfunction.13,19,29 This testing method is considered by many researchers as the most reliable test of CAN,1,13

- **Heart Rate Response to Valsalva Maneuver.** The Valsalva maneuver is dependent on sympathetic and parasympathetic cardiac nerve fibers.30 In this particular test, the patient is seated and blows into a mouthpiece at a pressure of 40 mm Hg for approximately 15 seconds.13 In most cases, reflex response to the Valsalva maneuver produces tachycardia and peripheral vasoconstriction during strain, with a subsequent increase in blood pressure and bradycardia after its release. In patients with CAN, the heart rate response is altered, and an abnormal decrease in blood pressure is seen with strain, with a slower recovery phase. These findings are indicative of parasympathetic and sympathetic nerve dysfunction.1,13,19,29

- **Heart Rate Response to Standing.** Normally the heart rate increases rapidly upon standing, reaching a maximal heart rate at the 15th beat after standing followed by reflex bradycardia at the 30th beat. The ratio between R-R interval at the 15th beat and R-R interval at the 30th beat as seen on ECG is referred to as the 30:15 ratio. This ratio is considered to be a measurement of cardiac parasympathetic function.30 In diabetic patients with CAN the 30:15 ratio is decreased. Only a gradual increase in heart rate is seen.1,13

- **Blood Pressure Response to Standing.** Orthostatic hypotension results from sympathetic nerve damage. Therefore, blood pressure response to standing is often used to assess sympathetic dysfunction.30 There is usually a small decrease in blood pressure when someone stands up from a supine position. In diabetic patients with CAN, however, sympathetic peripheral vasoconstriction is altered, causing an abnormal decrease in blood pressure. A diastolic blood pressure decrease greater than 10 mm Hg or systolic blood pressure decrease greater than 30 mm Hg within 2 minutes of standing is considered abnormal.1,13,19

- **Blood Pressure Response to Sustained Handgrip.** This test involves a handgrip to be maintained at the patient’s 30% maximal voluntary contraction using a handgrip dynamometer for 5 minutes.13 Effort sympathetic nerve fibers involved in sustained muscle contraction normally produce an increase in blood pressure, heart rate, and cardiac output as a result of increased peripheral resistance. The response is considered normal if diastolic blood pressure is increased greater than 16 mm Hg and is abnormal if the increase is less than 10 mm Hg. Patients with CAN usually experience only a slight increase in diastolic blood pressure.1,13,19

Two abnormal tests are required to establish the clinical diagnosis of CAN.16,29 Activity of both parasympathetic and sympathetic nerves is involved in all 5 autonomic tests just described. Changes in heart rate appear to be affected by cardiac parasympathetic dysfunction, whereas abnormal blood pressure changes are usually seen with more extensive sympathetic dysfunction.13 According to recent literature, heart rate response to deep breathing, Valsalva maneuver, and standing up (30:15 ratio) show the highest sensitivity in detecting CAN in diabetic patients.2 In a meta-analysis, several studies provided strong scientific evidence that these diagnostic tools are effective and useful in monitoring the progression of CAN in symptomatic and asymptomatic diabetic patients.1 Despite their extensive use in scientific research, the current literature fails to elaborate on the routine use and effectiveness of these tests in the nonresearch setting. Are these diagnostic tools really practical?

Recent research studies, however, argue that Ewing’s series of tests are impractical in the clinical setting, as they require patient cooperation and compliance that is not always feasible with pediatric and elderly patients.31 Other methods have been developed for the testing of CAN and appear to be gaining popularity in the assessment of autonomic nerve dysfunction. The noninvasive evaluation can be done with spectral analysis of heart rate variability. This modern technology utilizes a mathematical computerized approach (fast Fourier transform) to indirectly assess cardiac autonomic dysfunction. It assesses heart rate variability of diabetic patients with CAN by power spectral analysis using a series of consecutive R-R intervals.1,16,32 Heart rate amplitudes are presented.
as different oscillation frequencies and then analyzed.\(^2\)

The heart rate power spectrum is classified into low frequency of 0.04 to 0.15 Hz and high frequency of 0.15 to 0.4 Hz. High frequency analyzes parasympathetic activity while low frequency is a measurement of parasympathetic and sympathetic innervation.\(^1\)

Diabetic patients with CAN who present primarily parasympathetic dysfunction exhibit decreased or no high-frequency amplitudes, whereas patients with sympathetic dysfunction have decreased low-frequency amplitudes. In patients with severe CAN, there is an absence of all frequency amplitudes.\(^1,18\)

Spectral analysis method for assessing the cardiovascular nervous system appears to be a more sensitive tool in the detection of early stages of CAN by some researchers.\(^16,32\)

In addition, it does not require active participation from the patient, as it is performed at rest and demonstrates a high sensitivity of 99% and specificity of 100% in the early diagnosis of CAN.\(^16,31,32\)

Early identification of autonomic nerve dysfunction is crucial as progression causes irreversible autonomic nerve injury.\(^32\)

Despite all of the autonomic testing performed in scientific research, the current literature fails to elaborate on its usefulness and effectiveness in the nonresearch setting.

Future research studies are needed to demonstrate their reliability and accuracy in routine clinical practice. Lastly, monitoring and evaluation of prolonged QT interval could potentially provide useful information for the diagnosis of CAN, according to Krahulec et al.\(^16\)

The reliability of a prolonged QT interval on ECG as a diagnostic tool has yet to be established in the current research literature, however.

### Anesthetic Considerations

- **Preoperative Assessment.** Diabetic patients with evidence of CAN may present a major challenge to the anesthetist. Research studies have shown that CAN increases the risk of intraoperative cardiac events.\(^1,14\)

Therefore, a comprehensive preoperative assessment is essential for optimal anesthetic management of these patients. The preoperative medical history and physical assessment may provide useful information and reveal symptoms indicative of autonomic cardiac dysfunction such as loss of heart variability, exercise intolerance, orthostatic hypotension, and QT interval prolongation on ECG. The presence of these symptoms should caution the anesthetist of possible intraoperative hemodynamic instability.\(^14,33\)

A review of the preoperative ECG is important and may provide insightful information. As previously discussed, prolonged QT interval and loss of heart rate variability, as seen on ECG as R-R variation, have demonstrated an increase in the risk of cardiovascular complications during surgery as well as increased mortality in diabetic patients with CAN.\(^1,14\)

Furthermore, exercise tolerance can provide valuable information in regard to their cardiopulmonary function. Exercise intolerance could indicate possible dysfunction of the cardiac autonomic nervous system requiring further evaluation.\(^5\)

Some studies advocate preoperative CAN testing because of its sensitivity and effectiveness in detecting and diagnosing CAN in diabetic patients.\(^1,33\)

Screening of CAN preoperatively may be helpful to improve the management of diabetic surgical patients requiring general anesthesia.\(^2\)

Vinik and colleagues\(^1\) reported in their meta-analysis that the preoperative presence of 2 or more abnormal autonomic function tests in diabetic patients with CAN was associated with greater intraoperative hemodynamic changes and a higher incidence of sudden death in these patients. Despite this research evidence, it appears that screening for cardiac autonomic dysfunction in diabetic patients is not frequently performed in clinical practice.\(^1\)

Also noteworthy is the fact that cardiac manifestations exhibited by diabetic patients with CAN during general anesthesia could also potentially be influenced by home medications such as angiotensin-converting enzyme inhibitors, \(\beta\)-blockers, calcium channel blockers, and insulin.\(^34\)

The incidence of postinduction hypotension and bradycardia may be increased with the concomitant use of these medications (Table 2).\(^34\)

- **Induction and Maintenance of General Anesthesia.**

Type 1 and type 2 diabetic patients with CAN are at higher risk of cardiac complications and mortality during surgery than are nondiabetic patients.\(^2\)

Knowing these potential complications, the anesthetist needs to be cognizant of and prepared to effectively manage sudden intraoperative situations that may arise during general anesthesia. Vigilant monitoring of potential cardiovascular abnormalities is essential for optimal intraoperative anesthetic management of diabetic patients with CAN.\(^14\)

Diabetic patients with CAN experience a higher risk of intraoperative cardiovascular instability.\(^1,14\)

In a study involving ophthalmologic surgery, researchers demonstrated that diabetic patients with CAN experienced a more profound decrease in heart rate and arterial blood pressure during induction of anesthesia compared with nondiabetic individuals. The mean arterial blood pressure (MAP) decreased an average of 30 mm Hg during induction. The drop in MAP was significantly greater than in the nondiabetic group. The diabetic subjects also reported less tachycardia and hypertension after tracheal

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**Table 2. Perioperative Evaluations for Diabetic Cardiac Autonomic Neuropathy**

| 1. Review preoperative electrocardiogram. |
| 2. Evaluate preoperative exercise tolerance. |
| 3. Review medical history. |
| 4. Review physical assessment. |
| 5. Review home medications. |
| 6. Review past surgical history. |
| 7. Perform preoperative cardiac autonomic neuropathy testing. |

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intubation and extubation compared with nondiabetic subjects. Their data showed only a slight increase in MAP of 7 mm Hg during tracheal intubation, which was significantly less than the control group. In addition, 35% of diabetic patients with CAN required vasopressors such as phenylephrine to treat hypotension, whereas only 5% of the control group required treatment. The findings suggest that alterations to the cardiac autonomic fibers prevent compensatory mechanisms such as vasoconstriction and increased heart rate to respond to the vasodilating effects of general anesthesia. In this particular study, hypotension occurred most frequently after tracheal intubation and before surgical stimulation. There has been strong evidence in several studies that intraoperative vasopressor support is needed more often in diabetic patients with CAN than those without CAN.

Cardiac autonomic dysfunction can be greatly affected by anesthetic drugs used during general anesthesia. The literature suggests that induction or maintenance of anesthesia with an induction agent such as etomidate and opioids may produce less hemodynamic instability in diabetic patients with CAN. There is a significantly higher risk of hypotension with induction drugs such as thiopental and propofol; however, no specific anesthesia drug or volatile gas has been shown to be more advantageous in patients with diabetic CAN.

There have been published reports of unexpected occurrences of intraoperative bradycardia and hypotension during general anesthesia not responsive to intravenous (IV) administration of atropine and ephedrine in diabetic patients with CAN. Intravenous epinephrine proved to be the most effective treatment in the successful resuscitation of these patients. The lack of heart rate response to atropine suggests the presence of sympathetic nervous system dysfunction. Sudden deaths have also been reported during general anesthesia in diabetic patients with CAN. In one case report bradycardia suddenly developed in an elderly patient with diabetic CAN following muscle relaxant therapy with IV glycopyrrolate and neostigmine. The patient was, however, responsive to IV epinephrine and cardiac compressions.

Additionally, diabetic patients with CAN are at significantly increased risk of silent ischemia or infarct as previously discussed. Vigilant monitoring of ECG, heart rate, and blood pressure, as well as prompt treatment of hypotension, during general anesthesia are of utmost importance during the perioperative management of these patients. Invasive hemodynamic monitoring may be necessary depending on the severity of CAN or the nature of the surgical procedure.

Postoperative Care. The postoperative phase of anesthesia can be a period of great hemodynamic instability for diabetic patients. The coexistence of CAN, however, can greatly increase their risk of severe cardiac complications. Postoperative cardiopulmonary arrest and even deaths have been documented in diabetic patients with CAN. In a small prospective study, Charlson and colleagues showed that 7% of diabetic patients with 2 or more abnormal autonomic function tests experienced postoperative cardiopulmonary arrest or death. This finding suggests that all patients with evidence of CAN should be closely monitored for potential postoperative cardiac events.

Summary

Many diabetic patients will inevitably undergo some type of surgical procedure during their lifetime. Diabetic patients with coexisting CAN will be a great challenge to the anesthetist. Patients with either type of diabetes mellitus who have coexisting cardiac autonomic dysfunction are at greater risk of intraoperative hemodynamic instability, as well as other serious or fatal cardiac complications during general anesthesia. A good understanding of the pathophysiology process, clinical manifestations, autonomic testing, and potential intraoperative complications is necessary for effective anesthesia management of these patients. A comprehensive preoperative assessment and vigilant monitoring are of great importance for a successful outcome. The anesthetist must be fully prepared to react promptly and appropriately to prevent potential morbidity and mortality in diabetic patients with CAN.

Great progress has been made over the years in the research of autonomic nerve dysfunction. However, much still remains unknown about this serious complication of diabetes mellitus. Future research will hopefully provide the evidence needed to prevent the progression and fatal events experienced by the many diabetic patients who have CAN.

REFERENCES


