British Society of Echocardiography

A Guideline for the Practice of Echocardiography in the Cardiovascular Screening of Sports Participants

A Joint Policy Statement of the British Society of Echocardiography and Cardiac Risk in the Young

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Abbreviations and Definitions

HCM	Hypertrophic Cardiomyopathy
DCM	Dilated Cardiomyopathy
LVH	Left Ventricular Hypertrophy
ARVC	Arrhythmogenic Right Ventricular Cardiomyopathy
LAD	Left Anterior Descending Artery
LV	Left Ventricle
LA	Left Atrium
RV	Right Ventricle
RA	Right Atrium
IVSd	Inter-ventricular Septal Wall Thickness
LVPWd	Posterior Wall Thickness
LVDd	End Diastolic Diameter
EDV	End Diastolic Volume
SV	Stroke Volume
EF	Ejection Fraction
LA Size	Left Atrial Diameter
LVNC	Left Ventricular Non Compaction
LBBB	Left Bundle Branch Block
RBBB	Right Bundle Branch Block
RWT	Relative Wall Thickness

Eccentric Hypertrophy / Remodelling – Is a cardiac chamber response to increased preload and manifests as a larger cavity and proportional increased wall thickness in order to balance an elevated wall stress.

Concentric Hypertrophy / Remodelling – Is a cardiac chamber response to elevated afterload and manifests as an increase in wall thickness (of any walls) without a concomitant increase in cavity dimension.

Introduction

Which conditions to look out for? This British Society of Echocardiography (BSE) document is endorsed by Cardiac Risk in the Young (CRY) and is aimed at providing guidance for the use of echocardiography in screening young athletes (ages 14 to 35 years) for inherited cardiac disease. Sudden cardiac death (SCD) in young athletes is relatively rare however its impact is devastating to the individual, their family and the wider community. The causes of SCD in the athletic population have been relatively well reported[1,2,3] (see Figure 1) and therefore cardiac screening is aimed at identifying these conditions.

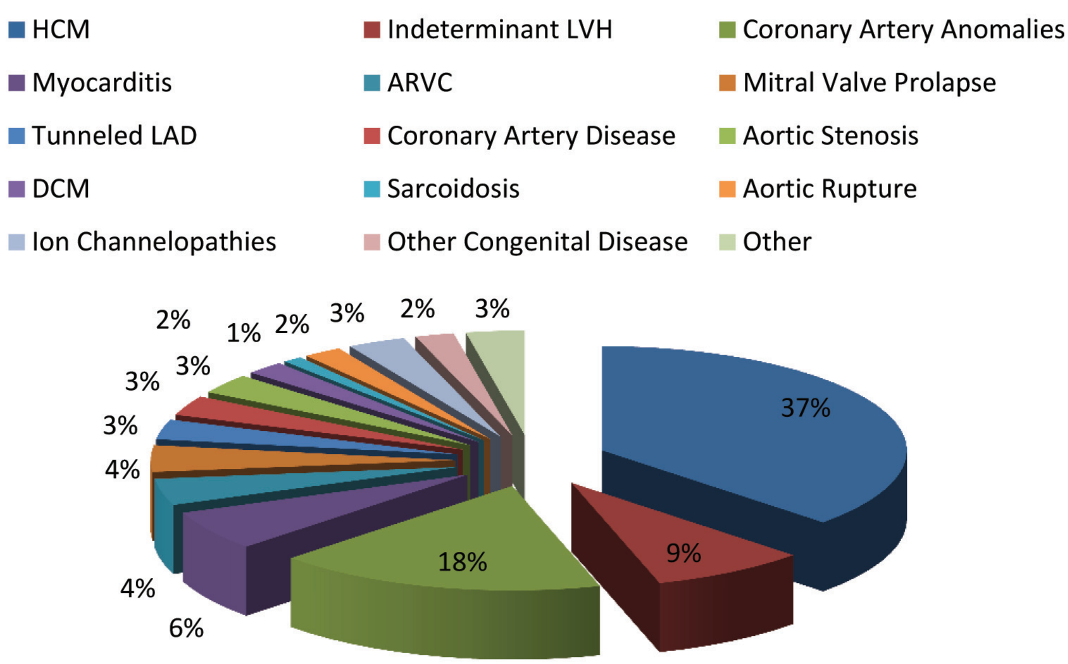


Figure 1 - Causes of Sudden Cardiac Death in the Athletic Population

The ECG should be the first investigation. Current European recommendations for cardiac screening of the athlete state that the electrocardiogram (ECG) should be the primary investigation. The ECG should be interpreted in accordance with specific European Society of Cardiology (ESC) guidelines[4] (see table 1) and in the context of the individuals' symptoms, family history and clinical examination. Transthoracic echocardiography (TTE) is recommended if an athlete presents with Group 2 ECG changes (see below), cardiovascular symptoms, abnormal physical examination findings or a family history of sudden death under the age of 40.

ESC Classification of ECG Abnormalities in athletes	
Group 1 (training-related)	**Group 2 (training-unrelated)**
Sinus Bradycardia	T-wave inversions
First degree AV Block	ST-segment depression
Incomplete RBBB	Pathological Q-waves
Early Repolarisation	Left Atrial Enlargement
Isolated QRS voltage criteria for LVH	Left axis deviation / left anterior hemiblock
	Right axis deviation / left posterior hemiblock
	Right Ventricular Hypertrophy
	Ventricular pre-excitation
	Complete LBBB or RBBB
	Long QT or short QT interval
	Brugada-like early repolarisation

Table 1 - ESC Classification of ECG Abnormalities in Athletes

Parameter	Endurance-Trained (ET)	Resistance-Trained (RT)	Sedentary Controls (CT)	P-value (All groups)
LV mass (g)	232 (200-260) [n=64; 1099]	220 (205-234) [n=25; 510]	166 (145-186) [n=59; 1239]	P<0.001
IVSd(mm)	11.0 (10.8-11.3) [n=68; 1802]	11.0 (10.3-11.8) [n=19; 408]	9.2 (8.9-9.5) [n=63; 1352]	P<0.001
LVPWd (mm)	10.6 (10.3-10.9) [n=57; 1928]	10.4 (9.8-10.9) [n=14; 370]	8.8 (8.6-9.1) [n=53; 1433]	P<0.001
LVDd (mm)	54.8 (54.1-55.6) [n=61; 1548]	52.4 (51.2-53.6) [n=17; 384]	50.1 (49.5-50.7) [n=56; 1174]	P<0.001
LVEDV (ml)	171 (157-185) [n=34; 493]	131 (120-142) [n=14; 189]	135 (125-145) [n=34; 539]	P<0.001
LV SV (ml)	106 (97-116) [n=28; 479]	86 (77-95) [n=9; 125]	83 (77-90) [n=27; 590]	P<0.001
LV EF (%)	63 (61-64) [n=42; 1330]	66 (62-70) [n=7; 85]	64 (62-65) [n=37; 878]	P=0.365
LV E/A	2.0 (1.9-2.1) [n=34; 844]	1.9 (1.7-2.0) [n=8; 214]	1.8 (1.7-1.9) [n=34; 868]	P=0.014
LV e’	13.6 (12.3-14.9) [n=7; 204]	* [n=1; 16]	11.0 (9.4-12.6) [n=4; 183]	P=0.014
RV mass (g)	91 (63-119) [n=5; 116]	*	37 (24-50) [n=4; 102]	P<0.01
RVD1(mm)	33.5 (21.0-46.0) [n=4; 140]	*	26.1 (16.1-36.1) [n=4; 95]	P=0.347
RVEDV (ml)	222 (216-227) [n=6; 136]	*	156 (153-159) [n=6; 150]	P=0.627
RV SV (ml)	114 (115-122) [n=5; 66]	*	94 (92-98) [n=4; 66]	P=0.415
LA Size (mm)	39.2 (35.9-42.5) [n=10; 206]	31.9 (29.7-34.1) [n=2; 58]	34.9 (31.9-37.9) [n=11; 243]	P<0.001

Table 2 - Structural and Functional Parameters in Endurance and Resistance Athletes – data is presented as mean (lower and upper limits) [number of studies, pooled sample size]

A full standard echo should be performed. The athlete’s TTE should be performed according to the BSE Minimum Dataset for a Standard Transthoracic Echocardiogram in an Adult, and should also take into account recommendations made in the Supplementary Protocols for (i) Comprehensive Assessment of the Right Heart and (ii) the Assessment of Diastolic Function. Details of where and how to measure these echo parameters are given in these three protocols, which are available on-line at www.bsecho.org. There are however, additional elements that may be considered optional in non-athletes that become mandatory for accurate interpretation of the athlete’s echocardiogram. If there is evidence of an abnormality, other supplementary guidelines may then become relevant and should be utilised. For example, the application of this protocol may identify RV enlargement and possible dysfunction and it would therefore be pertinent to then utilise the ARVC protocol to obtain further diagnostic information.

Type of athletic activity should be known. It is important to use the BSE normative values based on sex and age but take account of the type of sporting activity performed. All echocardiographers involved in cardiac screening should have an understanding of the physiological adaptation in cardiac structure and function to regular exercise. The main adaptation is eccentric hypertrophy of all cardiac chambers but this can be variable depending on the type and volume of exercise training. Table 2 is adapted from a recent systematic review and meta-analysis[5] that highlights normal ranges for trained athletes. This includes those that engage in resistance activity and endurance activity. Resistance activity is defined as anaerobic isometric exercise at incremental workloads of 40-60% of maximum heart rate and includes sporting disciplines such as martial arts, windsurfing, weight-lifting. Endurance activity is defined as aerobic isotonic dynamic exercise at incremental workloads of 70-90% of maximum heart rate and includes sporting disciplines such as long and middle distance running, swimming or cycling, soccer and basketball. It is important to note that many sporting disciplines involve a combination of resistance and endurance exercise such as boxing, rugby, rowing and American football and therefore there is likely to be an overlap in normal ranges.

Specific algorithms have been included at the end of this document to provide a systematic approach when absolute values fall outside of the BSE normal range. It is important to note that these should be used as guidance only and if in any doubt further investigations should be considered.

Amount of athletic activity should be known. When screening patients for inherited cardiac disease due to a family history, the referring physician / echocardiographer should establish the patient’s level of physical activity. The total volume of training can be defined as (volume = intensity x duration) or Metabolic Equivalent (MET-h/week = METS x duration). An example of a select range of sporting disciplines and their specific METS is highlighted in table 3[6]. In summary, low-intensity exercise is defined as corresponding to 1.8 to 2.9 METS, moderate-intensity is defined as corresponding to 3-6 METS and high-intensity exercise is defined as > 6 METS.

Pre-Echocardiographic Information

The aim of the TTE is to differentiate physiological adaptation from pathological abnormality where possible. Therefore it is vital that the echocardiographer knows the main pathological conditions that may be found and must be aware of normal variation in response to exercise. The extent and nature of physiological cardiac adaptation in the athlete's heart is based on a number of factors, and an attempt should be made to obtain information on each of these before the TTE is performed. This should include the list of information presented in Figure 2. Although a standard minimum dataset is recommended for all echocardiograms, prior knowledge of these demographics and ECG findings will help to focus the examination, aid interpretation of findings and contribute to the subsequent management of the athlete.

Sporting Discipline	Metabolic Equivalent (MET)
Soccer	10.0
Running (6 mph)	10.0
Running (7.5 mph)	12.5
Running (10.9 mph)	18.0
Cycling (>20 mph) racing	16.0
Cycling (<10 mph) leisure	4.0
Cricket	5.0
Rugby	10.0
Tennis (singles)	8.0
Hockey	8.0
Boxing	12.0
Golf	4.5
Rowing (competitive)	12.0
Swimming (leisure)	6.0
Swimming (competitive)	10.0

Table 3 - Sporting examples demonstrating specific MET values for determining exercise intensity

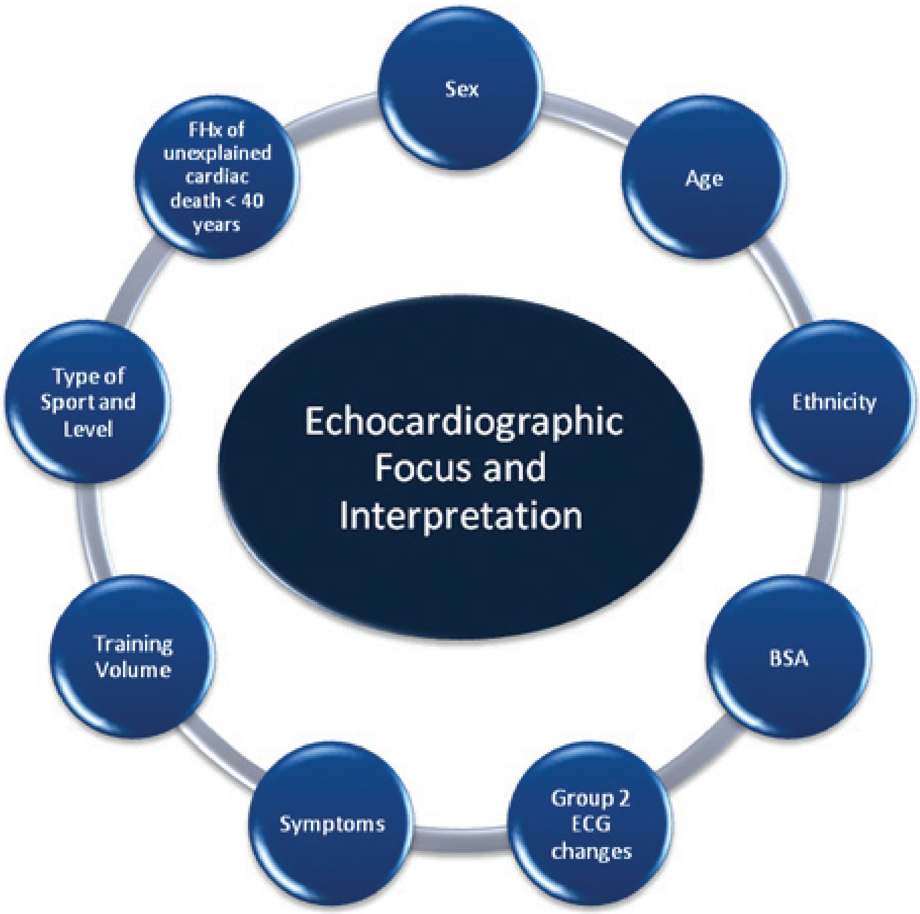


Figure 2 - Pre-Echocardiographic Information

Sex	Cardiac chamber dimensions in female athletes rarely fall outside of the established 'normal range'. If they do, further investigation is required[5,7]. It is more common for male athletes to demonstrate a degree of eccentric remodeling of all cardiac chambers[5,8].
Age	Highly trained junior athletes still develop cardiac remodelling in response to physiological conditioning[9] however this is often at a lower magnitude than in senior athletes. That aside, where structural values fall outside the BSE 'normal range' functional assessment is key.
Ethnicity	LV[10] and RV[11] cavity sizes are similar between African / Afro-Carribean and white athletes however wall thicknesses and LA size are often larger in the African/Afro-Carribean athlete[12]. Any wall thickness measurement with a value greater than 12mm in white athletes and greater than 14mm[10] in African/Afro-Carribean male or 13mm[13] in African/Afro-Carribean female athletes requires further investigation. There is a lack of data pertaining to the structure and function of Asian athletes although there is no significant difference in ECG findings between West Asian and Caucasian athletes[14]. The lack of available data on Asian ethnicity suggests that standard criteria as applied to Caucasian athletes should be utilised[15].
Body Surface Area (BSA)	The relationship between body size and chamber dimensions is well established[8,16] and therefore all chamber dimensions should be indexed for body surface area. That aside, cardiac adaptation to exercise involves eccentric hypertrophy beyond what may be attributable to body composition alone[5,8]. In the extremes of height and weight (BSA > 2.3m^2) non-indexed LV wall thickness and diastolic diameter should not exceed 14mm and 65mm respectively[17].
Symptoms	A positive history including exertional chest pain, syncope or near-syncope, irregular heartbeat or palpitations, shortness of breath or fatigue out of proportion with the degree of exertion should direct the echocardiographer to closely assess for potential causes of cardiac sudden death[4] (see figure 1). Symptoms are not specific and therefore it is important to ensure all possible causes are excluded. That aside it is important to be aware that exertional chest pain may direct further evaluation for coronary anomalies whilst syncope may be related to outflow obstruction or an arrhythmogenic substrate such as ARVC or HCM.

Group 2 ECG Changes	The type of ECG changes that are present on an athlete's ECG will further guide the focus of the examination. For example T-wave inversion in leads V1-V3 would direct a more focused assessment of the right heart. Lateral T-wave inversion is considered pathological and warrants further investigation.
Training Volume / Level	Elite athletes are likely to demonstrate a greater degree of physiological cardiac adaptation than those athletes who train at a much lower intensity.
Sporting Type	It is apparent that specific sporting disciplines create a specific stimulus that directs the degree of eccentric hypertrophy. Endurance athletes (cyclists, rowers, long distance runners) are likely to have a greater degree of eccentric hypertrophy of all chambers than athletes who engage in sport of a combined stimulus (soccer, tennis, hockey) or strength (powerlifting, wrestling, judo)[5,8,18,19]. As a guideline a RWT > 0.5 may be of particular concern.

Table 4 - Considerations for each of the specific pre-examination factors

Echocardiographic Examination

The following protocols should be strictly adhered to in order to exclude pathology:

- BSE Minimum Dataset
- BSE protocol for the assessment of LV diastolic function
- BSE protocol on the assessment of the right heart with a focus on ARVC
- BSE protocol for HCM
- BSE protocol for DCM *(in preparation)*

In addition the following image acquisition should be made.

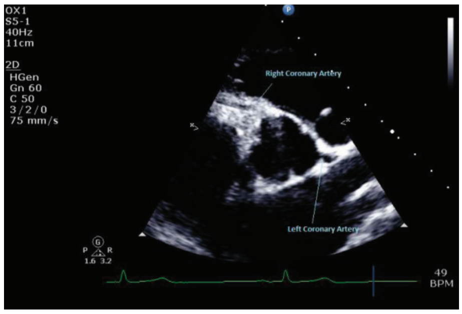
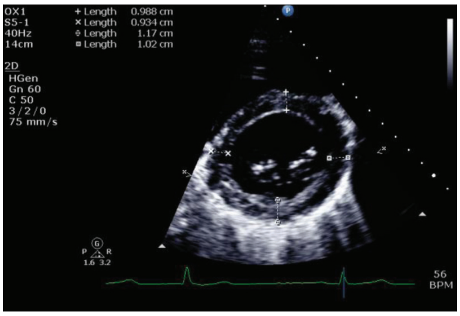
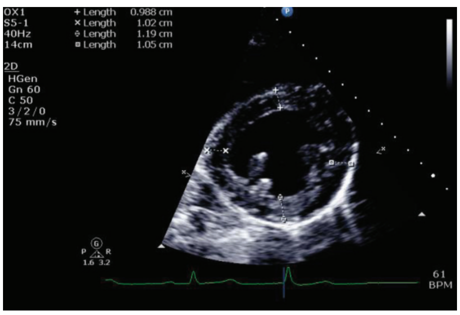
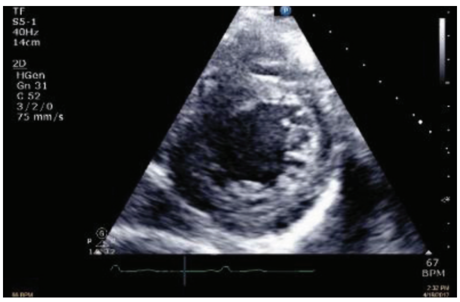
VIEW & MODALITY	EXPLANATORY NOTE	IMAGE
PSAX AV LEVEL (2D)	Identify Coronary Ostia	
PSAX BASAL LV LEVEL (2D)	LV wall thicknesses should be measured at end diastole from the basal anterior septum, inferior septum, posterior wall and lateral wall.	
PSAX MID LV LEVEL (2D)	LV wall thicknesses should be measured at end diastole from the mid anterior septum, inferior septum, posterior wall and lateral wall.	
PSAX MID TO APICAL LEVEL (2D)	Excess trabeculation is a common finding in elite athletes particularly of African / Afro-Caribbean ethnicity20. Left Ventricular Non-Compaction (LVNC) Cardiomyopathy needs to be excluded but making this diagnosis in an athlete may be challenging.	

Table 5 - Additional image acquisition

Data Interpretation

The following algorithms highlight possible interpretation of the athlete's echocardiogram when absolute values fall outside the BSE normal range. A reporting template adapted from Cardiac Risk in the Young is appended at the end of this document.

Figure 3 - Algorithm when Left Sided Parameters Fall Outside Normal BSE Ranges

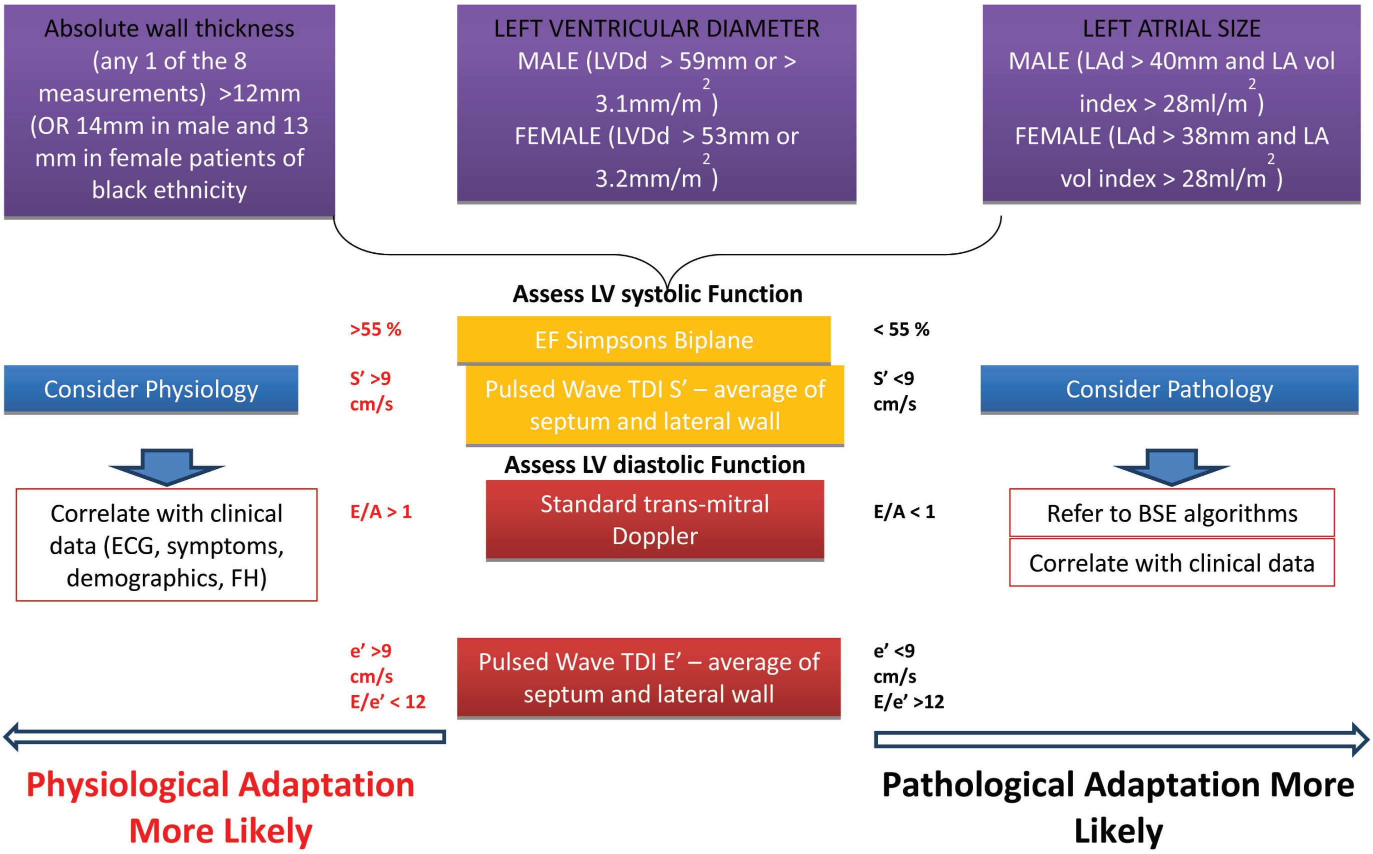
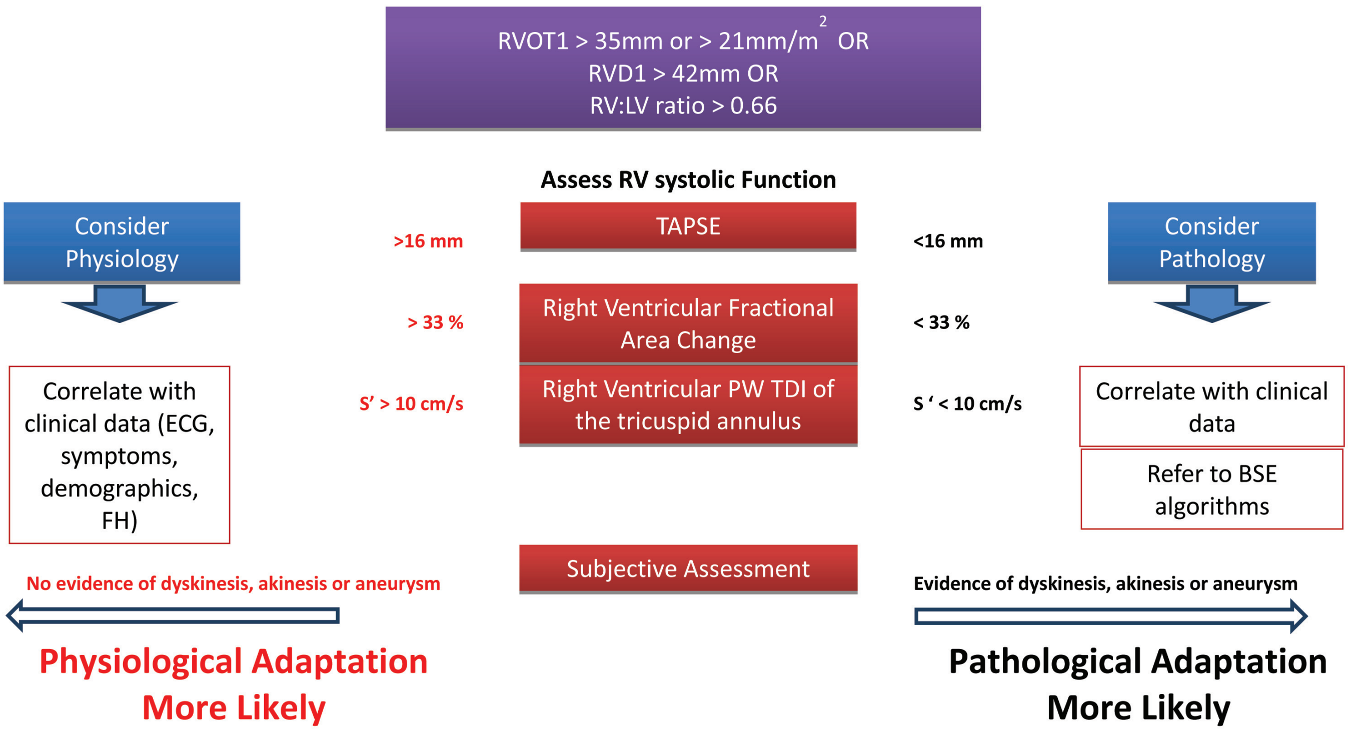


Figure 4 - Algorithm when Right Sided Parameters fall Outside BSE Normal Ranges

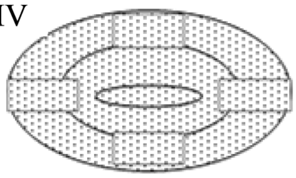


Reporting Template

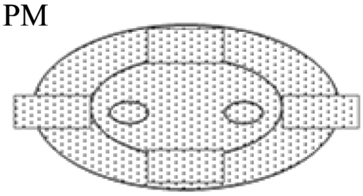
Name		Rate + Rhythm	
ID		DOB	
Operator			

LV Wall Thickness

MV

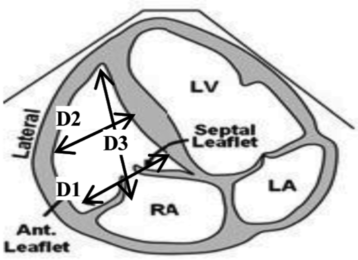


PM

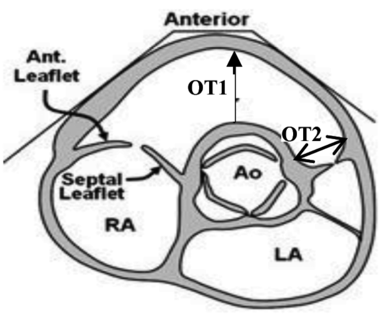


Minimum LV Dataset			
LA	mm	LVOT Vmax	m/s
Ao	mm	LVOT VTI	cm
LVES	mm	MV E/A	/ m/s
LVED	mm	DecT	ms
MR 0-4	AR 0-4	Septal E'/A'	/ cm/s
LCA ostium	☐ seen ☐ not seen	Lateral E'/A'	/ cm/s
RCA ostium	☐ seen ☐ not seen	Desc Ao Vmax	m/s
AV Vmax	m/s		

Right Heart



Minimum RV Dataset		
TR 0-4	PR 0-4	
TR max PG	mmHg	≤35
RVOT Vmax	m/s	
RVOT VTI	cm	
TAPSE	mm	≥ 16
IVC (max / min)	/ mm	
CW + PW TV inflow	Image acquired? ☐ ☐	
RV-focused A4C	Image acquired? ☐ ☐	
TV annulus TDI	Image acquired? ☐☐	



Additional Measurements					
RVOT $_{plax}$	mm	≤ 33	RAA	cm^2	≤ 18
RVOT1	mm	≤ 35	RVFW Thickness	mm	≤ 5
RVOT2	mm	≤ 27	PR end PG	mmHg	
RVD1	mm	≤ 42	TV E/A	/	
RVD2	mm	≤ 35	RV E'/A'	/	
RVD3	mm	≤ 86	RV S'	cm/s	≥ 10

Comments:

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