Journal of Bodywork & Movement Therapies 32 (2022) 163–170

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Diagnostic Methods

Cardiac autonomic neuropathy and physical therapy: A case report

Germaine Herman [a, b, *], Sara Zehr [a], Raymond Butts [c, d], James Dunning [e, f]

[a] Eskenazi Health, Indianapolis, IN, USA
[b] Fellow-in-training, American Academy of Manipulative Therapy, USA
[c] Research Physical Therapy Specialists, Columbia, SC, USA
[d] American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, USA
[e] Montgomery Osteopractic Physical Therapy and Acupuncture, Montgomery, AL, USA
[f] American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy, USA

ARTICLE INFO

Article history:
Received 20 September 2021
Received in revised form
3 March 2022
Accepted 15 May 2022

Keywords:
Cardiac autonomic neuropathy
Physical therapy
Emergency department
Diabetes mellitus
Case report

ABSTRACT

Cardiac autonomic neuropathy (CAN) is a complication of diabetes mellitus, which imposes significant functional limitations and at times, sudden death. In an evolving healthcare landscape, physical therapists are assuming greater clinical responsibility and thus must be aware of this potential complication and tailor the plan of care appropriately. The purpose of this case report is to highlight the need for increased awareness of CAN among physical therapists in order to improve screening, diagnosis, and treatment. A 41-year-old Spanish-speaking male with uncontrolled type 2 diabetes arrived to the emergency department (ED) with dizziness and syncope leading to an inability to walk, work, or complete community service hours. After evaluation by the ED physical therapist, the patient was admitted for further work-up and diagnosed with CAN. After a short hospital course, the patient returned home symptomatic, fell, and was re-admitted the same day. Throughout the second hospital stay, the patient's symptoms improved with robust medical management allowing physical therapy treatment and functional independence for safe discharge home. Additionally, patient-specific goals were met with the help of social work and the medical team. Clinical knowledge of CAN for the non-cardiopulmonary specialist physical therapist is lacking. As physical therapists prepare to be advanced practice providers in a rapidly evolving healthcare landscape, increasing awareness has the potential to lead to improved screening, diagnosis, and treatment of persons with CAN, a severe complication of diabetes.

1. Background

Approximately 30.3 million people in the United States have diabetes mellitus, with one in four people undiagnosed (Centers for Disease Control and Prevention, 2017). Cardiac autonomic neuropathy (CAN) is a common, yet serious complication of diabetes mellitus that has no cohesive treatment algorithm (Serhiyenko and Serhiyenko, 2018; Agashe and Petak, 2018; Spallone et al., 2011). Given the prevalence of diabetes and its complications and, in light of the evolving role of the physical therapist in the present healthcare landscape, physical therapists must be able to recognize CAN and intervene appropriately.

Autonomic neuropathies are an irreversible complication of diabetes that affect multiple organ systems and pose a significant challenge to a person's quality of life and medical management (Spallone et al., 2011; American Diabetes Association, 2019; Vinik et al., 2013). CAN is a specific type of diabetic autonomic neuropathy characterized as a denervation of the cardiovascular autonomic nervous system (Vinik et al., 2013). Symptoms of CAN may include dizziness, syncope, poor exercise tolerance, erratic blood pressure, headaches, and constant fatigue (Serhiyenko and Serhiyenko, 2018; American Diabetes Association, 2019). In its early stages, the disease may be silent presenting only as a decrease in heart rate variability (Serhiyenko and Serhiyenko, 2018; Vinik et al., 2013). As the disease progresses, signs and symptoms become more pronounced and include tachycardia, a fixed heart rate, orthostatic hypotension without an increase in heart rate, postural hypotension and syncope, asymptomatic hypoglycemia, electrocardiogram changes, silent myocardial infarction, and sudden death (Serhiyenko and Serhiyenko, 2018; American Diabetes Association 2019; Vinik et al., 2013). CAN is associated with multiple organ systems and is known to have a high morbidity and

* Corresponding author. Eskenazi Health, Indianapolis, IN, USA.
E-mail address: germaine.herman@eskenazihealth.edu (G. Herman).

https://doi.org/10.1016/j.jbmt.2022.05.013
1360-8592/

mortality rate, with a relative risk of 3.65 and 6.2 as reported in separate meta-analyses (Agashe and Petak, 2018; Spallone et al., 2011; Vinik et al., 2013; Maser et al., 2003; Vinik and Ziegler, 2007).The presence of CAN increases with length of disease; it is hypothesized that up to 60% of persons having type 2 diabetes for at least 15 years may present with symptoms of CAN (Pop-Busui et al., 2017).

When evaluating for CAN, common differentials include but are not limited to: peripheral vascular syndromes, various other central neurological diagnoses, genitourinary syndromes, metabolic syndromes, and cardiorespiratory diseases (Balcıoğlu and Müderrisoğlu, 2015). However, the gold standard for the diagnosis of CAN are cardiovascular autonomic reflex tests (CARTs), also known as Ewing's battery, developed by Ewing and Clarke in the 1970's (Serhiyenko and Serhiyenko, 2018; Spallone et al., 2011; Duque A et al., 2021). These five bedside tests assess sympathetic and parasympathetic cardiac function in persons with suspected CAN (Andersen et al., 2018); they are sensitive, specific, reproducible, standardized and should be performed by medical practitioners trained in their implementation (Table 1) (Spallone et al., 2011a,b). Because of its clinical and prognostic significance and ease of applicability, the orthostatic hypotension test (Spallone et al., 2009) should be applied yearly by all medical practitioners in persons with diabetes, regardless of the presence of symptoms (Spallone et al., 2011). In this test, the patient's blood pressure is measured after 5 minutes in supine and again after 1 and 2 minutes of standing and is considered abnormal if there is a systolic decrease $\geq$30 mmHg between the supine and the lowest standing value (Spallone et al., 2011a,b). The presence of one positive CART's test indicates a possible diagnosis whereas two positive tests are needed for a definitive diagnosis (Serhiyenko and Serhiyenko, 2018; Spallone et al., 2011). Diagnosis criteria is based on the strong association between CAN and risk of mortality: in the presence of one abnormal CART the pooled relative risk is 1.20 (1.02–1.41; $P = 0.03$), in the presence of 2 or more abnormal tests the pooled relative risk is 3.45 (95% CI 2.66–4.47; $P < 0.001$) (Maser et al., 2003)). The presence of orthostatic hypotension in addition to any one positive CARTs test indicates severe disease (Serhiyenko and Serhiyenko, 2018; Maser and Lenhard, 2005). The feasibility of CART's tests has recently been called into question and more up-to-date tools such as nuclear imaging are under consideration as this may increase the sensitivity of CART's (Duque et al., 2021). When using myocardial scintigraphy as a reference standard a cutoff score of two or more abnormal CART's tests proved highly sensitive in the diagnosis of CAN (Sn 100%, Sp 33%) (Didangelos et al., 2018). In the absence of CART's testing, CAN is a diagnosis of exclusion (Vinik et al., 2013; Balcıoğlu and Müderrisoğlu, 2015). Because CAN is often mis-diagnosed, the importance of diagnosis must be overstated (Spallone et al., 2011). A clinical diagnosis of CAN allows the implementation of timely and possibly life-sparing therapies, enhances provider and patient motivation to correct glycemic abnormalities and cardiac risk factors and provides necessary information for disease management, such as the safe implementation of exercise (Boulton et al., 2005).

To date, no consensus nor evidence-based treatment algorithm exists for CAN (Serhiyenko and Serhiyenko, 2018). Treatment is multifaceted and interdisciplinary and includes nutrition and lifestyle changes in addition to medication management with emphasis on glycemic control and modification of cardiac risk factors (Serhiyenko and Serhiyenko, 2018; Vinik et al., 2013). If orthostatic hypotension is present, non-pharmacological interventions such as fluid volume replacement, liberal salt intake and compression wear are used in conjunction with pharmacological care. Slowly titrated sympathomimetics are the first drugs of choice in the management of orthostatic hypotension (Serhiyenko and Serhiyenko, 2018).

Physical therapists across all settings must be able to screen and treat persons with CAN (Lebec and Jogodka, 2009; Vinik et al., 2013). Although changes in state practice acts have expanded the scope of direct access to physical therapy Garrity et al., 2020; Magel et al., 2020; Hon et al., 2021), variability remains (American Physical Therapy Association, 2016). Some states allow unrestricted direct access, that is the evaluation and management of patients without a physician referral, while others allow provisional or limited direct access (American Physical Therapy Association, 2016; Mabry et al., 2020). Physical therapists have successfully acted as advanced practice providers in the United States military for many decades (McLean, 2006; Mabry et al., 2020; Greathouse et al., 1994), evaluating and managing patients without a physician referral, ordering imaging and prescribing medication, performing thrust manipulations, and dry needling (Mabry et al., 2020). However, this broad scope of practice remains elusive in civilian settings (Mabry et al., 2020). For instance, physical therapists employed in emergency departments (ED) are prohibited by federal law from providing triage and initial medical evaluation (Centers for Medicare and Medicaid Services, 2021) and consultation of the ED PT occurs only after clearance from the referring ED provider (Matifat et al., 2019; Kim et al., 2018). However, this physician-centric model is expected to change (McLean, 2006; Mabry et al., 2020; Hon et al., 2021). In light of projected physician shortages (American Academy of Medical Colleges, 2021) and rising healthcare costs (Dieleman et al., 2017) physical therapists must be

Table 1
Cardiovascular autonomic reflex tests (Agashe and Petak, 2018; Serhiyenko and Serhiyenko, 2018; Spallone et al., 2011; Pafili et al., 2015).

Test	Administration	Response
Deep breathing heart rate test (Sn 19%, Sp 98%, PPV 88%, NPV 57%, OR 2.34)	Patient supine, patient maximally breathes in and out 6 breaths per minute with use of metronome. Heart rated is monitored via EKG.	Normal response: Difference in heart rate >15 bpm. Abnormal response: A difference in heart rate <10 bpm.
Lying to standing heart rate test (Sn 96%, Sp 65%, PPV 72%, NPV 95%, OR 44.07)	With continuous EKG monitor: Measure R-R interval at beats 15 and 30 after rapid standing from supine position	Result is expressed by the 30:15 ratio. Longest R-R interval to the shortest R-R interval ratio after standing up. Normal is > 1.03, borderline is 1.01–1.03
Valsalva maneuver heart rate test (Sn 62%, Sp 92%, PPV 76%, NPV 85%, OR 18.56)	With continuous EKG monitor: Patient forcefully exhales into manometer to 40mHg for 15 seconds. Measure longest and shortest R-R intervals	Longest R-R interval to the shortest R-R interval ratio with maximal expiration. Normal is > 1.2, borderline is 1.11–1.2
Orthostatic hypotension test (Sn 51%, Sp 71%, PPV 62%, NPV 61%, OR 2.50)	Measure systolic BP of patient in supine and after 1 and 2 minutes of standing. The last BP taken in supine is compared with the lowest value in standing.	Typical response is fall in systolic of <10 mmHg, borderline is fall of 10–29 mmHg, and abnormal is fall of >30 mmHg
Diastolic blood pressure response to isometric exercise (Sn 64%, Sp 75%, PPV 70%, NPV 69%, OR 5.22)	Establish maximum handgrip on dynamometer. Patient squeezes hand dynamometer at 30% maximum for 5 minutes.	Typical response for diastolic BP is a rise of >16 mmHg on contralateral arm, borderline is 11–15 mmHg

Abbreviations: EKG, electrocardiogram; bpm, beats per minute; mmHg, millimeters mercury; BP, blood pressure.

Table 2
Vitals.

Day Service/Unit	Supine BP and HR	Seated BP and HR	Standing BP and HR
9/10/18	147/92 mmHg	119/85 mmHg	89/57 mmHg[a]
ED PT evaluation	94bpm	96bpm	106bpm[a]
9/11/18	122/75 mmHg	107/70 mmHg	92/64 mmHg[a]
CDU	85bpm	95bpm	105bpm[a]
9/12/18	132/83 mmHg	94/59 mmHg	59/32 mmHg[a]
CDU	89bpm	95bpm	109bpm[a]
9/13/18	106/59 mmHg	70/47 mmHg	Standing not tolerated
Inpatient PT evaluation	83bpm	86 bpm	
9/14/18	NT	124/74 mmHg	Standing not tolerated
PT treatment			
9/15/18	141/68 mmHg	NT	NT
2nd ED visit	107bpm		
9/16/18	109/77 mmHg	NT	NT
PT withheld	92bpm		
9/17/18	111/70 mmHg	89/59 mmHg	48/33[a]
Inpatient PT evaluation	99 bpm	104bpm	104 bpm[a]
9/19/18	120/75 mmHg	83/57 mmHg	62/29 mmHg
PT treatment	98bpm	103bpm	106bpm
9/20/18	117/75 mmHg	103/62 mmHg	64/42 mmHg
PT treatment	84bpm	88bpm	98bpm
9/20/18 after ambulating 400ft	NT	NT	83/56 mmHg 98bpm
9/21/18	NT	125/80 mmHg	80/54 mmHg
PT treatment		95bpm	100bpm

Abbreviations: BP, blood pressure; HR, heart rate; ED, emergency department; PT, physical therapist; mmHg, millimeter of mercury; bpm, beats per minute; CDU, clinical decision unit; ft, feet; NT, not tested.
[a] Denotes crouched standing to avoid syncopal episode.

prepared to take on the role of advanced practice providers by assuming greater clinical accountability (Mabry et al., 2020) through autonomous practice (Sandstrom, 2007), appropriate medical screening (Mount et al., 2016), and successful management of patients with multiple complex chronic medical conditions (Murphy et al., 2005; Lebec and Jogodka, 2009) all-the-while remaining rooted in a team-based approach to medical care (Mabry et al., 2020). In light of this evolving healthcare landscape, increased knowledge of CAN among physical therapists across all settings is necessary for differential diagnosis and appropriate medical referral of a condition frequently mis-diagnosed (Spallone et al., 2011) as well as safe and effective implementation of rehabilitation paradigms in a population at risk for disabling disease and sudden death (Boulton et al., 2005; Maser et al., 2003; Vinik and Ziegler, 2007).

The following case underscores the role of the physical therapist in the medical care of a person with CAN, as well as accentuates the perils of failure to recognize this type of neuropathy. Although this case takes place in a physician-centric model of care, its lessons can be extended to all physical therapists preparing to be advanced practice providers in a rapidly evolving healthcare landscape. Thus, the purpose of this case report is to highlight the need for physical therapists' awareness regarding the screening, diagnosis, and treatment of CAN, a severe complication of diabetes.

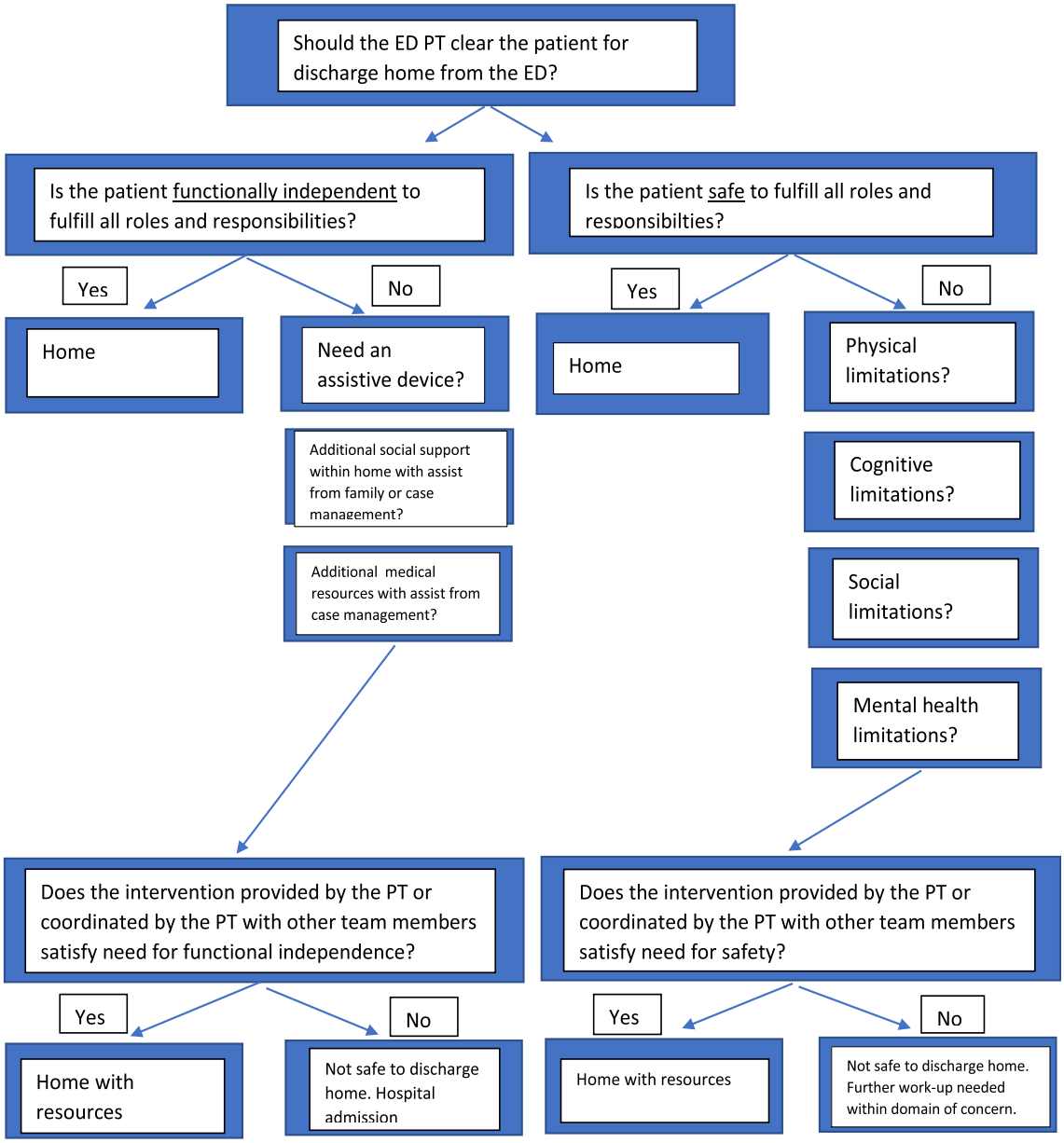
2. Case description

A 41-year-old Spanish-speaking male with a past medical history of hypertension, hyperlipidemia, and type 2 diabetes mellitus presented to the emergency department (ED) with complaints of dizziness and syncope for 8 months. His last medical follow-up was one year prior, during which his hemoglobin A1c was 12.5%. It is unknown if he adhered to his listed daily medications, which included: insulin, pravastatin, and lisinopril. Per chart review, multiple provider notes mention that patient frequently confused his medication dosing. The ED work up was notable for hyperglycemia, with a point-of- care glucose of 262 mg/dL, and tachycardia at rest as well as a normal chest x-ray, head computed tomography, basic metabolic panel, complete blood count and thyroid stimulating hormone. The ED physician referred the patient to the ED staff PT for a safety evaluation and with the expectation that the ED PT would provide disposition recommendations or request further assessment if warranted (Ferreira et al., 2018).

During the initial interview with the PT, the patient reported syncopal episodes multiple times a week, dizziness with upright postures, and syncope upon near-standing leading to an inability to walk or work construction. He maintained independence with activities of daily living as long as he was sitting or walking in a crouched position, including navigating five stairs to his basement living quarters. He denied any red flags, as well as alcohol, tobacco or illicit drug use. He explained that, six months prior, he was found by police parked on the roadside slouched over his steering wheel due to worsening symptoms and was cited for drunk driving after being unable to fully stand to complete sobriety testing. As an undocumented person, he was sent to an immigration center for 6 months before being able to post his bond. His goal for the ED visit, therefore, was to provide his probation officer with a physician's letter detailing his inability to complete community service hours related to this citation.

Upon ED PT arrival to the patient's room, he was lying comfortably in supine and appeared thin, pale, and with normal muscle bulk. Examination in supine revealed intact sensation, myotomes, coordination, tone, and reflexes for all extremities. Passive and active joint mobility of all extremities and cranial nerve screens were normal. He performed bed mobility asymptomatically, experienced constant dizziness in sitting, and did not tolerate standing due to feeling like he was going to "pass out". In supine and sitting, tests performed to rule out central and peripheral vestibular causes of dizziness were unremarkable. He ambulated with dizziness, maintaining a crouched position, while holding

Table 3
Emergency department physical therapist's decision-making tree within a physician-centric model of care.



items for stability. Vitals demonstrated orthostatic hypotension (fall in systolic ≥30 mmHg), and fixed tachycardia (Table 2). The ED physical therapist determined that symptoms were attributable to a systemic dysfunction of unknown etiology. Due to pre-syncopal symptoms, unstable vitals, and orthostatic hypotension, the ED physical therapist deemed the patient unsafe for discharge home and referred the patient back to the emergency medicine physician recommending further workup (Table 3).

The patient remained in the ED for further observation and symptom control. He received 6L of intravenous fluids over a 48-h period, but was eventually admitted due to ongoing symptomatic orthostatic vitals. On the day of admission, neurology, cardiology, endocrinology, and internal medicine teams diagnosed CAN based off of exclusion of various other diseases and the presence of severe orthostatic hypotension with uncontrolled diabetes mellitus. The medical team then initiated sympathomimetics and insulin titration, recommended liberal caffeine and salt intake, hydration, and advised rising slowly. On hospital admission day one, PT evaluated the patient but deferred ambulation due to unstable vitals; he was, however able to transfer bed to chair with stand-by assistance. On hospital admission day two, the medical team entered their discharge summary and during physical therapy treatment the patient performed wheelchair mobility 300 feet independently with complaints of dizziness. The PT recommended the patient discharge home at wheelchair level with intermittent assistance as needed. Five days after the initial ED visit, on hospital admission day three, the patient discharged home symptomatic, with assistive devices to maximize safety, but without needed medical/legal paperwork (Table 4).

3. Outcomes

Six hours after discharge, the patient returned to the ED reporting syncope upon standing, in spite of rising slowly as

Table 4
Timeline.

Date		Medical Course	Physical Therapy
9/10/18	First ED visit.	Transferred to an observation area.	Physical therapy evaluated patient and deemed unsafe to discharge home. ED PT coordinates with ED social work for legal needs.
9/11/18	In observation:	Further medical workup and 4 L of IV fluids with ongoing orthostatic vitals and syncope.	
9/12/18	In observation:	Additional 2L IV fluids given. Admitted to hospital for ongoing unstable vitals and syncope. Medicine initiates titration of sympathomimetics and insulin	ED PT and social work coordinate with inpatient team regarding patient-specific goals.
9/13/18	HAD 1.	Medication titration continues.	During physical therapy patient is only able to sit edge of bed and performs squat transfers to bedside chair. Vitals are unstable.
9/14/18	HAD 2.	Medication titration continues. Medical team enters discharge summary.	Patient performs wheelchair mobility 300 ft at Mod I. Physical therapy recommends home at wheelchair level with intermittent assistance; no standing, gait, nor stairs attempted
9/15/18	HAD 3.	Patient discharges home in a wheelchair with assistive devices and updated medications, with ongoing unstable symptoms and without legal/ medical paperwork for probation officer.	
9/15/18	Second ED visit.	Six hours after discharge patient returns to the ED after syncopal episode. Patient is re-admitted to hospital. Medicine consults Endocrinology, PT and Social Work.	
9/16/18	HRAD 1.	Sympathomimetics and insulin titration initiated.	Physical therapy evaluation deferred due to unstable vitals, held at MD request.
9/17/18	HRAD 2.	Medication titration continues.	Physical therapy evaluation reveals continued OH and inability to ambulate.
9/18/18	HRAD 3.	Continued titration of sympathomimetics.	Social work confirms legal needs and faxes legal/medical paperwork to probation officer
9/19/18	HRAD 4.	Sympathomimetics titrated.	Patient tolerates 2 minutes of standing with ongoing unstable vitals and near syncope.
9/20/18	HRAD 5.	Sympathomimetics titrated.	Patient is able to walk 400ft independently and ascend/descend 7 steps with orthostatic vitals and dizziness, but no syncope.
9/21/18	HRAD 6.	Discharged home with adjusted medications.	Patient is asymptomatic, walking 400 ft independently and negotiating 1 flight of stairs.

Abbreviations: ED, emergency department; PT, physical therapist; HAD, hospital admission day; IV, intravenous; CAN, cardiac autonomic neuropathy; HRAD, hospital re-admission day; Mod I, modified independent.

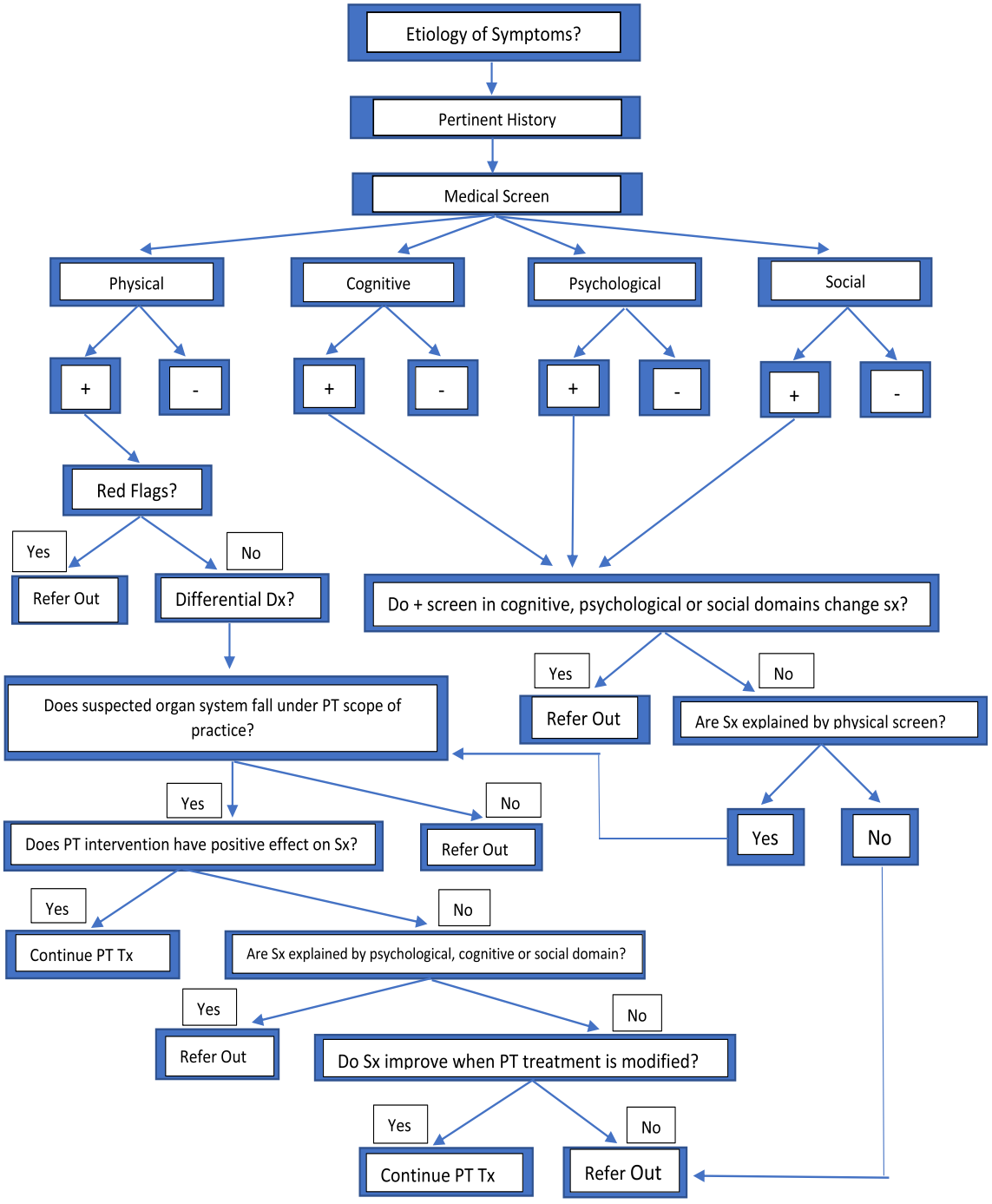
previously instructed. The patient was re-admitted to the hospital where the medicine teams titrated sympathomimetics daily with close monitoring and re-consulted physical therapy. On hospital re-admission day one inpatient physical therapy deferred evaluation due to unstable vitals. During the physical therapy evaluation on hospital re-admission day two the patient demonstrated ongoing orthostatic hypotension leading to the inability to ambulate. During physical therapy on re-admission day four the patient tolerated 2 min of standing with dizziness, orthostatic vitals, and near syncope. The next day the patient walked 400 feet independently and negotiated seven steps over the course of two separate therapy sessions with dizziness, but no syncope. On readmission day six, the patient was discharged home asymptomatic with all necessary medical paperwork for pending legal proceedings and adjusted medications; he was able to safely ambulate and negotiate stairs (Table 4).

4. Discussion

Physical therapists should tailor the medical screening portion of their examination with persons at risk for CAN so as not to overlook this common complication of diabetes. In particular, persons with type 2 diabetes with a history of poor glycemic control (hemoglobin A1c >7%), and/or cardiac risk factors require focused inquiry (Agashe and Petak, 2018; Spallone et al., 2011; Pop-Busui et al., 2017). Although the present case study depicts a male patient, the literature does not suggest that sex is an increased risk factor for CAN (Kempler et al., 2002). The physical therapist should inquire about common symptoms of CAN such as lightheadedness, dizziness, visual impairment, weakness or syncope with standing (Spallone and Ziegler et al., 2011; Andersen et al., 2018; Balcıoğlu and Müderrisoğlu, 2015). Additionally, the physical therapist should assess vital signs for tachycardia at rest and measure blood pressure gauging for systolic and diastolic abnormalities and apply the orthostatic hypotension test (Serhiyenko and Serhiyenko, 2018; Vinik et al., 2013; Pop-Busui et al., 2017; Spallone et al., 2011). In light of a positive medical screen suspicious for CAN, or in this instance when the physical therapist encountered highly irregular and unfamiliar signs and symptoms in a person with diabetes, the physical therapist should refer the patient for further work-up (Spallone et al., 2011). This case evolved within a physician-centric model of care. However, whether operating within or outside of physician-centric models of care, physical therapists are tasked with unique decision-making paradigms that, in the end, should lead to equivalent outcomes. (Table 3, Table 5).

Once a diagnosis of CAN is confirmed, physical therapists must be vigilant of the pathophysiological abnormalities of CAN when prescribing physical activity and lifestyle education (Serhiyenko and Serhiyenko, 2018; Harris-Hayes et al., 2020). When working with patients with CAN-induced orthostatic hypotension, physical therapists in the inpatient setting should be aware that, with failure of non-pharmacological interventions, treatment of orthostatic

Table 5
Proposed decision-making tree for physical therapists in non-physician-centered facilities.



hypotension is entirely dependent on the administration of slowly titrated sympathomimetic medications until symptoms stabilize (Agashe and Petak, 2018). Then, to optimize safety prior to discharge home, physical therapists should progress patients with orthostatic hypotension from recumbent to upright exercise forms, ensuring tolerance to all functional positions (Serhiyenko and Serhiyenko, 2018; Pop-Busui et al., 2017). Considering the case at hand, the physical therapy team upon re-admission carefully considered patient orthostatic vitals and symptomatology during evaluation and treatment, ensuring a safe progression of movement and tolerance to all functional positions before clearing for discharge home. In contrast, during initial hospitalization, a lack of knowledge of CAN management and treatment led to an apparently premature discharge at wheelchair level, despite the patient's specific needs to stand, walk, navigate stairs, work, and complete community service hours. Arguably, the aforementioned knowledge deficits jeopardized the PT's clinical recommendations leading to inadvertent consequences: a preventable fall, a hospital re-admission, and unmet patient-specific goals (Table 4).

Physical therapists should consider the following general

guidelines when treating persons with CAN. Ensure symptomatic patients, with or without abnormal CARTs, are up-to-date with recommended annual CARTs testing to evaluate for disease progression (Spallone et al., 2011). Preliminary evidence suggests aerobic exercise may improve glycemic control, cardiorespiratory fitness and autonomic function in persons with CAN (Bhati et al., 2018; Röhling et al., 2017). However, little else is known on the efficacy of exercise mode or training parameters (Bhati et al., 2018). Therefore, avoid implementing any exercise routine above functional baseline in patients with suspected or known disease until receipt of cardiovascular clearance including an exercise stress test (Serhiyenko and Serhiyenko, 2018; Spallone et al., 2011). Monitor exercise intensity using the heart rate reserve method or rate of perceived exertion (Röhling et al., 2017; Serhiyenko and Serhiyenko, 2018). Educate on the risks of exercise in extreme environments (eg heat or cold), rebound hypotension after high intensity exercise, and the benefits of aerobic exercise to minimize disease progression (Bhati et al., 2018; Serhiyenko and Serhiyenko, 2018; Agashe and Petak, 2018). Because joint manipulation and dry needling have a known effect on autonomic nervous system activity, physical therapists should exert caution and consider severity and stability of disease when utilizing these techniques (Sillevis et al., 2021; Picchiottino et al., 2019; Savva et al., 2014). To date there are no studies evaluating these techniques in persons with CAN. Unfortunately, as pertains to this case, the patient was not offered outpatient physical therapy in spite of persistent functional incapacity with work and probation-related activities. It appears outpatient was not suggested due to a lack of awareness and knowledge surrounding physical therapy treatment efficacy and CAN.

Given the rise of the diabetes epidemic and in light of an evolving healthcare landscape, CAN is no longer a problem reserved for the cardiorespiratory specialist, but must be familiar to the entire healthcare team. In preparation for their role as advanced practice providers, it is imperative that physical therapists across the continuum of care obtain a more thorough understanding of CAN for the purposes of differential diagnosis and medical referral for timely and accurate diagnosis (Spallone et al., 2011) as well as safe and effective treatment implementation in a population at high risk for disease progression and sudden death (Boulton et al., 2005; Maser et al., 2003; Vinik and Ziegler, 2007). Future research could assess the impact of physical therapy-specific treatments on quality of life in persons with CAN, the development of CAN-specific functional outcome measures, and the efficacy of mode and exercise guidelines on CAN disease progression.

Clinical relevance

- In an evolving healthcare system, physical therapists across all settings must have greater awareness of CAN for improved patient-centered outcomes.
- Physical therapists may immediately implement screening and management strategies for CAN after learning clinical tests and treatment guidelines.

Patient consent

Patient written consent obtained and retained by the author.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Germaine Herman: Conceptualization, Investigation, Supervision, Writing – original draft, Writing – review & editing, Project administration. **Sara Zehr:** Writing – review & editing, Visualization. **Raymond Butts:** Writing – review & editing. **James Dunning:** Writing – review & editing.

Declaration of competing interest

Germaine Herman and Sara Zehr are part-time employees at Eskenazi Health. The remaining authors have no conflicts of interest to declare.

Acknowledgement

We would like to acknowledge Lynn McKinnis PT, DPT for her expertise, mentorship and encouragement in the development of this paper.

References

Agashe, S., Petak, S., 2018. Cardiac autonomic neuropathy in diabetes mellitus. Methodist DeBakey Cardivascular J. 14, 251–256. https://doi:10.14797/mdcj-14-4-251.

American Academy of Medical Colleges, 2021. The Complexities of Physician Supply and Demand: Projections from 2019 to 2034. Washington, DC. https://www.aamc.org/media/54681/download.

American Diabetes Association, 2019. Standards of medical care in diabetes-2019: summary of revisions. Diabetes Care 42, S124–S138. https://doi:10.2337/dc19-Srev01.

American Physical Therapy Association, 2016. Levels of patient access to physical therapist services in the US. Updated. https://www.apta.org/contentassets/4daf765978464a948505c2f115c90f55/direct-access-by-state-map.pdf. (Accessed 26 February 2021).

Andersen, S.T., Witte, D.R., Fleischer, J., Andersen, H., Lauritzen, T., Jørgensen, M.E., Jensen, T.S., Pop-Busui, R., Charles, M., 2018. Risk factors for the presence and progression of cardiovascular autonomic neuropathy in type 2 diabetes: ADDITION-Denmark. Diabetes Care 41, 2586–2594. https://doi.org/10.2337/dc18-141.

Balcıoğlu, A.S., Müderrisoğlu, H., 2015. Diabetes and cardiac autonomic neuropathy: clinical manifestations, cardiovascular consequences, diagnosis and treatment. World J. Diabetes 6, 80–91. https://doi.org/10.4239/wjd.v6.i1.80.

Bhati, P., Shenoy, S., Hussain, M.E., 2018. Exercise training and cardiac autonomic function in type 2 diabetes mellitus: a systematic review. Diabetes Metabol. Syndr. 12, 69–78. https://doi.org/10.1016/j.dsx.2017.08.015.

Boulton, A.J., Vinik, A.I., Arezzo, J.C., Bril, V., Feldman, E.L., Freeman, R., Malik, R.A., Maser, R.E., Sonsenko, J.M., Ziegler, D., American Diabetes Association, 2005. Diabetic neuropathies: a statement by the American diabetes association. Diabetes Care 28, 956–962. https://doi.org/10.2337/diacare.28.4.956.

Centers for Disease Control and Prevention, 2017. National Diabetes Statistics Report. Centers for Disease Control and Prevention, US Department of Health and Human Services, Atlanta, GA.

Centers for Medicare and Medicaid Services, 2021. State operations manual: Appendix V interpretive guidelines responsibilities of medicare participating hospitals in emergency cases. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/Downloads/som107ap_v_emerg.pdf. (Accessed 9 April 2021).

Didangelos, T., Moralidis, E., Karlafti, E., Tziolamos, K., Margaritidis, C., Kontoninas, Z., Stergiou, I., Boulbou, M., Papagianni, M., Papanastasiou, E., Hatzitolios, A., 2018. A Comparative Assessment of Cardiovascular Autonomic Reflex Testing and Cardiac ^{123}I-Metaiodobenzylguanidine Imaging in Patients with Type 1 Diabetes Mellitus without Complications or Cardiovascular Risk Factors. Int. J. Endocrinol. 12, 5607208. https://doi.org/10.1155/2018/5607208.

Dieleman, J.L., Squires, E., Bui, A.L., Campbell, M., Chapin, A., Hamavid, H., Horst, C., Li, Z., Matyasz, T., Reynolds, A., Sada, N., Schneider, M.T., Murrapy, C., 2017. Factors associated with increases in US healthcare spending, 1996-2013. J. Am. Med. Assoc. 318, 1668–1678. https://doi.org/10.1001/jama.2017.15927.

Duque, A., Mediano, M., De Lorenzo, A., Rodrigues, L., 2021. Cardiovascular autonomic neuropathy in diabetes: pathophysiology, clinical assessment and implications. World J. Diabetes 12, 855–867. https://doi.org/10.4239/wjd.v12.i6.855.

Ferreira, G.E., Traeger, A.C., O'Keeffe, M., Maher, C.G., 2018. Staff and patients have mostly positive perceptions of physiotherapists working in emergency departments: a systematic review. J. Physiother. 64, 229–236. https://doi.org/10.1016/j.jphys.2018.08.

Garrity, B.M., McDonough, C.M., Ameli, O., Rothendler, J.A., Carey, K.M., Cabral, H.J., Stein, M.D., Saper, R.S., Kazis, L., 2020. Unrestricted direct access to physical

therapy services is associated with lower health care utilization and costs in patients with new-onset low back pain. Phys. Ther. 100, 107–115. https://doi.org/10.1093/ptj/pzz152.
Greathouse, D., Schreck, R., Benson, C., 1994. The United States Army physical therapy experience: evaluation and treatment of patients with neuromusculoskeletal disorders. Journal of Orthopedic Physical Therapy 19, 261–266.
Harris-Hayes, M., Schootman, M., Schootman, J.C., Hastings, M.K., 2020. The role of physical therapists in fighting the type 2 diabetic epidemic. J. Orthop. Sports Phys. Ther. 50, 5–16. https://doi.org/10.2519/jospt.2020.9154.
Hon, S., Ritter, R., Allen, D., 2021. Cost-effectiveness and outcomes of direct access to physical therapy for musculoskeletal disorders compared to physician-first access in the United States: systematic review and meta-analysis. Phys. Ther. 101. https://doi.org/10.1093/ptj/pzaa201 pzaa201.
Kempler, P., Tesfaye, S., Chaturvedi, N., Stevens, L.K., Webb, D.J., Eaton, S., Kerényi, Z., Tamás, G., Ward, J.D., Fuller, J.H., EURODIAB IDDM Complications Study Group, 2002. Autonomic neuropathy is associated with increased cardiovascular risk factors: the EURODIAB IDDM Complications Study. Diabet. Med. 19, 900–909. https://doi.org/10.1046/j.1464-5491.2002.00821.x.
Kim, H.S., Strickland, K.J., Mullen, K.A., Lebec, M.T., 2018. Physical therapy in the emergency department: a new opportunity for collaborative care. Am. J. Emerg. Med. 36, 1492–1496. https://doi.org/10.1016/j.ajem.2018.05.053.
Lebec, M.T., Jogodka, C.E., 2009. The physical therapist as a musculoskeletal specialist in the emergency department. J. Orthop. Sports Phys. Ther. 39, 221–229. https://doi.org/10.2519/jospt.2009.2857.
Mabry, L.M., Notestine, J.P., Moore, J.H., Bleakley, C.M., Taylor, J.B., 2020. Safety events and privilege utilization rates in advanced practice physical therapy compared to traditional primary care: an observational study. Mil. Med. 185, e290–e297. https://doi.org/10.1093/milmed/usz176.
Magel, J., Kim, J., Fritz, J.M., Freburger, J.K., 2020. Time between an emergency department visit and initiation of physical therapist intervention: health care utilization and costs. Phys. Ther. 100, 1782–1792. https://doi.org/10.1093/ptj/pzaa100.
Maser, R.E., Mitchell, B.D., Vinik, A.I., Freeman, R., 2003. The association between cardiovascular autonomic neuropathy and mortality in individuals with diabetes: a meta-analysis. Diabetes Care 26, 1895–1901. https://doi.org/10.2337/diacare.26.6.1895.
Maser, R.E., Lenhard, M.J., 2005. Review: cardiovascular autonomic neuropathy due to diabetes mellitus: clinical manifestations, consequences and treatment. J. Clin. Endocrinol. Metab. 90, 5896–5903.
Matifat, E., Méquignon, M., Cunningham, C., Blake, C., Fennelly, O., Desmeules, F., 2019. Benefits of musculoskeletal physical therapy in emergency departments: a systematic review. Phys. Ther. 99, 1150–1166.
McLean, T., 2006. The 80-Hour Work Week: why safer patient care will mean more health care is provided by physician extenders. J. Leg. Med. 26, 339–384. https://doi.org/10.1080/01947640500218349.
Mount, H.E., Graham, C., Clark, D., Morris, D., Foley, K., 2016. An investigation of screening for medical referral by Physical Therapists. Internet J. Allied Health Sci. Pract. 14, 2. https://doi.org/10.46743/1540-580X/2016.1582.
Murphy, B., Greathouse, D., Matsui, D., 2005. Primary care physical therapy practice models. J. Orthop. Sports Phys. Ther. 35, 699–707.
Pafili, K., Trypsianis, G., Papazoglou, D., Maltezos, E., Papanas, N., 2015. Simplified diagnosis of cardiovascular autonomic neuropathy in type 2 diabetes using Ewing's Battery. Rev. Diabet. Stud. 12, 213–219. https://doi.org/10.1900/RDS.2015.12.213.
Picchiottino, M., Leboeuf-Yde, C., Gagey, O., Hallman, D.M., 2019. The acute effects of joint manipulative techniques on markers of autonomic nervous system activity: a systematic review and meta-analysis of randomized sham-controlled trials. Chiropr. Man. Ther. 27, 17. https://doi.org/10.1186/s12998-019-0235-1.
Pop-Busui, R., Boulton, A.J., Feldman, E.L., Bril, V., Freeman, R., Malik, R.A., Sosenko, J.M., Ziegler, D., 2017. Diabetic neuropathy: a position statement by the American diabetes association. Diabetes Care 40, 136–154. https://doi.org/10.2337/dc16-2042.
Röhling, M, Strom, A, Bönhof, GJ, Roden, M, Ziegler, D, 2017. Cardiorespiratory fitness and cardiac autonomic function in diabetes. Curr. Diabetes Rep. 17, 125. https://doi.org/10.1007/s11892-017-0959-z.
Sandstrom, R.W., 2007. The meanings of autonomy for physical therapy. Phys. Ther. 87, 98–106. https://doi.org/10.2522/ptj.20050245.
Savva, C., Giakas, G., Efstathiou, M., 2014. The role of the descending inhibitory pain mechanism in musculoskeletal pain following high-velocity, low amplitude thrust manipulation: a review of the literature. J. Back Musculoskelet. Rehabil. 27, 377–382. https://doi.org/10.3233/BMR-140472.
Serhiyenko, V., Serhiyenko, A., 2018. Cardiac autonomic neuropathy: risk factors, diagnosis and treatment. World J. Diabetes 9, 1–24. https://doi.org/10.4239/wjd.v9.i1.1.
Sillevis, R., Van Duijn, J., Shamus, E., Hard, M., 2021. Time effect for in-situ dry needling on the autonomic nervous system, a pilot study. Physiother. Theory Pract. 37, 826–834. https://doi.org/10.1080/09593985.2019.1644691.
Spallone, V., Bellavere, F., Scionti, L., Maule, S., Quadri, R., Bax, G., Melga, P., Viviani, G.L., Esposito, K., Morganti, R., Cortelli, P., Diabetic Neuropathy Study Group of the Italian Society of Diabetology, 2011. Recommendations for the use of cardiovascular tests in diagnosing diabetic autonomic neuropathy. Nutr. Metabol. Cardiovasc. Dis. 21, 69–78. https://doi.org/10.1016/j.numecd.2010.07.005.
Spallone, V., Morganti, R., Fedele, T., D'Amato, C., Maiello, M.R., 2009. Reappraisal of the diagnostic role of orthostatic hypotension in diabetes. Clin. Auton. Res. 19, 58–64. https://doi.org/10.1007/s10286-009-0517-0.
Spallone, V., Ziegler, D., Freeman, R., Bernardi, L., Frontoni, S., Pop-Busui, R., Stevens, M., Kempler, P., Hilsted, J., Tesfaye, S., Low, P., Valensi, P., Toronto Consensus Panel on Diabetic Neuropathy, 2011. Cardiovascular autonomic neuropathy in diabetes: clinical impact, assessment, diagnosis, and management. Diabetes Metabol. Res. Rev. 27, 639–653. https://doi.org/10.1002/dmrr.1239.
Vinik, A.I., Erbas, T., Casellini, C.M., 2013. Diabetic cardiac autonomic neuropathy, inflammation and cardiovascular disease. Journal of Diabetes Investigation 4, 4–18. https://doi.org/10.1111/jdi.12042.
Vinik, A.I., Ziegler, D., 2007. Diabetic cardiovascular autonomic neuropathy. Circulation 115, 387–397. https://10.1161/CIRCULATIONAHA.106.634949.