THE ROLE OF IMAGING IN THE MANAGEMENT OF CARDIORENAL SYNDROME

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Abstract: *The cardiorenal syndrome (SCR) is a complex syndrome which represents the interaction between the two organs when the dysfunction of one involves the dysfunction of the other. Imaging methods are necessary for the diagnosis and management of the patients with cardiorenal syndrome and they are useful in characterizing the dynamics of cardiac and renal performance, in order to define the interaction between the two systems and to characterize their progress in treatment. In the patients with cardiorenal syndrome, ultrasound provides valuable information on cardiac structure and function and on the acute or chronic nature of kidney disease. Modern imaging techniques are useful in characterizing the status of the two organs damage. These data are integrated with the results of the biological investigations to complete the pathophysiological profile and the evolution of this complex syndrome.*

Cuvinte cheie: *insuficienţa cardiacă, insuficienţa renală, sindrom cardiorenal*

Rezumat: *Sindromul cardiorenal (SCR) este un sindrom complex ce reprezintă interacţiunea dintre cele două organe atunci când disfuncţia unuia antrenează disfuncţia celuilalt. Metodele imagistice sunt necesare în diagnosticul şi managementul pacienţilor cu sindrom cardiorenal, fiind utile în caracterizarea performanţelor cardiace şi a afectării renale în dinamică, pentru definirea interacţiunii dintre cele două sisteme şi a urmăririi evoluţiei acestora sub tratament. La pacienţii cu sindrom cardiorenal ecografia oferă informaţii valoroase cu privire la structura şi funcţia cardiacă, precum şi despre natura acută sau cronică a afecţiunii renale. Tehnicile imagistice mai moderne sunt utile în caracterizarea stadiului evolutiv al afectării celor două organe. Datele obţinute astfel sunt integrate alături de rezultatele investigaţiilor biologice pentru a contura profilul fiziopatologic şi evolutiv al acestui sindrom complex.*

Cardiorenal syndrome (CRS) is "a pathophysiological disorder of the heart and kidney in which acute or chronic dysfunction in one organ may induce acute or chronic dysfunction in the other organ", as defined by Ronco at the World Congress of Nephrology in 2008.(1) CRS was classified in 5 types according to the acute or chronic mechanism that caused the injury (Table no. 1).

Table no. 1. CRS classification

Type	Syndrome	Primary condition	Secondary condition
1	Acute Cardiorenal	Acute heart failure	Acute kidney injury
2	Chronic Cardiorenal	Chronic heart failure	Chronic renal failure
3	Acute Renocardiac	Acute kidney injury	Acute heart failure
4	Chronic Renocardiac	Chronic renal failure	Chronic heart failure
5	Secondary	Systemic condition	Heart and renal failure

Imaging methods are necessary in the diagnosis and management of the patients with CRS; they are useful in characterizing cardiac performance and renal damage, with a special interest in defining the interaction between the two systems and tracking the progress achieved by treatment. Table no. 2 shows schematically the use of different imaging techniques in all types of CRS.

Table no. 2. Imaging methods in CRS

CRS type	Imaging methods
Acute Cardiorenal and Renocardiac Syndrome	Cardiac and renal US, Contrast enhanced renal US, abdominal CT, MRI
Chronic Cardiorenal and Renocardiac Syndrome	Cardiac and renal US, SPECT, PET, MRI, Radionuclid ventriculography, Abdominal CT

SPECT- Single-photon emission computed tomography, PET - Positron emission tomography, CT - computed tomography, MRI - magnetic resonance imaging, US - ultrasonography

Cardiac imaging

a) Ultrasonography. In the patients with cardiorenal syndrome, echocardiography provides valuable information on cardiac structure and function. Ultrasound may use two-dimensional mode, M mode, pulsed, continuous and colour Doppler parameters to study blood flow and tissue Doppler. There are new techniques that allow a better viewing of the

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heart, such as transoesophageal ultrasound and three-dimensional echocardiography. In addition to providing information on the systolic and diastolic performance of the heart, echocardiography is useful in the evaluation of ventricular wall kinetic disorders, heart valves disorders and of hemodynamics. It is important to define and measure the parameters that are extremely useful in establishing the prognosis: left ventricular and diastolic volume, left ventricular ejection fraction (LVEF), right ventricular performance, left atrial volume, mitral deceleration time, severity of mitral regurgitation, pulmonary hypertension.(1)

Thus, ultrasound allows us to define two types of heart failure: systolic dysfunction HF with LVEF <45% and diastolic heart hailure (HF) or HF with preserved ejection fraction.

There are three essential criteria for the diagnosis of heart failure with normal ejection fraction: the presence of signs and symptoms of HF, normal systolic function and normal left ventricular size and evidence of ventricular diastolic dysfunction. Diastolic mitral flow, pulmonary flow and tissue Doppler measurements at the mitral ring provide very useful information about LV filling pressures.(2,3,4,5).

Depending on the changes that can occur, there are three profiles that characterize LV filling: normal, impaired relaxation, pseudonormalized and restrictive.(2) Valsalva manoeuvre is useful to distinguish the pseudonormal profile from the normal filling pattern.(3) Parameters specific for each profile are summarized in table no. 3.

Table no. 3. Doppler parameters of the left ventricle diastolic function

Diastolic function type / Parameters	**Normal**	**Impaired relaxati**	**Pseudo - normal**	**Restric tive**
Mitral flow	E>A	E<A	E>A	E>>A
Mitral flow-Valsalva manoeuvre	E>A	E<A	E<A	E>A
Mitral TDI	E/E'<8	E/E'<8	E/E'≥15	E/E'≥15
Pulmonary flow	S≥D	S>D	S<D Ar>A+30ms	S<D Ar>A+30ms
Vp	E/Vp >2	E/Vp >2	E/Vp <2	E/Vp <2

E – passive wave of ventricular filling, A - active wave of ventricular filling (pulsed Doppler), E - velocity of mitral annulus (Doppler tissue), S - wave of systolic pulmonary venous flow, D - diastolic wave of pulmonary venous flow, Ar- pulmonary venous flow wave of active ventricular filling (pulsed Doppler), Vp - flow propagation velocity in the left ventricle of the mitral regurgitation (colour Doppler and M mode)

b) Computed tomography (CT) provides images of the heart with high temporal and spatial resolution. Multiple slice CT obtains cardiac images in different plans and are able to provide information on volumes and cardiac dimensions. The combination with ECG triggering reduces motion artefacts. Ultrafast electron beam imaging makes recordings within milliseconds, thus solving the problem of heart motion during examination, but it requires contrast agent for defining and determining the studied cavity size. The most commonly used imaging in nuclear cardiology is photon emission computed tomography (SPECT) - a myocardial perfusion imaging. Photons emitted by the myocardium are proportional to the magnitude of absorption of tracer and thus provides information on perfusion. This describes the structure and heart function at rest and during exercise.

Positron emission tomography (PET) is used to assess myocardial viability by assessing cell metabolism by myocardial perfusion using rubidium. PET imaging has several advantages over SPECT, including better spatial resolution and higher counting efficiency.

c) Radionuclide ventriculography can be used to estimate left and right ventricular function.(6)

d) Magnetic resonance imaging (MRI) is useful in evaluating cardiac anatomy and coronary blood flow, ventricular function, myocardial viability and perfusion. Cardiac MRI is capable of imaging the heart in any desired plane with an unrestricted view with high precision and reproducibility for the determination of ventricular volumes, their structure and ejection fraction. Using different sequences or magnetic resonance techniques, it is possible to detect fibrosis, scars and inflammation of the myocardium.(7)

Renal imaging

a) Renal ultrasound is valuable in differentiating acute from chronic kidney disease and in excluding obstruction as a cause of renal function worsening. In acute cases of CRS, renal ultrasound may be normal due to the acute nature of the disease. Images from previous examinations are important for comparison. Kidney size and renal parenchymal echogenicity are the first evaluated in renal disease. In chronic kidney disease, the kidneys are small, while large kidneys are common in diabetic nephropathy, in monoclonal gammopathies and HIV-associated nephropathy. Increased cortical echogenicity suggests the existence of a chronic disease. Obstructive uropathy is easily diagnosed by echography, by evidencing hydronephrosis, dilatation of pelvis and proximal ureters. Colour Doppler and renal B mode ultrasound images have limited ability to assess the intrarenal arteries and arterioles. Ultrasound imaging with contrast agent may overcome this potential limitation, using microbubbles that remain in the intravascular space; thus, they are completely different from the contrast used for CT or MRI.

Several small studies suggest a role for Doppler ultrasound in establishing the differential diagnosis of acute renal failure, when the measurement of the resistive index is of great importance. It is defined by using maximum systolic and diastolic velocity values and it correlates with fractional excretion of sodium.(7) More recently, contrast-enhanced ultrasound is studied in order to measure the renal blood flow and could be of great value in suspected cases of CRS with impaired renal hemodynamics.(7)

b) Computed tomography (CT) imaging is the preferred technique for diagnosing urolithiasis, renal masses and renal artery pathology. Progress in post-processing techniques with three-dimensional image reconstruction has improved the CT diagnostic accuracy.

In many cases, CT urography has replaced intravenous urography. It shows filling defects in the collecting system that may be due to lithiasis, thrombus or neoplasm. Contrast enhanced CT assesses arterial and venous vessels, renal parenchyma and collecting system. This technique can be used to estimate glomerular filtration rate. Due to the increased risk of nephropathy induced by contrast, it is less used in the patients with acute or chronic renal disease.

The preferred agent for renal radionuclide imaging is technetium (99mTc). It offers good image quality with reduced radiation exposure and has short half-life, useful in the differential diagnosis of acute renal failure. Renal uptake of 99mTc in the first minutes after injection is reduced in cases of acute tubular necrosis while in prerenal acute renal injury, it is normal. Renal uptake of tracer during the late phase (20 minutes after injection) is expected to be high in prerenal acute renal injury, but low in postrenal acute failure.

c) MRI is useful in assessing genitourinary tract mainly in staging malignant tumours. Magnetic resonance angiography can be used to study the renal arteries.

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