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REVIEW ARTICLES

From neurocardiology to Stroke-Heart syndrome

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Abstract. The Stroke-Heart syndrome is a major chapter in neurocardiology. Both brain-heart and stroke-heart correlations are based on neurophysiological studies that define and describe the relation between the central autonomic system and cardiac function and it will be presented in this narrative review.

The Stroke-Heart syndrome groups the entire spectrum of cardiac changes – clinical, ECG, echocardiographic, biological, morphological – that occur in the first 30 days from the onset of stroke, especially in the first days. Their presence significantly marks the evolution and prognosis of stroke.

The damage resulted from hypothalamus-pituitary-adrenal axis activation and high catecholamine release (adrenergic storm) targets mainly the myocyte and the microcirculation. The Takotsubo syndrome and Stunned myocardium are distinct forms of neurogenic myocardial ischemia – with changes in ECG, parietal motility, and biological markers – usually reversible although evolution towards cardiac dysfunction is also possible.

The concept of Stroke-Heart syndrome and the brain-heart correlation brought new scientific information regarding stress cardiomyopathy or neurogenic myocardial injury.

Keywords: neurocardiology, Stroke-Heart syndrome, Takotsubo syndrome.

IDEAS AND CONCEPTS

Neurocardiology is currently a dynamic and bidirectional domain of research, which covers a wide area of topics, e.g. the effects of neurological diseases on the heart structure and function and the effects of cardiac pathology at the cerebral level (1). It is also an area of interferences and collaboration between several medical specialties, especially neurology, neurophysiology, cardiology, and neuroradiology.

A major element of neurophysiology that led to the development of neurocardiology was represented by studies that defined the brain-heart axis and the interrelations between the central autonomic system and the heart (cardiovascular) function (2, 3). The brain-heart axis covers multiple areas of connections in the brain (insular cortex, regions of the hypothalamus) that regulate the balance of the central autonomous system (parasympathetic/ sympathetic) (2). Samuels M.A., in two fundamental studies (1987 and 2007), presented the neurophysiological and clinical background of the brain-heart connection (4, 5).

Clinical observations have validated the Brain-Heart concept. Burch *et al.* (1954) described electrocardiographic changes (ECG) – QT prolongation, broad negative T waves – in patients with stroke, which were assumed to myocardial ischemia (6). After many years (1969), Connor R.C. noticed myocardial damage secondary to brain lesions (7).

Observations that increased the interest in neurocardiology were published by Japanese authors (1990) who described a clinical syndrome with ECG findings similar to acute myocardial infarction (STEMI), but with normal coronaries, occurring particularly in women with psychoemotional stress. The cardiac changes accompanied by cardiac dysfunction were defined as the Takotsubo Syndrome (TTS) or stress cardiomyopathy.

A significant number of publications analysed the pathogenic mechanisms, clinical, ECG, ecochardiography, biological and coronarographic characteristics of TTS (8). Imaging evidence of transient left ventricular wall motion abnormalities, which are frequently asymptomatic and different from those occurring in TTS and during cerebral events (in terms of localization) have led to the definition of the neurogenic stunned myocardium (NSM) (9).

The physiological/pathophysiological knowledge of the brain-heart axis and the neurogenic conditions that cause heart injury were followed by the

 DOI: 10.2478/rjim-2023-0020

definition of the Brain-Heart Syndrome concept (10). This includes multiple neurological events that cause myocardial injury, as well as the cardiac events that cause cerebral injury. Stroke (ischemic, intracerebral haemorrhage ICH – subarachnoid haemorrhage SAH), traumatic brain injury and brain tumours, intracranial hypertension, epilepsy are found in the first category, while atrial fibrillation (AF), malignant arrhythmias, heart failure and post resuscitation hypoxia are found in the second category (11).

The growing incidence of strokes in the general population and their consequences have led to the formulation of the Stroke-Heart syndrome concept.

The pioneers of the definition of the Stroke-Heart syndrome are Scheitz *et al.* (2018, 2022) and Sposato (2020), who have analysed the clinical and pathophysiological conditions of the syndrome in their main papers (12, 13, 14).

The concept of Stroke-Heart syndrome groups the entire spectrum of ischemic cardiac changes (functional, morphological, biological) which occur in the first 30 days of acute stroke. The ischemic stroke – by far the most frequent – but also other subtypes of stroke or neurological events – are potential causes of the neurogenic myocardial injury. Stroke-induced heart injury (SIHI) encompasses a series of pathophysiological processes that lead to clinical cardiovascular outcomes called "stroke-heart syndrome" (SHS), which can occur after a stroke. These mechanisms include inflammation, autonomic dysregulation, catecholamine release, endothelial dysfunction, myocardial structural changes, and many more. (14).

Scheitz and Sposato, in 2018 and 2020 respectively – have classified the clinical manifestations of S-H syndrome in 5 groups (Table I).

Between the clinical classifications of S-H syndrome (SHS) formulated by Scheitz (Z2) and Sposato, there are only formulation differences, but the content is similar and complete.

Table I.

Clinical manifestations in the SH syndrome

Scheitz (12)	
1	Acute myocardial injury
2	Acute coronary syndrome (including type 1 and 2 myocardial infarction (MI))
3	Systolic and diastolic dysfunction (including TTS)
4	Cardiac arrhythmias
5	Neurogenic sudden death

Sposato (14)	
1	Acute myocardial injury, ischemic-non-ischemic, and increased troponin levels
2	Post-stroke acute myocardial infarction (AMI)
3	LV dysfunction, heart failure (HF) and post-stroke TTS
4	ECG changes and cardiac arrhythmias
5	Neurogenic sudden death

MANIFESTATIONS OF THE S-H SYNDROME

MYOCARDIAL INJURY

Myocardial injury represents an essential item in the diagnosis, prognosis, and treatment of acute stroke. Its presence is identified by the precence of clinical signs and symptoms, biological markers, various ECG changes and imaging evidence of cardiac dysfunction.

Myocardial injury in acute stroke is biologically expressed via serum troponin (sTn) levels. Myocardial injury (15) is defined by the presence of elevated values of serum troponins over 99% upper reference limit. The myocardial injury is considered acute if there is a rise and/or fall of cTn values.

Increased serum levels of sTn are reported in 30–60% of ischemic stroke patients but also in 20–40% of haemorrhagic strokes (16). In two previous studies, with 1,016 and 834 ischemic stroke patients, in 5–20% cases the troponin levels have evolved on an ascendent/descendent curve characteristic for acute myocardial injury (14). In a recent statistics of 365,383 acute stroke patients (summed up from 53 medical organisations), acute coronary syndromes (ACS) were found in 11.1%

of patients in the first 4 weeks of the stroke evolution (16).

The increased serum levels of sTn in ischemic stroke are associated with old age, stroke severity, lesion location (especially at insular cortex level) and the presence of a structural heart disease. For approx. ½ of the acute stroke patients, the increase of sTn levels is found in the absence of coronary disease (14).

For most patients with cerebrovascular events, the sTn increase is present in the absence of clinical manifestations of coronary disease, ECG or ecochardiography changes (17). Increased levels of Tn are found in most major stroke complications (MACE – major adverse cardiovascular events). MACE – including ACS (acute coronary syndrome), acute HF (heart failure), AF (atrial fibrillation) or malignant ventricular arrhythmias, cardiac death – could develop in approx. 26% of acute stroke patients. In the previously cited study, 5-year cardiac complication rates are not negligible: ACS 11.1%; AF 8.8%; heart failure 6.4%; severe arrhythmias 1.2% and Takotsubo syndrome 0.1% (16).

The meaning of increased sTn levels in stroke is judged in relation their dynamics, the estimation methods – especially hs-Tns and clinical data. Ascendent/descendent profile of curve in the first days of stroke is characteristic for acute myocardial ischemia/ necrosis (e.g. type 1 MI, type 2 MI). If the moderately increased levels are maintained in plateau – for a longer period – they have the meaning of a chronic ischemia and the presence of a structural heart disease (stabilised HF, left ventricular hypertrophy LVH) or a comorbidity (18). Very high levels of sTn are associated with cardiac dysfunction (diastolic/systolic), reduction of left ventricular ejection fraction (LVEF) and with segmental ventricular hypokinesia (17).

Increased levels of sTn in acute stroke are generally associated with a potentially unfavourable evolution – both in the acute period and on long term (12).

ACUTE CORONARY SYNDROMES (ACS)

The acute coronary syndromes (ACS) in stroke, especially type 1 MI and type 2 MI, are variably developing in over 5% of patients (19). Some patients have a history of angina pectoris or MI or other atherosclerotic lesions. The diagnostic elements for ACS include: clinical manifestations, increased sTn levels with rise and/or fall pattern, new ECG changes and variable LV wall motion abnormalities. The stroke severity and the disturbance of consciousness in stroke mask the clinical manifestations, thus the diagnosis is based on repeatedly recorded ECG data, imaging criteria and serum troponin monitoring (14, 18).

The acute coronary syndromes in stroke mainly include type 1 acute MI (STEMI) and type 2 acute MI (non-STEMI). The Takotsubo syndrome and stunned myocardium are also based on acute ischemia, but they have almost specific wall motion particularities and different pathophysiological conditions.

The incidence of acute MI in acute stroke is not well established; it is an uncommon coronary event, in ischemic stroke as long as in other types of stroke (SAH, ICH). It is estimated that approx. 5% of STEMIs – are in reality Takotsubo syndrome. However, there are rare cases when TTS and MI can sometimes coexist (18).

STEMI is caused by thrombotic occlusion on a critical or non-critical atherosclerotic coronary lesion. This acute cardiac event can be suspected in stroke even in the absence of anginous pain, due to the sudden worsening of the cardiac function or rapid decrease of blood pressure (BP) levels. The ECG recording shows ST-T segment elevation followed by the development of pathological Q waves. Rapid diagnosis is based on the increased troponin levels in 1–6 hours with a rise/fall pattern.

The prognosis of patients with stroke complicated with STEMI is poor. In part, this is due to the limitations or contraindications of current treatment methods (thrombolysis, interventional coronary revascularisation) (20).

Non-ST elevation myocardial infarction complicating acute stroke is more frequently encounterd than STEMI. ECG changes present at the time of hospital admission (ST-T segment depression, negative T waves) could be overlooked and diagnosis could be missed, in the absence of ECG monitoring and assessment of necrosis markers (sTn) (12).

Non-STEMI develops in conditions of myocardial ischemia/ necrosis, through "the imbalance between the oxygen demand and supply (demand ischemia - infarction). It has a subendocardial localization and new ST-T changes, usually reversible or stationary; could be accompanied by LV dysfunction (NT-proBNP levels, ecochardiography).

Non-STEMI has variable pathophysiological mechanisms: coronary spasm, prolonged hypotension, severe arrhythmias, heart failure (14).

About 5–20% of patients with acute stroke, associate acute myocardial injury or necrosis. They have 2–3 fold higher hospital and 1-year mortality risks, compared to the general population (20).

WALL MOTION ABNORMALITIES. CARDIAC DYSFUNCTION

Neurogenic myocardial injury in acute stroke manifests via LV wall motion changes, described with imaging techniques, mainly ultrasonography. Left ventricular hypokinesia, akinesia, diskinesia hyperkinesia, can implicate various segmentsand are the basis of systolic cardiac dysfunction encountered in acute stroke.

The LV wall motion abnormalities in acute stroke are transient (days, weeks) and have variable locations and extension (e.g. multisegmental) that do not necessarily respect the perfusion area of an epicardial coronary artery (16). Cardiac systolic dysfunction can be asymptomatic and discovered during ecochardiography assessment or it can be clinically manifest and accompanied by abnormal values of cardiac biomarkers – sTn and NT-proBNP (8). In a study on 1,209 ischemic stroke patients, 38% had wall motion abnormalities, accompanied by moderate LV impairment (21).

The incidence of wall motion abnormalities in stroke, and also in other cerebral acute events (e.g. traumatic brain injury), varies between 20–40%, higher in SAH (14, 17). Wall motion abnormalities in stroke could be accompanied by various degrees of cardiac dysfunction (systolic and/or diastolic) (16). In a study regarding ischemic stroke outcome during hospitalization – in patients without pre-existing cardiovascular comorbidities – 4.9% developed HF (19). Clinical heart failure complicating acute severe stroke may have multifactorial etiology – other than neurogenic ischemia – *e.g.* hypoxia, anemia, and infection-sepsis.

The cardiac dysfunction in S-H syndrome is accompanied by increased NT-proBNP levels in 24 hours from the onset of stroke. Increased NT-proBNP levels correlate with the severity of ventricular dysfunction, the extension of the new wall motion abnormalities, and with an increased risk ofcardiovascular adverse events and death (22).

Wall motion abnormalities in S-H Syndrome have specific patterns in Takotsubo syndrome (TTS) and Stunned myocardium (NSM).

THE TAKOTSUBO SYNDROME

Described in 1990, Takotsubo syndrome is the most studied entity of S-H syndrome, being the prototype of neurogenic myocardial injury (23). The definition criteria were formulated in "Mayo Clinic Diagnostic Criteria" but also in other scientific documents, like BP/ ESC and Inter TAK Diagnostic Criteria (23, 24). Currently accepted criteria are (23):

- Transient regional wall motion abnormalities of LV or RV myocardium (typically apical ballooning, but other forms also exist);
- Physical or emotional stress, preceding the cardiac event;
- The absence of obstructive coronary artery disease (If coronary disease is found, the diagnosis of stress cardiomyopathy can still be made if the wall motion abnormalities are not in the distribution territory of the coronary disease);
- New and reversible ECG anomalies (ST-T segment elevation or inverted T waves);
- Moderate elevation of troponins and significantly elevated serum natriuretic peptide during the acute phase ;

The clinical, ECG, and ultrasonographic aspects are often suggestive of acute MI, thus the differential diagnosis often requires coronary angiography.

The primary Takotsubo syndrome is rarely found in acute. In patients hospitalized with ischemic stroke, secondary Takotsubo syndrome is found in 0.5–1% of cases, and more frequently in SAH (15–25%). Both ECG and wall motion abnormalities, (present in 8–12% of patients), are reversible in weeks or months (12). Complications may occur during hospitalization – acute HF, intraventricular thrombosis – that can change the evolution towards an unfavorable one. The mortality is estimated to 2–5% of cases, predominantly via cardiogenic shock or ventricular tachycardia (VT) (25, 26). A study from the SWEDE Heart Register – reported a similar mortality in TTS as in acute MI (27).

THE NEUROGENIC STUNNED MYOCARDIUM (NSM)

NSM has no strict diagnostic criteria. Similar to TTS, it mimics myocardial infarction and has transient left ventricular hypokinesia. Due to their catecholamine-mediated nature, both TTS and NSM are thought to have the same pathophysiology NSM is characterized by rapidly reversible LV global hypokinesia, new ECG changes (ST depression, negative T waves, but not ST-T elevation) and small (limited) changes of cardiac markers (9).

NSM is asymptomatic most of the time and the diagnosis is suggested by ECG and imaging changes occurring in pts with stroke. It is rarely accompanied by symptomatic ventricular dysfunction and other cardiac complications. The NSM diagnosis

is understated in practice, and could be missed in the absence of a thorough patient assessment (troponin, NT-proBNP, ECG/echocardiographic examination) (28). These changes are frequently regarded as being present prior to the neurological event.

There are some differentiation elements between NSM and TTS, the following elements being more frequently encountered in NMS: the absence of angina or equivalent; new transient ST-T changes other than ST-T elevation and diffuse hypokinesia; possibly LV dysfunction with or without clinical HF (28, 29, 30). However, there are many criteria of similarity and overlapping, including the pathogenic mechanisms. A World Stroke Organisation Brain & Heart Task Force group of neurology experts recommends for NSM the term neurogenic secondary TTS (14).

In fact, TTS and NSM are two phenotypes of stress cardiomyopathy (neurogenic myocardial injury), occurring in conditions of S-H syndrome (30).

ECG CHANGES. ARRHYTHMIAS

Electrocardiographic (ECG) changes in stroke patients were reported since the 1960s period, especially in patients with subarachnoid haemorrhage; they were considered, also, related to myocardial ischemia (32).

The assessment and ECG monitoring of acute stroke patients – in the emergency department or in hospital, in the first 24–72 hours, showed the magnitude of the problem (33). ECG changes – morphological and arrhythmias, were reported in 70–90% of ischemic stroke patients (12). In a meta-analysis of 25 studies and 2,690 patients, ECG changes during the first 24 hours since the onset of stroke were found in 67% of patients (10). An important part of the morphological ECG changes precede the neurological event and are caused by prior cardiac pathology (e.g. old MI, hypertension with left ventricular hypertrophy (LVH), asymptomatic coronary diseases). After exclusion of the pre-existing cardiac pathologies, approx. 1/3 of ischemic stroke patients are still regarded as having new ECG changes (17).

The differentiation between new ECG changes – related to the ischemic stroke, compared to "old" ones – can be better done after 2–3 days of monitoring; recent changes are – partly transient and are found in patients with increased troponin levels (14).

The morphological changes of ECG are more frequent than arrhythmias and have prognostic implications in acute stroke. More frequently reported are: QTc prolongation in 20–65% of cases, ST-T depressions in 15–25% and large, negative T waves in 12–18% (cerebral T waves) (12). They are the expression of neurogenic myocardial ischemia and can be accompanied by an increase in troponin levels.

QT prolongation occurs early in the evolution of a stroke, from the first hours; however, it is transient and decreases in approx. 48 hours. Values of >500 ms have a negative prognosis, with a higk risk of malignant arrhythmias and sudden death (16).

New ECG repolarisation changes – ST-T depressions are the direct expression of subendocardial ischemia/necrosis and stunned myocardium. The development of negative, large T waves (cerebral T waves), localized in precordial leads is characteristic.

ST segment elevation, accompanied or not by new Q waves, raises the problem of differential diagnosis between the acute MI and Takotsubo syndrome. The ST segment elevation in Takotsubo syndrome exceeds the perfusion area of an epicardial coronary artery, the Q waves are usually absent, and the sTn levels are usually moderately or minimally increased (13, 14). The pattern of wall motion abnormalities– with apical ballooning and akinesia, along with basal hypercontractility, is characteristic of Takotsubo syndrome (8).

Cardiac arrhythmias mostly within 72 hours from the onset of acute stroke, are frequent and diverse: AF, other atrial tachyarrhythmias, atrial/ ventricular premature beats, and atrio-ventricular (AV) block.

AF in acute ischemic stroke represents a serious problem of diagnosis and therapeutical attitude. AF ascertained in the emergency department – is considered, most of the time, the cause of the ischemic stroke.

New AF is detected in 7–10% of patients within the first 3–5 days after an acute stroke, while prolonged monitoring (6–12 months), detects AF in 24% of pts (34). However, development of AF could have a neurogenic mechanism via the ischemic disorder of central autonomous system and reflects only the preexisting cardiac vulnerability and the presence of atrial cardiomyopathy (13). It is considered that paroxysmal AF occurs more frequently when the left insular cortex, a region supplied by the middle cerebral artery, is involved. (14).

When a neurogenic mechanism, directly related to the cerebral event (autonomous centres ischemia), is the cause of the arrhythmia, AF is usually self-limited (35).

AF management in stroke is individualised with respect to the stroke type and severity as well as clinical particularities (36).

NEUROLOGICAL SUDDEN DEATH

The cardiac sudden death, defined as the abrupt, unexpected death, within 1 hour from the onset of symptoms of an unexpected event or in 24 hours after an apparently stabilised event, is relatively rare in stroke.

The neurogenic sudden death is part of the Stroke-Heart syndrome, if the stroke is considered to be the cause of sudden death. However, the proof of the involvement of stroke in sudden death requires complete heart and brain necropsy, as well as data from electrocardiographic monitoring (37). In practice, the cardiac sudden death diagnosis in stroke is probably overestimated.

Published studies regarding sudden death in stroke – are relatively limited. An old study (1977) has analysed the deaths after the first stroke in 255 patients. Among these patients, 52 cases were consistent with the definition of sudden death. 26 patients died of primary intracerebral haemorrhage and 20 due to SAH. Death due to ischemic stroke – in 2 observations – was produced by basilar artery thrombosis with infarction in the pons and cerebellum, or cerebral infarction. For the remaining 4 patients, the cause of sudden death was classified as unknown. Thus, the sudden death occurred in approx. 3% of acute stroke cases, the majority by hemorrhagic stroke (38).

A more recent Danish study has analysed the causes of death in a cohort of 14,562 patients under 49 years of age for a period of 10 years. Sudden death was considered in 1,698 observations, 52 (3%) of which were by acute stroke. Hemorrhagic stroke was by far the most prevalent (94%) direct cause of sudden death compared to 5.6% by ischemic stroke (39).

The potential mechanism of sudden death in acute stroke is the neurocardiogenic injury induced by sympathetic hyperstimulation, which affects the myocardium (contraction band necrosis) and the cardiac conduction system (cardiac arrest or induced malignant ventricular tachyarrhythmia) (12). Sudden increase of the intracranial pressure and its consequences on autonomic nervous system and cerebral perfusion could explain the sudden death in hemorrhagic stroke. ECG changes with early repolarisation may suggest an increased risk of sudden death (40).

THE PATHOPHYSIOLOGY OF THE STROKE-HEART SYNDROME (SYNTHESIS)

The pathophysiology of the S-H syndrome gathers all mechanisms leading to neurogenic myocardial injury. Three factors are major in the pathogenic chain: 1) Stressors; 2) Stress response which includes the central autonomic system and the hypothalamus-pituitary-adrenergic axis; 3) Neurohormonal mediators and their effects on the heart (cardiomyocytes) and on the microcirculation. In the last years it was noticed that the intestinal microbial dysbiosis, immunological response and inflammation, release of microvesicles and micro RNA may participate in the pathogenic chain (12, 17).

The pathogenic stages that lead from stressors (including cerebral ischemic injury) to clinical manifestations of the S-H syndrome are illustrated in Fig. 1.

The stressors are strong emotional factors, physical stress or neurological events that produce injury of the central autonomic network – including the insular cortex – involved in the cardiovascular function control and sympathoadrenal tonus increase. The insular cortex, prefrontal cortex, amygdala and hippocampus participate in the central autonomic network (41).

Stressing factors produce activation or dysregulation of both autonomic control and the hypothalamus-pituitary-adrenal axis, with excessive release of catecholamines, cortisol and pro-inflammatory cytokines (12). The synthesis and release of catecholamines (CCA) takes place at the central level, but also at the adrenal and myocardial levels.

The excess of CCA (catecholamine storm) causes alteration of calcium homeostasis in myocytes, leading tocalcium influx – (42). The consequence of these processes is stimulation of myocyte contraction (hypercontractility), reduction of relaxation, and arrhythmogenesis. Moreover, stimulation of adrenoreceptors causes an increase in heart rate and, together with hypercontractility, conditions for an inbalance between O_2 demand and supply, hypoxia, and demand ischemia appear. The catecholamine excess is, also, toxic for cardiomyocytes (41).

The myocyte energetic metabolism disorder, oxidative stress and O_2 free radicals (ROS) release cause lysis or contraction band necrosis in myocytes – a typical lesion for sympathetic hyperstimulation.

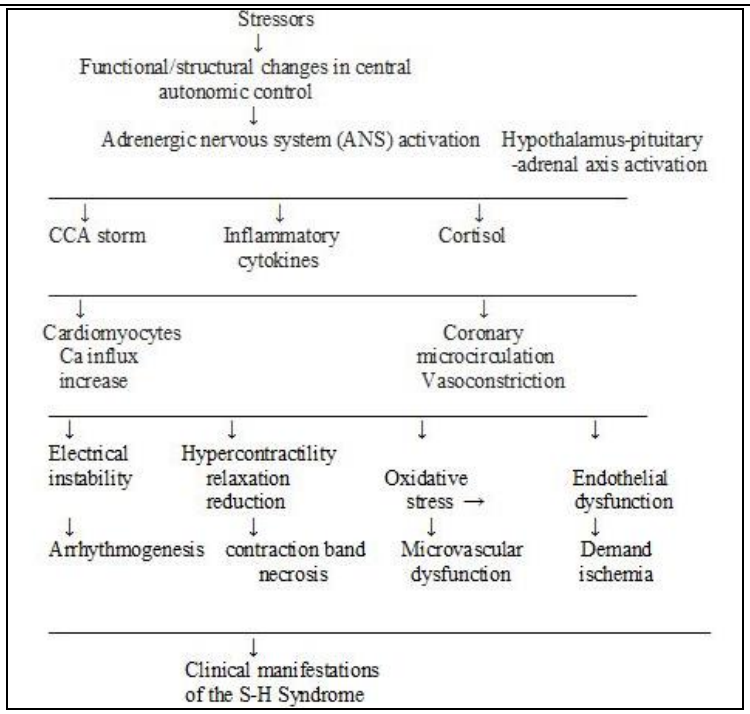


Fig. 1 The pathophysiology of the S-H syndrome, modified.

The coronary microcirculation is also negatively influenced by the excess of catecholamines, cortisol and other neurohormonal mediators.This, along with the oxidative stress, causes endothelial dysfunction. Other neurohormonal factors, like endothelin, angiotensin II, vasopressin lead to microvascular vasoconstriction and eventually ischemia – especially demand ischemia (12). The acute hypertensive reaction in stroke can worsen the demand ischemia.

Excessive activation of hypothalamus-pituitary-adrenal axis at myocardial level and coronary microcirculation level are, eventually lead to contraction band necrosis, microvascular dysfunction and myocardial ischemia (12).

Myocardial ischemia during acute neurological conditions, explains wall motion abnormalities, cardiac dysfunction, and abnormal biomarker values. The lesional and functional reversible stunned myocardium, resulted from the effects of catecholamines, represents the common item in TTS and NSM. The extent of stunned myocardium and ischemia is probably related to stroke severity, the presence of comorbidities (*e.g.* asymptomatic coronary disease), unequal distribution of microcirculation and adrenoreceptors. Different distribution of the adrenoreceptors – larger by 40% at the base of the LV than the apex, creates an increased vulnerability to catecholamine storm and eventually leads to apical ballooning, typical in TTS (43).

Sindromul "stroke-heart" este un capitol important al neurocardiologiei. Corelaţiile creier-cord, ca si "stroke-heart" se bazează pe studii de neurofiziologie care definesc şi descriu relaţia dintre sistemul nervos autonom central şi cord şi vor fi prezentate în această sinteză narativă.

Sindromul "stroke-heart" grupează un spectru întreg de modificări cardiace – clinice, ECG, ecocardiografice, biologice şi morfologice care apar în primele 30 de zile de la debutul accidentului vascular cerebral, în special în primele zile. Prezenţa lor influenţează semnificativ evoluţia şi prognosticul accidentului vascular cerebral.

Leziunile produse de activarea axului hipotalamo-hipofizaro-suprarenalian şi de eliberarea de cagtecolamine (furtuna adrenergică) au ca ţintă principală miocitele şi microcirculaţia. Sindromul Takotsubo şi miocardul "uluit" (Stunned) sunt forme distincte ale ischemiei miocardice neurogene, cu modificări ECG, ale motilităţii parietale şi ale markerilor biologici, în mod obişnuit reversibile, cu toate că este posibilă evoluţia spre disfuncţie cardiacă.

Conceptul de sindrom "stroke-heart" şi corelaţiile creier-cord au adus informaţie ştiinţifică nouă despre cardiomiopatia de stres sau despre leziunea miocardică neurogenă.

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Received 23rd July 2023