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Examination of whole lengths of coronary arteries by color flow echocardiography

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Abstract: Introduction: increased cases of cardiac diseases in our world, and the absence of non-invasive, accurate, and feasible method of examination necessitate the looking for one's which achieved these criteria, that is the visualization of the coronary arteries (CAs) by means of the color flow transthoracic echocardiography.

Aim of work: To check the possibilities of color flow mode of Transthoracic Echocardiography for seeing the whole lengths of coronary arteries and areas of stenosis, dilatations, and possibilities of visualization of collateral vessels.

Materials and Methods: In Adhale governorate, Yemen republic, an observational study was conducted at Dr. Nashwan Al-Ashwal Clinic for medical and cardiac diseases. Cases were selected randomly. The total number of them was 763 participants, 700 males and 63 female ranging from 5 months to 70 years old, and then divided into two groups; 228 control and 535 patients. Period of study was from 1st January to 31th December 2021. The collected information was entered into Microsoft excel and word. Technique of examination by using of routine transthoracic echocardiography and the color flow mode with adjustments of its parameters as explained in the context.

Results: A success in visualization of the whole lengths of coronary arteries in all patients (100%), in addition to some other features also were seeing, as the following: "group 1" few areas of beaded shape scattered along the vessel course, and one or two blue segments connecting the red vessel end to end of the same artery, and small area/areas of either red or blue colors with network shapes, while in "group 2"; there are more beaded areas, more than two areas of mosaic color reflections (stenosis), arterial segment/segments with dilatation, more than two blue segments of short or long distances that connecting end to end of the same red (artery) vessel and to another vessel/vessels, local and diffused color changes in the blue (collateral arteries or connector vessel) or red vessels to tint white or yellow colors respectively, large areas of either red or blue color (network arteries), blood pooling focus that pumping blood into more than one areas distal to level/levels of coronary arteries stenosis, and lastly, appearance of a darken area/side in the left ventricle. decreased in /absence of blood vessels, particularly, the red ones, in few patients with severe ischemic dilated cardiomyopathy.

Conclusion: The examinations by color flow mode of transthoracic echocardiography permits the visualization of whole lengths of coronary arteries, stenotic and dilated segments, in addition to the small coronary arteries and the collateral vessels or rescuing circulation, and discovered that the collateral circulation is in needs for higher pressure in the pre stenotic segments, to open their vessels one by one, and also to facilitate blood flowing through the stenotic segments before development of collateral circulations, that also affected by atherosclerotic changes, and leads to arise of blood pooling focus.

Keywords: Color flow echo, Stenosis, Dilatation, collateral vessels, whole lengths of CAs,

الكشف عن الامتداد الطولي الكامل للشرايين التاجية القلبية بالتدفق اللوني لجهاز موجات فوق الصوتية القلبية الصدرية

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المستخلص: المقدمة: إن ارتفاع اعداد الحالات المرضية القلبية في عالمنا، مع عدم وجود وسيلة كشفية عملية، دقيقة وغير باضعة، وسهلة المنال بواسطة مرضى الفقراء، يحتم علينا أن نبحث عن واحدة تحقق هذه المعايير، وتمكننا من رؤية الامتداد الطولي الكامل للشرايين التاجية القلبية بواسطة التدفق اللوني لجهاز الموجات فوق الصوتية القلبية الصدرية.

الأهداف: اختبار إمكانية رؤية الامتداد الطولي الكامل للشرايين التاجية القلبية بالتدفق اللوني لجهاز الموجات فوق الصوتية القلبية الصدرية، ومناطق التضيق. والاتساع الشرايني وإمكانية رؤية الأوعية الشرايينية المكملة أو الإنقاذية.

المواد والمنهجية: تمت الدراسة في عيادة الدكتور نشوان الأشول للأمراض الباطنية والقلبية والكائنة في محافظة الضالع بالجمهورية اليمنية، مستخدما دراسة الملاحظة ومنتقيا للحالات بطريقة الاختيار العشوائي. العدد الإجمالي للمشاركين في الدراسة بلغ 763 مشارك بينهم 700 من الذكور و63 من الإناث، وتتراوح أعمارهم بين 5 أشهر و70 عاما، حيث تم تقسيمهم الى مجموعتين؛ إحداها للمراقبة 228 مشارك، والأخرى 535مريضا ممن لديهم أعراض مرضية صدرية وقلبية، وقد تمت في الفترة من 1 يناير وحتى 31 ديسمبر 2021. تم إدخال المعلومات وتوثيقها في برامج ميكروسوفت الحاسوبية. تقنية الكشف تعتمد على الطريقة الكشفية المعتمدة عالميا بالإضافة لاستخدام طريقة معدلة للكشف بالتدفق اللوني لجهاز الموجات فوق الصوتية القلبية الصدرية، كما تم إيضاحها في متن الدراسة.

النتائج: أظهرت النتائج نجاح الدراسة بنسبة 100%، حيث تم رؤية الامتداد الطولي الكامل للشرايين التاجية القلبية في جميع المشاركين، في كلا المجموعتين، بالإضافة الى رؤية بعض الميزات البارزة كالتالي؛ في المجموعة الاولى (مجموعة المراقبة) بضعة مناطق ذات أشكال سبحية أو خرزية متفرقة على طول الوعاء الدموي الشرايني، وقطعة الى قطعتان وعائيتان توصيليتان، ذات وظيفة توصيلية بين النهايات المغلقة او المسدودة للشريان التاجي او الإكليلي المصاب، ولها لون أزرق بخلاف اللون الأحمر للشريان الأصلي، منطقة أو مناطق صغيرة تتخذ شكل الشبكة الشرايينية إما حمراء أو زرقاء، بينما في المجموعة الثانية (مجموعة المرضى)؛ يوجد مناطق سبحية أو خرزية أكثر، ووجود أكثر من منطقة مزيقة أو فسيساء؛ تضيق شرايني، وقطعة أو أكثر متمددة، وتزيد في هذه المجموعة طول القطع الشرايينية الزرقاء التي توصل بين النهايات الحمراء المسدودة في نفس الشريان او بشرايين أخرى قريبة أو بعيدة، تغير منتشر في لون الشرايين من أزرق الى أبيض باهت ومن أحمر الى أصفر بشكل أكثر اتساع عن المجموعة الأولى، مناطق واسعة من الشبكات الشرايينية أكبر مما هي عليه في المجموعة الأولى، وتكون أشكال سبحية او خرزية في الشرايين الزرقاء، وجود بؤرة واحدة أو أكثر لتجميع الدم وضخه الى أكثر من منطقة قاصية عن مستوى الانسداد في الشرايين التاجية الحمراء، وأخيرا، ظهور منطقة طولية معتمة في البطين الأيسر من الشرايين الحمراء وذلك في عينة المرضى باعتلال العضلة القلبية التمددية الإقفارية.

الخاتمة: الكشف بطريقة التدفق اللوني لجهاز الموجات فوق الصوتية القلبية الصدرية يسمح برؤية كامل الامتداد الطولي والعرضي للشرايين التاجية القلبية، والقطع الوعائية المتضيقة وكذلك المتمددة، بالإضافة الى رؤية الشرايين الصغيرة والأوعية المكملة او الدورة الدموية الإنقاذية، واكتشاف حاجة الدورة الدموية الإنقاذية لضغط مرتفع في القطع الوعائية الواقعة قبل مناطق التضيق كي يساعد في مرور الدم عبر التضيق حتى تنفتح الأوعية الاحتياطية الشرايينية التي امدنا الله تعالى بها كي تعوض النقصان في التروية الدموية للمناطق البعيدة والقريبة من التضيق، وهذا سبب ظهور البرك الدموية الوعائية.

الكلمات المفتاحية: صدى التدفق اللوني، تضيق، تمدد، أوعية إنقاذيه، الطول الكامل للشرايين التاجية.

1- INTRODUCTION:

Cardiovascular diseases cause approximately one-third of deaths worldwide [1, 2], and among these illness, ischemic heart disease (IHD) ranks as the most prevalent [1, 3], for example; about 15.4 million persons older than 20 years in the united states alone have ischemic heart disease [4], i.e. The disease

involved younger persons, which predicted increasing numbers of an early occurrence of coronary arteries problems in the next decades. The examinations of coronary arteries by coronary catheterizations can't be done for every person with a recurrent chest pain or discomforts and normal electrocardiogram due to the possible risks of the invasive procedures in spite of its benefits [5]. Also, it is a very expensive, and infeasible to everyone, which be impossible to do it routinely, in order to discover the latent pathological process of the CAs, which necessitate the looking for inexpensive, feasible and accurate non-invasive mode of examinations, particularly after the possibilities of seeing the CAs by 2-Dimensional echocardiography[6, 7, 8, 9, 10, 11, 12, 13], that permits the visualization of stenosis and dilatation, then with the advancing in color flow and Doppler echocardiography, *Krzanowski K. et al.* (2003) [8], *Watanabe, N. et al.* (2001) [14], and *Pizzuto F. et al.* (2006) [15], were used the examination approach of segment by segment to see coronary arteries along their anatomical courses, recently, for more easiest examinations, I have done this study to examine the possibilities of color flow mode of transthoracic echocardiography for seeing the whole lengths of coronary arteries and their collateral vessels, in addition to the stenotic and dilated segments as possible as, by applying some modifications to their approach, in order to visualize a longer lengths of the coronary arteries in the view. This way of color flow echocardiographic examinations will make the visualizations of coronary arteries easiest and facilitate early detection of visible pathological changes in the coronary arteries and a rescuing circulation (the collateral circulation), that of course, provoking an early medical or surgical interventions; for example, as an urgent medical therapeutic and/or Percutaneous Coronary Interventions before the occurrence of myocardial injuries, to decrease the global cardiac morbidity and mortality.

2- Materials and Methods:

An observational study on randomly selected patients, they have suffered of different diseases; as gastrointestinal, renal, musculoskeletal, diabetic, respiratory or cardiac. The collected information was entered into Microsoft excel and word programs. It's aiming to use transthoracic Color Flow Echocardiography for coronary arteries (CAs) examinations. The study was conducted at Dr. Nashwan Al-Ashwal Clinic for Medical and Cardiac Diseases, in Adhale Governorate – Yemen, in the period from 1st January to 31th December 2021. The total number of patients is 763; 63 females and 700 males, their ages ranging from 5 months to 70 years old. They were divided into two groups: "group 1" (228 persons); with no chest complaints, "group 2" (535 patients); with chest pain and/or discomforts even before one's year ago. Excluded criteria as the inability to stay in the examination bed for 15 to 30 minutes, as severe breathlessness and vertebral column problems. Inclusion criteria; any patient with no relation to the age, who has the ability to stay in the bed for 15 - 30 minutes without back pain or breathlessness. The advantages of this examination approach are its fitness for any person with no age effect on its technique, the examiner can see the visible coronary arteries and their ventricular walls, the colors give more

attention and by it the shape and diameters can be detected, while its disadvantages are the need for good patience, continuous and hard training by the examiners, and the use of helpful electronic device such as modern phones or tablets for videos interpreting, if the examiner needs to know the condition of the smaller coronary arteries, and also there is some difficulty in patients with diseases of lung hyperinflation, which can be solved by using the subcostal and splenic windows, and the aliasing problem will be solved by individualization of adjustments. The examinations have done by a curved probe of multi-frequency, using 2 - 5 MHz of Cardiac mode, for routine cardiac examinations, as explained in the references[7, 8], including examinations of all long axes of cardiac walls, as explained in previous studies[6, 9], to detect any latent ischemic effects, and lastly, the color flow mode was applying to all patients with an adjustment of the color flow box size, contrast and pulse repetition frequency (PRF) individually to get clear images of the coronary arteries and their details, and for visualization of the left anterior descending coronary artery on long parasternal view the two dimensional mode should be switched on 4 or 5 MHz before switching to color flow mode. Coronary catheterization was taking for patients with distant collateral circulation in order to compare between results of it and of color flow echocardiography.

Results:

In both groups the whole lengths of coronary arteries are seeing with a success of 100%, as shown in figure 1, and these vessels are showing as tubular structures

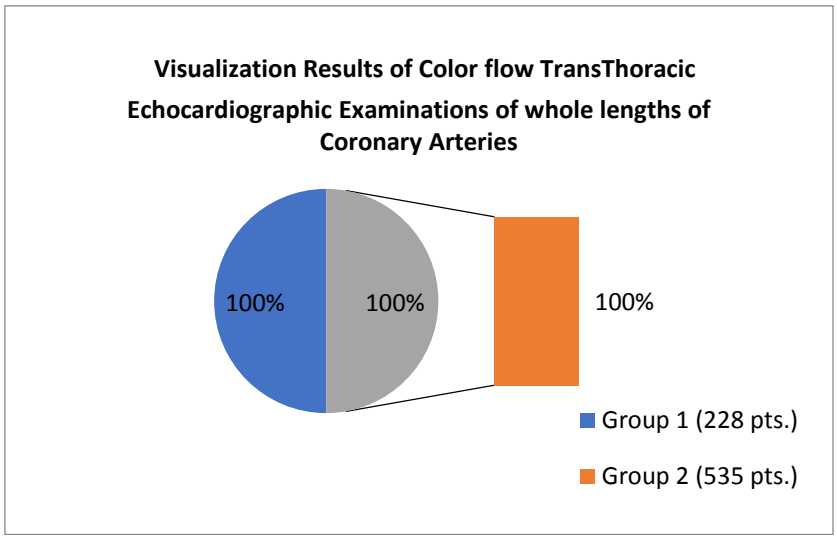

Figure 1: Represents the percent of success in seeing the whole lengths of coronary arteries, that examined by transthoracic color flow echocardiography, which is possible in all patients achieving 100% success.

(blood vessels) of red (more abundant) and blue color reflections that were arising from the left and right coronary sinuses of aortic artery by 4 chambers view, on both sides of the inter-ventricular septum, directed from base to apex, along both sides of IVS, near to the lateral wall of LV, and intermediate

between them, and on right side of inter-ventricular septum, near to right ventricular wall and intermediate between them from the base to the apex as shown in figures (2, 3), and movies (1, 2, 3, 4, 5)

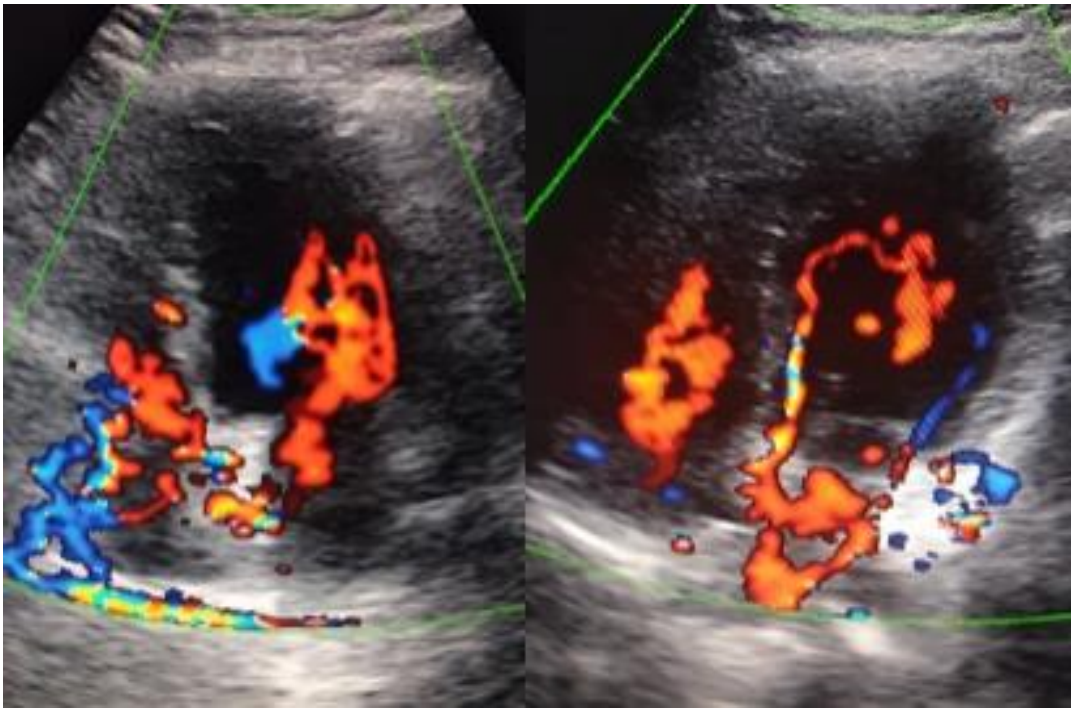

Figure 2:four chambers & modified views; show right and left CAs in addition to the collateral vessels with mosaic colors from right to left and vice versa (right side), and connecting blue segment of the lateral LV wall CA (left side of the figure).

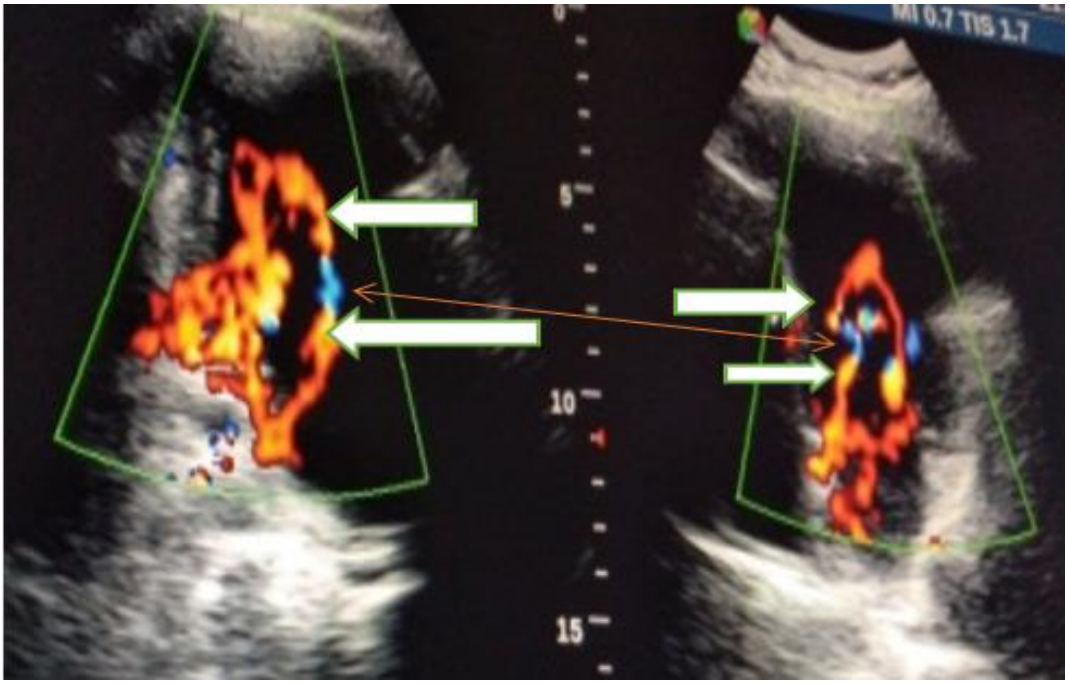

Figure 3: two and four chambers views respectively, show the blue connecting segment in the LAD-CA (double heads red arrow), connecting both ends (white arrows); instead of the obstructed segment, and CAs of inferior, septal and lateral LV walls.

Also by long parasternal, 5-chambers and modified views, as shown in figures (4 & 5), and movies (1, 6, 7 & 8). CAs of one side as by long parasternal and

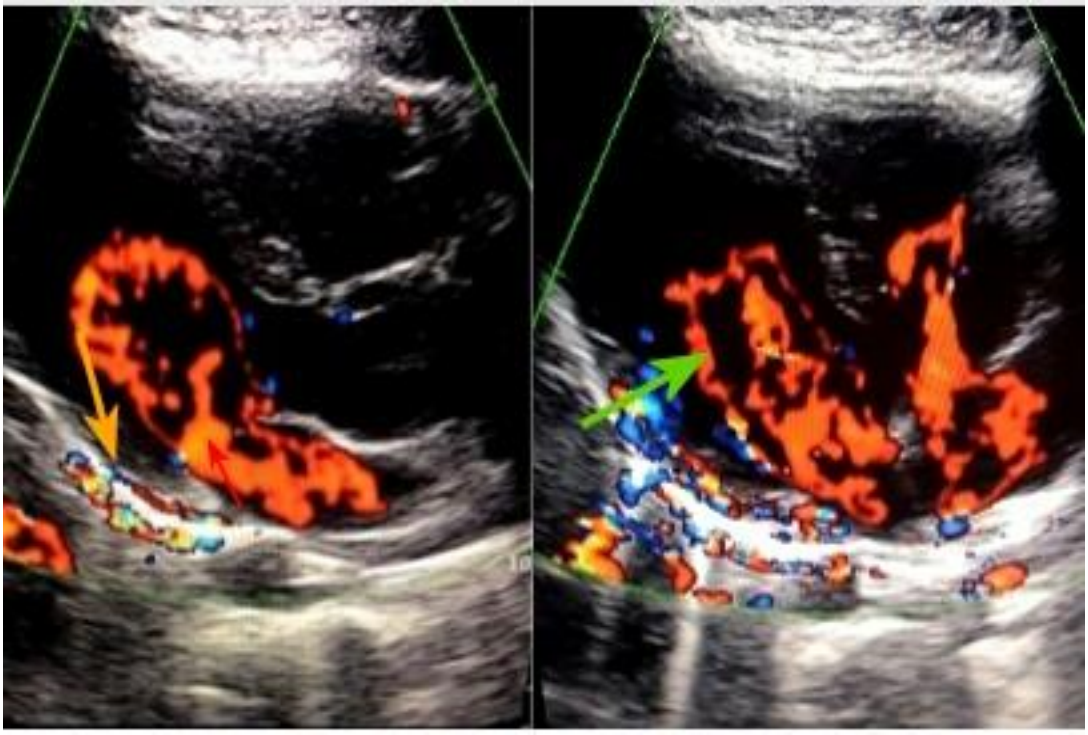

Figure 4: Long parasternal and Modified views; show the coronary arteries of the related walls left & both ventricles respectively, in addition to the small network arteries (red arrow), Stenosis (yellow arrow), dilated pre-stenotic segment (green arrow), & the blue vessel segments.

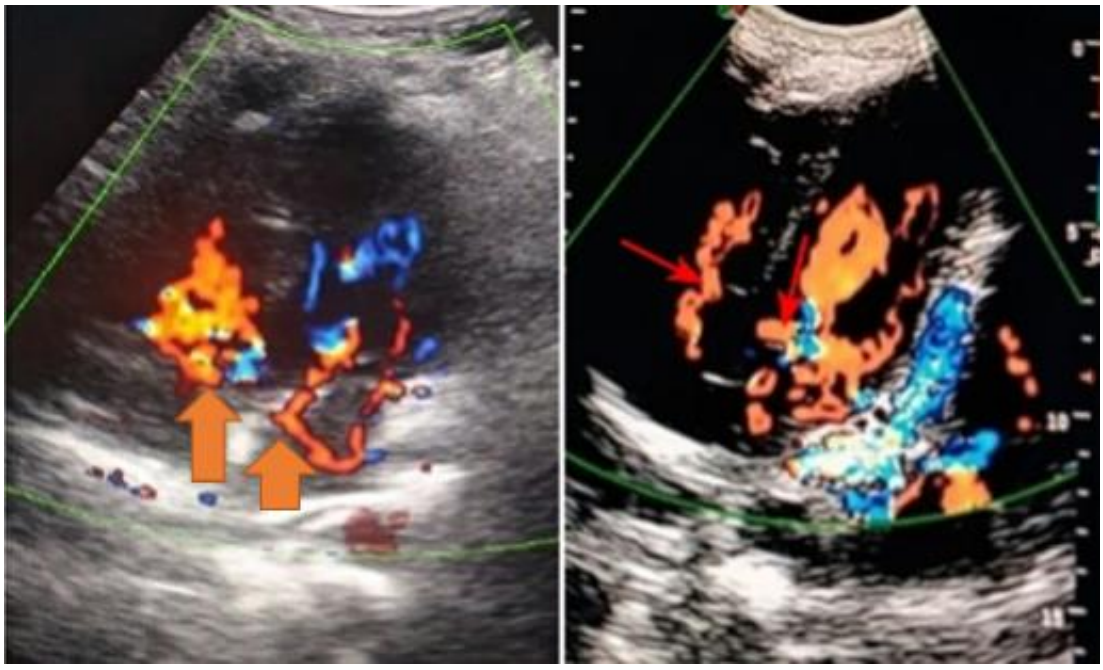

Figure 5: five chambers & modified views; show the right and left stems of CAs (red arrows) with their branches, they are more apparent by the modified five chambers view, in addition to visualization of lateral wall collateral blood vessels (left side).

two Chambers views as shown in figures (6, 7), and movies (6, 7 & 8). Also by long

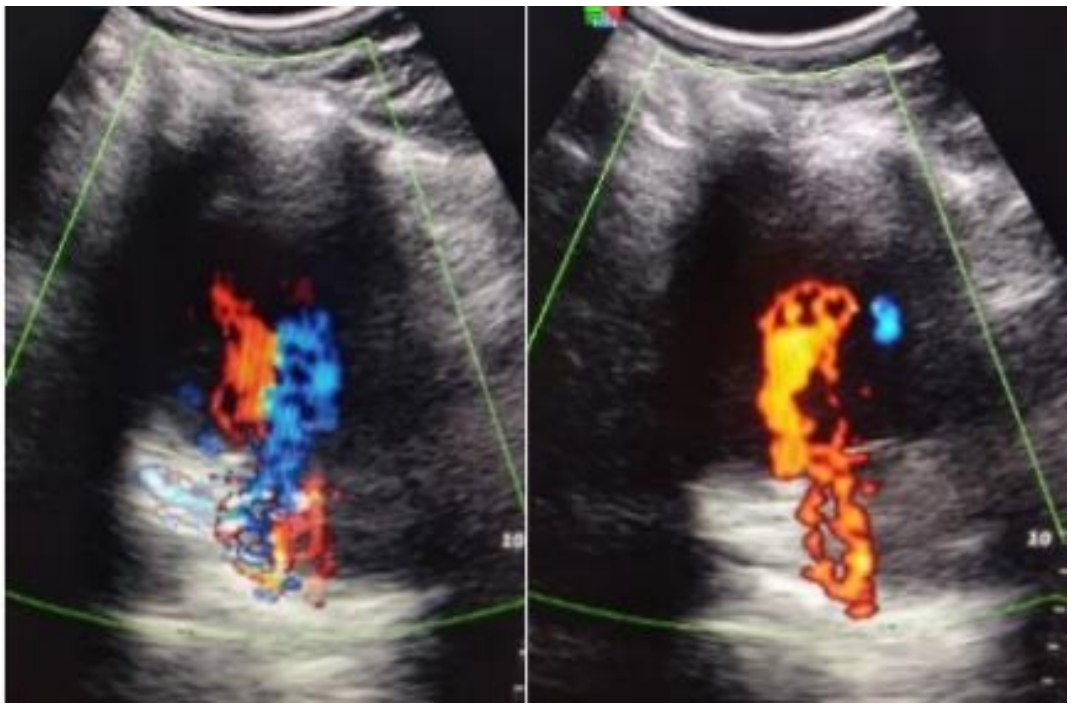

Figure 6: two chambers view & modified one's; show the CAs of related walls (anterior & inferior walls), and large network arteries (solid colors)

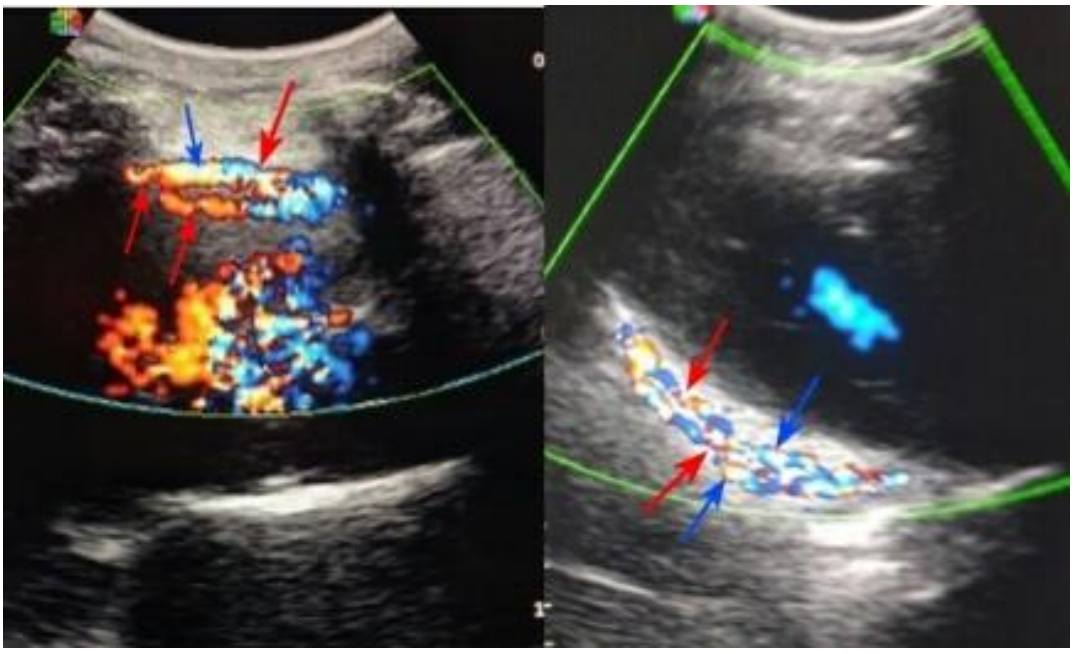

Figure 7: long parasternal view & modified one's (in direction opposite to figure 2), show the anterior & posterior descending CAs respectively, with the stenosis (red arrows), and dilatation (blue arrows).

and short subcostal views the vessels are seeing bilaterally but with one side more than the other's depending on the angulation as shown in figures (8, 9), and movies (13 & 14). And also by short parasternal views there are vessels that runs

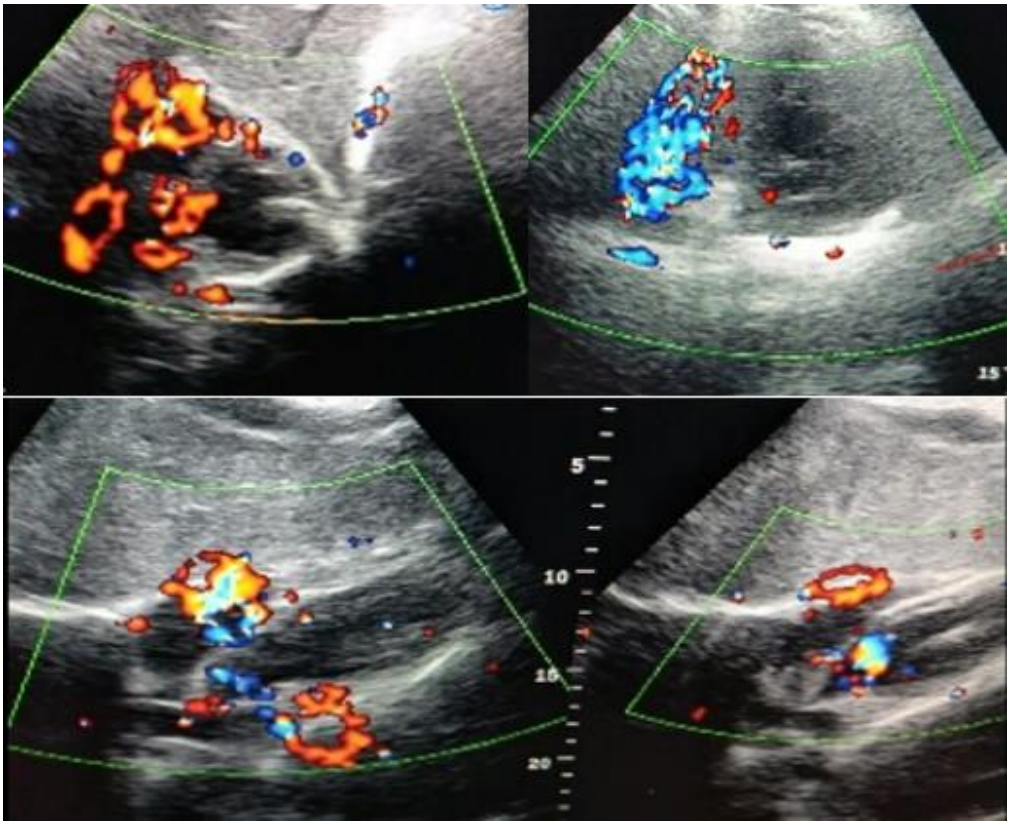

Figure 8: long subcostal views below and short one's above; it show the right and left coronary arteries with different angles and levels.

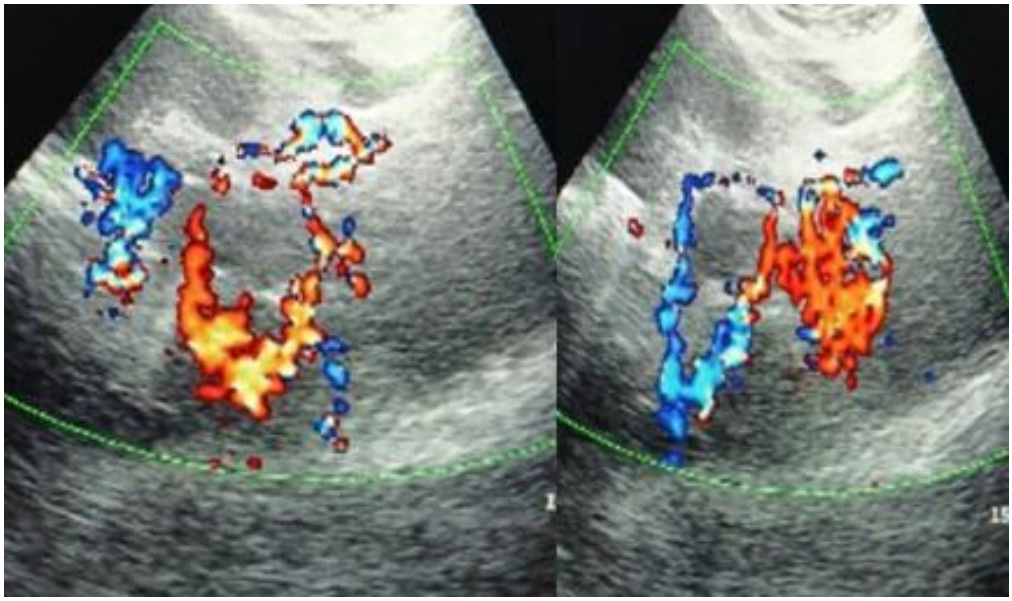

Figure 9: Long subcostal views show multiple branches of the right coronary artery beside the left coronary artery branches for collateral circulation to pass the stenosis

horizontally and have seen in the field of both ventricular cavities as shown in figure (10), and movie (9, 10 & 11). Also in anterior and posterior atrioventricular grooves

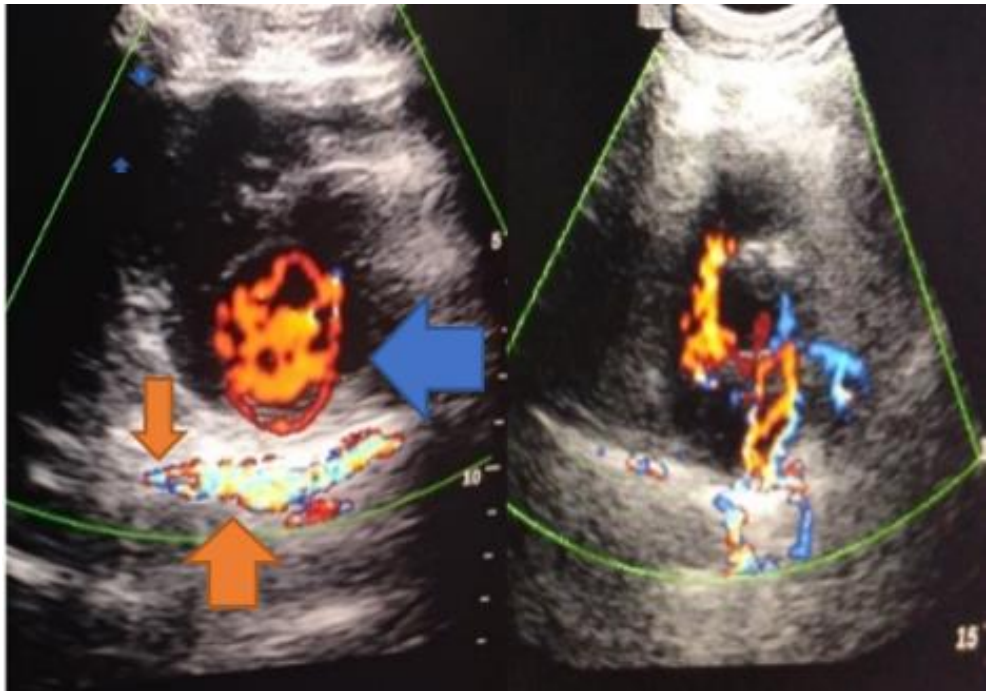

Figure 10: Short - axis parasternal views; on right side; show CAs of middle LV level that connected to each other via parts of the network arteries (blue arrow), and the posterior descending part (because the level at papillary muscles, not at atrial level that shows circumflex artery), with another artery from right to left (red arrows), on the left side the horizontal view of proximal CAs at level of aortic annulus were seeing.

related coronary arteries were seeing, as shown by long parasternal and modified one's in figure (7) above, and also for posterior descending coronary artery by short parasternal as shown above in right side of figure (10), also both arteries can be seen, as shown by movies (from 6 to 14), Also, there are some features which characterizing the vessels in each group, as shown in (table 1), related figures, and all movies from 1 to 14. As the following: In "group 1" two neonates (0,9%) aged 5 and

Table 1: represent numbers of patients and control groups and percentage of success in visualization of the whole lengths of coronary arteries lengths and the stenosis, dilation and collateral vessels

Groups	Age	Success of visualization of coronary arteries per cent				
		Whole lengths	beaded	Stenosis*	Dilation	Collateral vessels
Control (228 patients)	5 months to 50 yrs.	228 (100%)	228 (100%)	195 (85,5%)	228 (100%)	228 (100%)
patients (535)	35 to 70 yrs.	535 (100%)	535 (100%)	535 (100%)	535 (100%)	535 (100%)

*stenosis in the 85,5% of patients in the control group can be considered as 100% because the 14.5% has beaded shapes and the narrower areas constitutes a stenosis but of non-significant percentage

in relation to the others, because the beading changes in the arterial wall are preceded and followed by dilated segments.

9 months, they have vessels with red and blue colors (arteries) with scattered beaded shapes, scattered reflections of tent yellow colors in the lumen, no significant stenosis or dilatations were seeing, as shown in right side of figure (11), and movie (16), and

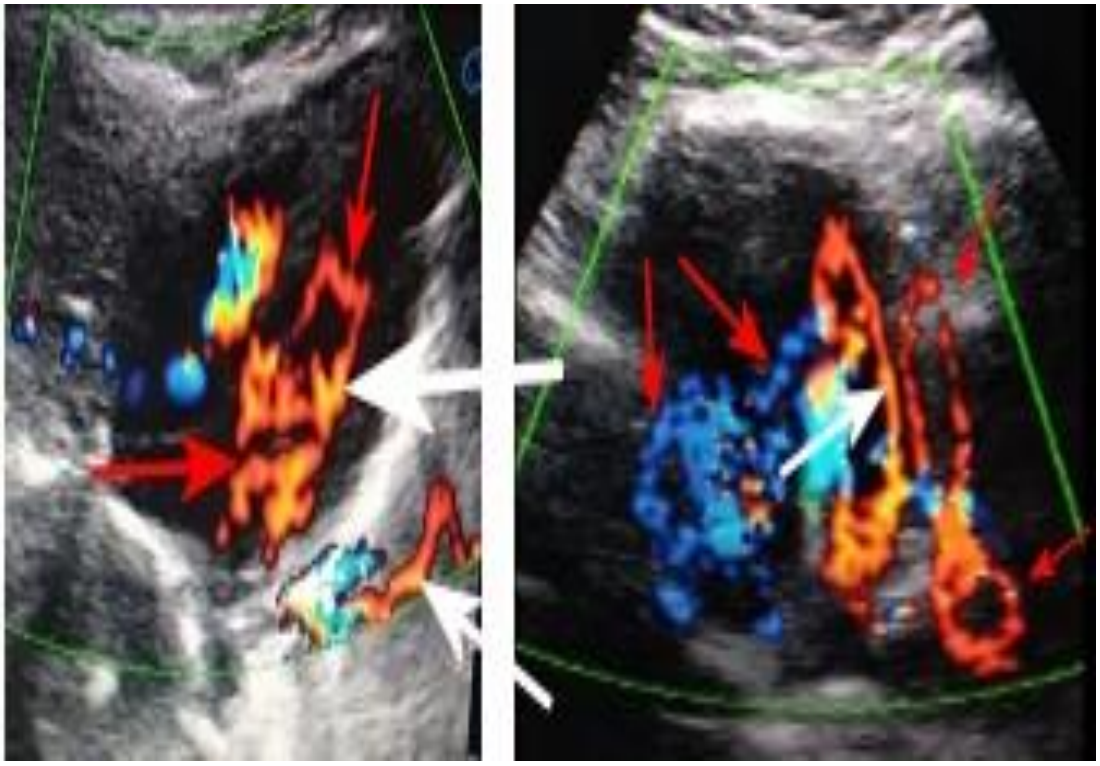

Figure 11: subcostal view of neonate (right side) & four chambers view of adult (left side); show scattered beads on right side (red arrows), and multiple beads in main and collateral circulatory vessels; advanced stage of atherosclerosis, on left side (red arrows), in addition to the yellow tent color in the CAs lumens (white arrows).

in the 13,6% (31 patients; aged from 5 to 16 years old), there are few beaded shapes in one or two parts of one artery, one or two blue segments connecting the red vessel end to end in the same artery, tint yellow color changes in the arterial lumen and small to medium areas of network arteries as shown above in figures (4 & 6), and movie (17), the other 85,5% (195 patients; aged from 20 to 50 years old), have a more beaded areas, as shown above in figures (7, 11), one to two areas of mosaic color reflections inside the red vessels, with stenosis, as shown in figures (7, 9, 10, 12 & 13), more than two blue segments of short or long distances, that connecting end to end of same red vessel or to another vessels, as shown in all figures except number 18, local color changes in the blue vessels (collateral or connector vessels), from blue to tint white colors as shown above in figures (7, 9, 10, 11) and below in figures (12, 13 & 14), and all movies except movies (15 & 16), The small to medium areas of network arteries, either with red or blue color as shown above in figures

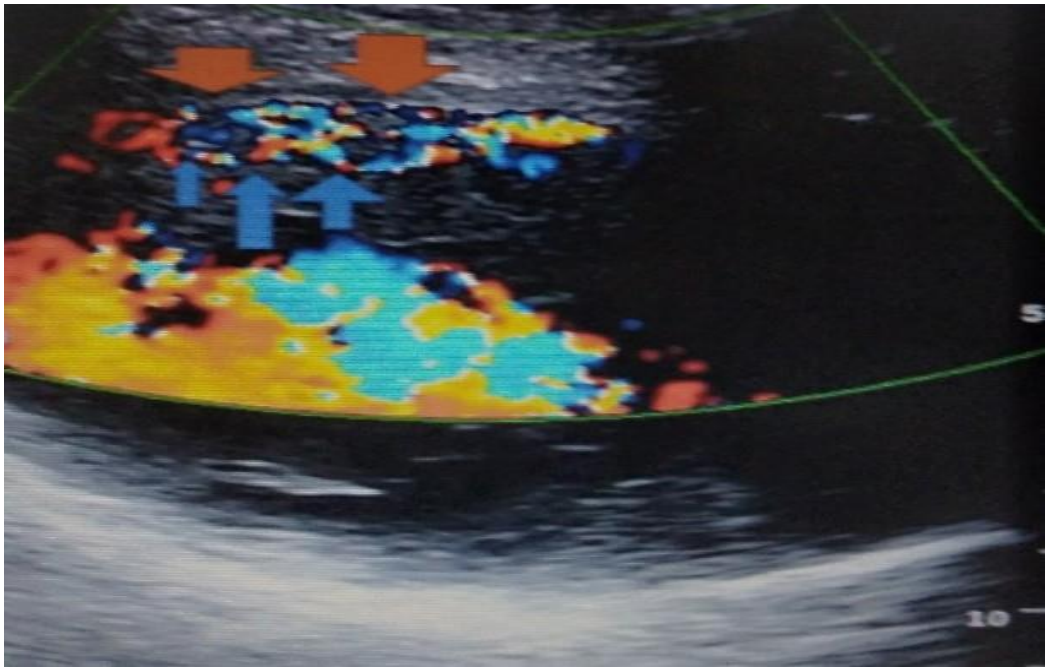

Figure 12: Long parasternal view of left anterior descending coronary artery, shows multiple stenosis and rescuing vessels or proximal collateral vessels, red arrows pointing to severe stenosis to obstruction of the original LAD-CA, and blue arrows pointing to stenosis of the collateral vessels, in between left red and blue arrows there are three arteries; original, first and second collateral, and in between the right; one red and two blue arrows, also there are three arterial parts; one original and two collaterals.

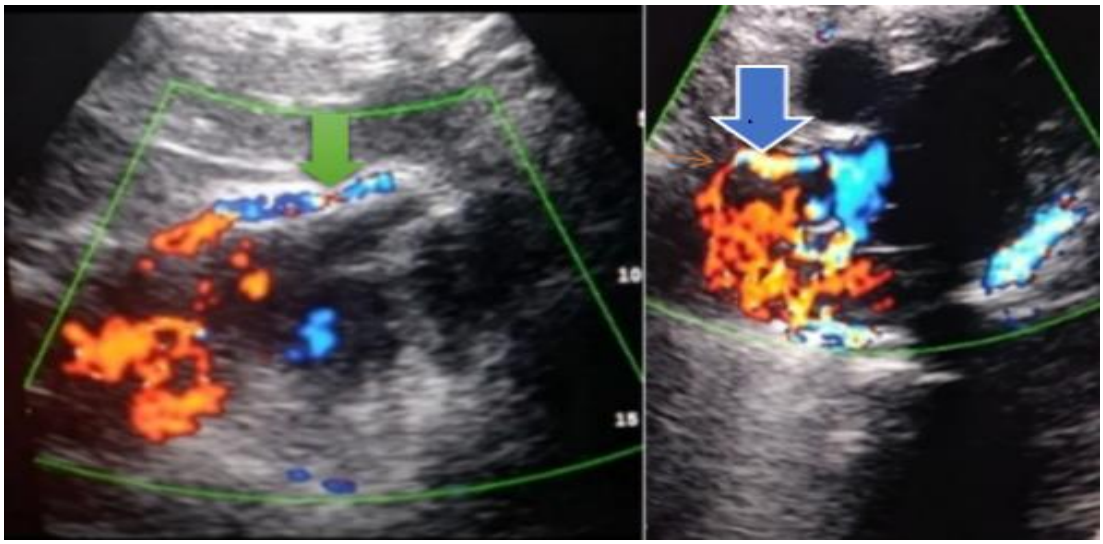

Figure 13: subcostal (right) & apical parasternal (left) views; show severely stenotic PD-CA (green arrow), and branch of right CA (red arrow) with pre-stenotic dilatation (white blue arrow), with Rt. to Lt. blood supply.

(2, 3 , 10, 11), while those in "group 2" 99,1%; (530 patients; from 35 to 70 years old), all of them have a more beaded areas, white colored blotches in the narrowest vessels, more than two areas of mosaic

color reflections inside the pre and narrowest segments of the red/blue vessels, more blue segments of short or long distances that have connected the end to end of the same red vessel or to another vessels, local to diffuse color changes in the blue vessel (collateral or connector vessels), from blue to tint white color, large area/areas of network arteries of red and blue vessels, as shown in movie (18) figure (17) and some other movies and figures (except for right side of figure 11 and 15), and movies (from 1 to 14, 17 & 18), while for 10 patients (1,9%) from the 530 patients (99,1%) of group 2, in addition to the aforementioned

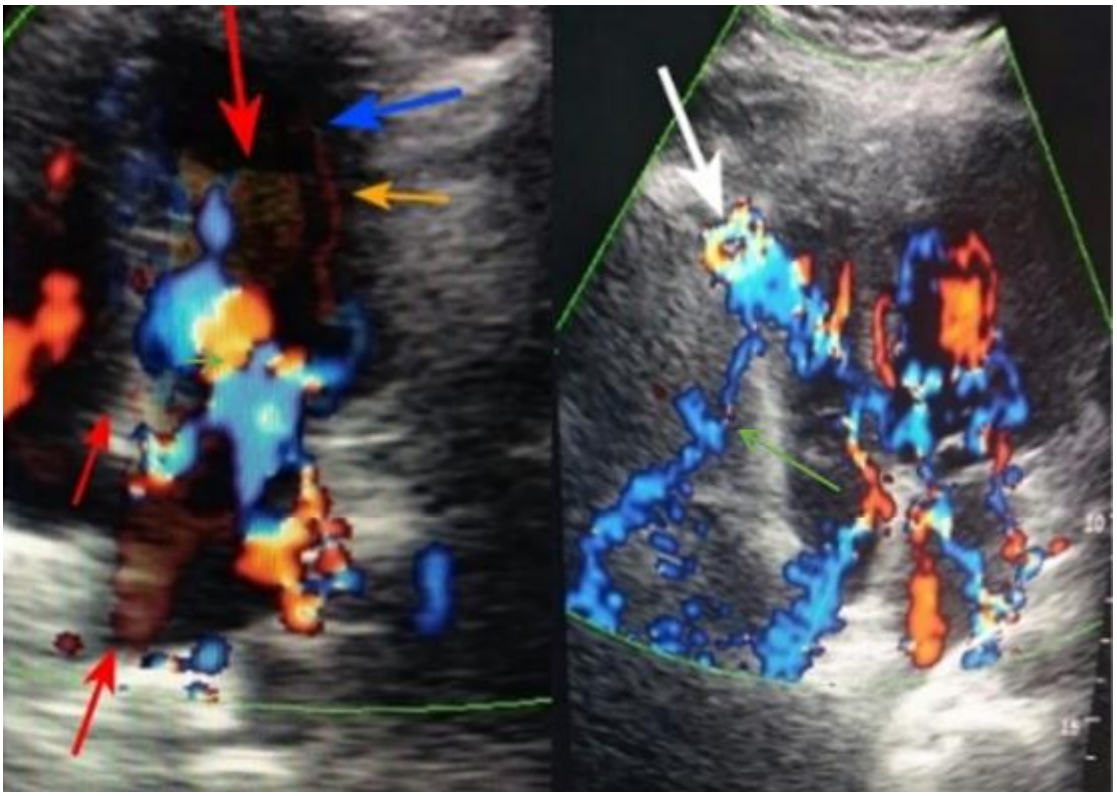

Figure 14: four chambers views; show on right side, very small coronary arteries that penetrated the inter-atria and inter-ventricle septum's (red arrows), and blue connecting segment of collateral vessel parallel to the lateral LV wall connected to small original CA (yellow arrow), that has stenotic area more distally (blue arrow), and solid colors of arterial networks (right green arrow), and on left side a blood pooling focus appear on right ventricular wall (white arrow), & stenosis of the collateral or blue vessels (left green arrow), in addition to very small areas of solid colors (arterial networks).

features also have a pool/s of blood with two or more inflow and outflow vessels, as shown in figures (13, 14, 15 & 16), and movies (2, 3, 6, 8, 12, 13), and in the last 0,9%, (5-patients); of group 2" whose aged 35 to 60 years old

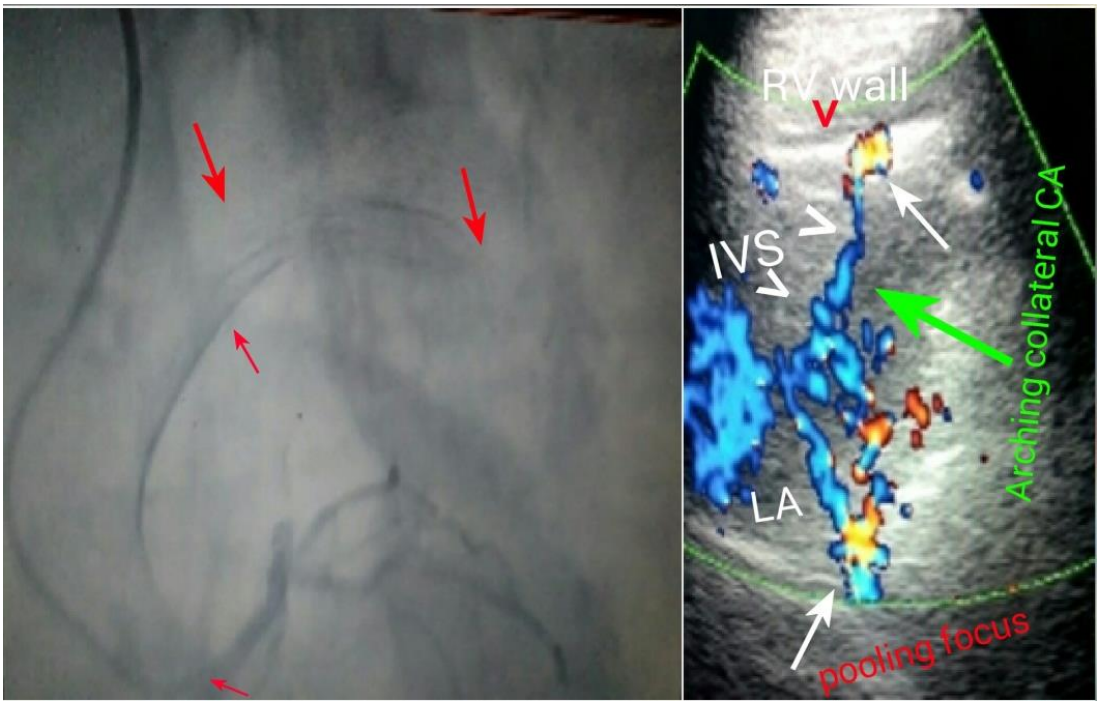

Figure 15: two views; right, for left main stem CA catheterization, it shows arching of multiple coronary arteries that arises from point pre to the main bifurcation, and extended in an arc shape to the pre apex level (red arrows), left is for long apical parasternal color flow echogram; it shows the same arteries in blue color which extended from a structure like a swirl (blue gathered vessels) that has bifurcates to basal and anterior divisions (arms), the basal one's connecting to blood pooling focus (red-orange color), which has six opening (white arrow; pooling focus); four at the level of the upper left atrium surface, one's that joined with the basal arm, and last one was connected with blue vessel segment that joined with smaller B.P Focus, then to blue vessel near the anterior arm, and both vessels (green arrow) joined with another pooling focus anteriorly (upper white arrow).

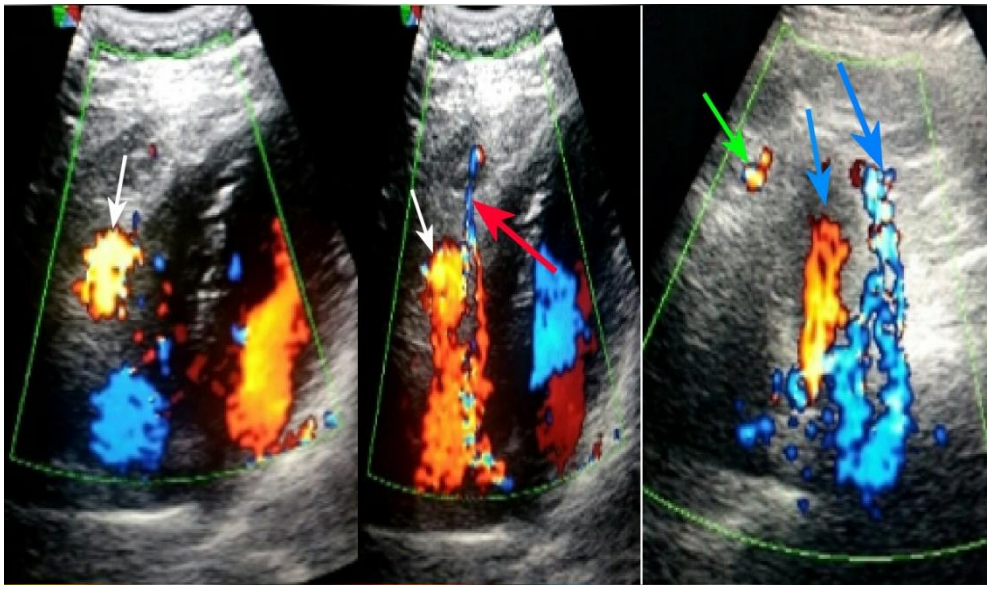

Figure 16: four chambers view, it shows three events; pooling focus of blood (white arrow), then reversed blood supply to the level of right atrium cavity, and forward blood supply from this level to the pre apex area (red arrow), and lastly, other small pooling focus (green arrow), and two reversed blood supply one over the surface of the left ventricle and another over the lateral wall (blue arrows), last rescuing maneuver; distal collateral circulation, due to very severe proximal collateral circulation involvements, critical stage.

Old), have no apparent color flow in some parts of the left ventricle, while it was detected in other parts of the cardiac ventricle as shown in figure (17), and movie (5) that have same features as what seen in the 99,1%, but with larger areas of network arteries. Coronary catheterization of left main stem that had taken for

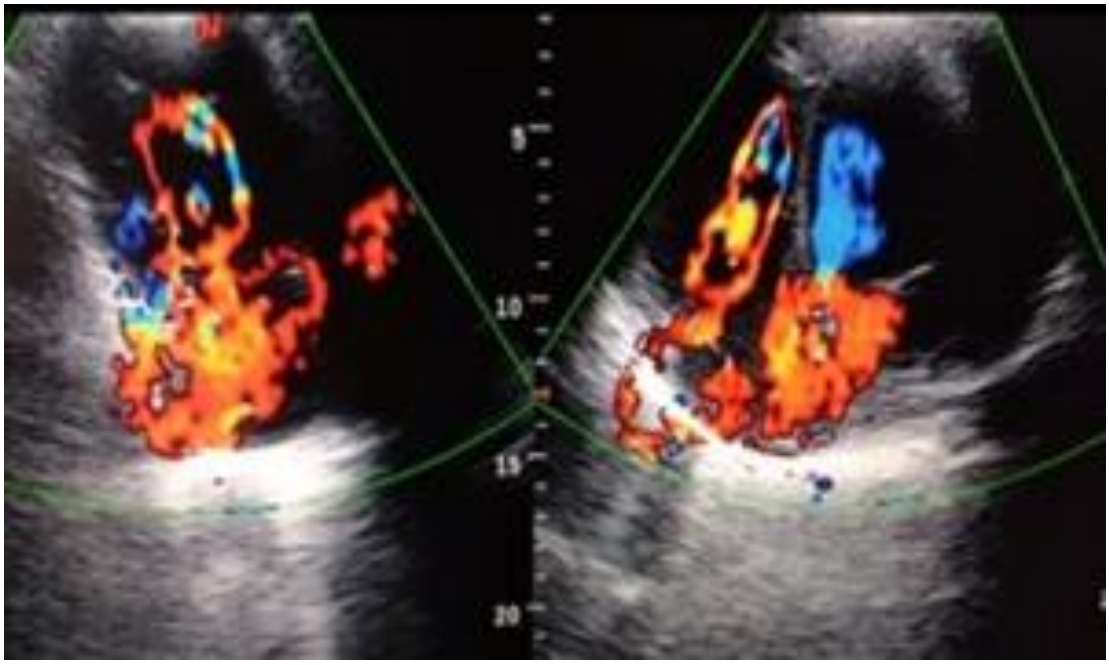

Figure 17: two and four chambers views of heart with ischemic dilated cardiomyopathy, show no blood vessels (colors) in the lateral and middle parts of the left ventricle in compare with the septal, anterior, and inferior parts of it, and the right ventricle, due to deleterious damage to proximal and distal collateral vessels in the darken regions.

patients with multiple blood pooling focus and longest collateral vessels, as shown by figures (15 & 17) and by movie (2, 3, 6, 8, 12, 13 & 15).

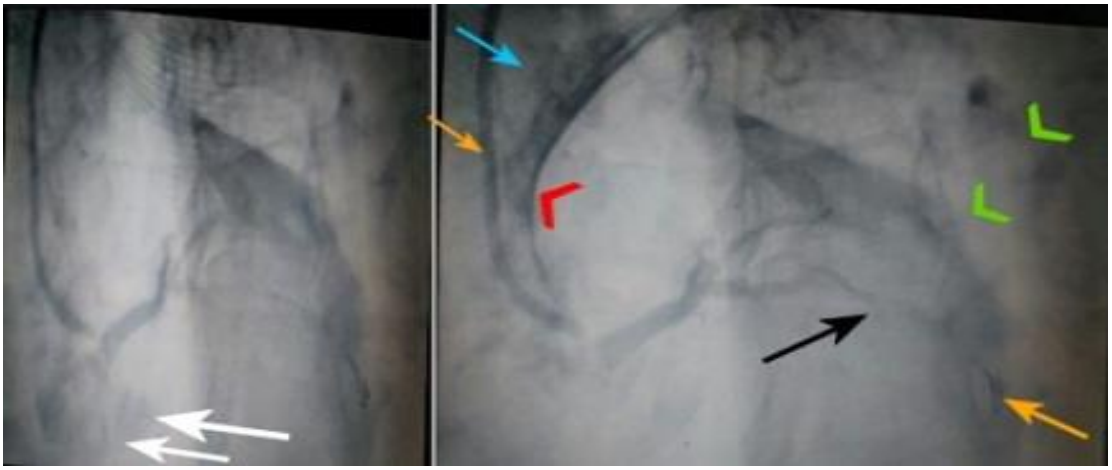

Figure 18: left CA angiography by catheterization; with swirl like blood vessels (white arrows) and blood pooling focus (blue arrow), that flow through arc-shape vessel (red arrow head), & multiple branches of it with two from their (green heads of arrows), into post stenotic area (black arrow), catheterization wire in place (yellow arrow).

Discussion:

The examination of coronary arteries by transthoracic echocardiography with help of color flow mode is enabling me to see multiple vessels, arising from both sides of the aortic artery and courses from base to apex over the left and right ventricular surfaces, other vessels run horizontally in the field of the ventricular cavities, and lastly vessels that run from right to left or vice versa. *Krzanowski K, et al.* (2003) [8], *Watanabe, N. et al.* (2001) [14], and *Pizzuto F. et al.* (2006) [15], had Proved the possibilities of seeing the coronary arteries by Color flow transthoracic echocardiography, and enabling velocity measurements of blood flow passing the stenotic segments, and as *Krzanowski K, et al.* (2003) [8], said; Usually a small part of the artery can be seen at first. Then, by moving step-by-step up and down the course of vessel, the entire artery (or its long part) may be assessed, while, I have applied a modified approach for examination of the whole lengths of multiple coronary arteries of both sides that located in longitudinal or horizontal planes in the examining views by using a larger color flow box that may modified according to the case for better visualization of a longest distance as shown in related figures from 2 to 17, and it's enabling me to see multiple things in the coronary arteries as aforementioned among groups "1 and 2". as the *Krzanowski K, et al.* (2003), *Watanabe, N. et al.* (2001) [14], and *Pizzuto F. et al.* (2006) [15], were pointing to the blue

colored vessel as an arterial one's, and because no one's before me have used the color flow mode echocardiography for seeing the whole lengths of the coronary arteries, no one have mentioned or described the connector segments before this time, because I have examined a larger area, that enable me to see the whole lengths of the coronary arteries, in addition to other features as aforementioned. Hence, by this examination the wideness of the arterial lumens would be known roughly from the reflected images as shown by the figures (from 2 to 17), and it can be also measured, therefore, stenosis can be diagnosed by this mode and be coincident with the results of the invasive mode of coronary angiography as said by *Krzanowski K. et al. and others* [8, 14, 15], and also the dilatation of pre-stenotic segment, for example; as shown by all movies from 1 to 14, and 16 to 18, and all figures except 5 & 11, also another changes as visualization of areas with blue and/or red colors or were seeing as a network of arteries either small, medium or large which reveals a grouping of multiple arteries connected to or crossed over each other's, as shown in all figures except number 18, that shown coronary arteries by catheterization, in addition to the focus of blood pooling that seen as to be arising from the wall/walls of the ventricle/ventricles, as shown in figures (13, 14, 15, 16), and movies (2, 3, 6, 8, 12 & 13), where it received blood from many parts then pumping it through multiple arteries to more than one directions such as the base and medially to a network arteries that carrying it into the post stenotic arterial parts, anywhere, this sign of transient blood pooling & pumping are pointing to the 'rescuing maneuver' that probably has represented the last step of myocardial collateral circulations, if we noticed the multiple steps of this maneuver as collecting focus (dilated artery/arteries) from many arteries and pumping it into multiple areas distal to the stenotic levels, as shown by figures (13, 14, 15, 16). Thus, if we noticed that 'the color flow mode of echocardiography, makes the examinations of whole lengths of coronary arteries easiest & already possible', in addition to revealing the CAs pathological features, for example; atherosclerotic process; tent yellow/white lumens discolorations, stenosis, dilatation, beadings, complete obstructions, and appearance of another vessel segments connecting one end's to another in the same artery, that can be called proximal collateral circulation; within the same artery, as shown by figure (12), and movie (7 & 8), in addition to other movies, or into another ones which can called distal collateral circulation, as shown by all movies except movies (7, 16), and figures (13, 14, 15 & 16), that actually, open due to an increasing pressure in the pre-stenotic segment/segments resulting in opening of the reserving arteries of the reserved collateral circulation one by one; a rescuing maneuvers that be directly proportional to the CAs blood pressures, which results in grouping of multiple arteries forming a shape like networks of either small, medium or large size; depending on the chronicity of the diseased process, then the blood pooling focus that supply multiple myocardial areas in different directions, as proven by the CAs catheterization and color flow echocardiography in figure (13, 14, 15 & 16), and movies (2, 3, 6, 8, 12, 13 & 15), in which the vessels arching from base to apex, of course, it's pointing to the occurrence of a deleterious damage to the proximal reserving arteries by the pathological process, that had started by the white tent color and

beading changes of the blue colored vessels, and culminated by the CAs obliterations as a result of deleterious damage to the distal collateral circulation also; that results in ventricular field darkening, as shown in figure (17), and movie (5) lastly, this mode of examination enabling me to visualize the smaller coronary arteries, as shown by figure (14), and this only possible by interpretation of color flow echocardiographic movies by help of motion monitoring in the phones or tablets (i.e. rapid and controlled finger on/off motion). all of these give me a chance to visualize and know the sophisticated saving maneuvers created by the GOD, 'Allah'. Thus, if we are using this approach in the future for clinical routine examinations of coronary arteries in every cardiac clinic or hospital, or for any given populations, it will facilitate the planning for early interventions, and contributes to decreasing cardiac morbidity and mortalities

Conclusion:

Examinations by a Color flow mode of echocardiography enable me to visualize the whole lengths of coronary arteries, stenotic and dilated segments, in addition to the small coronary arteries and the collateral coronary vessels or the rescuing circulation. Also the use of high frequency in 2-Dimensional mode increased the appearance of true and false solid colors after switching to color flow mode; that facilitated small CAs visualizations, by help of rapid controlled on/off motion of finger on modern phones or tablets, and use of low frequency for seeing of large and medium sized coronary arteries and small arterial networks, therefore this approach reveals the atherosclerotic changes; in chronological way, and pointing to the age of its starts; at neonatal period or earlier, a point that warrants more attention to detect the causative agents in order to treat it and prevent its sequels. And lastly it suggests that there is a relation between the progressive increase in systemic blood pressure and the continuous atherosclerotic process of the coronary arteries as a physiological mechanism, in order to save the myocardium by facilitating blood flow to the post stenotic areas, which mean that the aggressive use of antihypertensive drugs will consider as a risk factor for damage of myocardium but in faster period than involvement of collateral circulation by atherosclerotic process that also involved it at younger age recently.

Recommendations:

This approach of coronary arteries examinations by the transthoracic color flow mode echocardiography provides an accurate, non-invasive, feasible, and inexpensive procedure that can be used for routine checkups of coronary arteries of complaining patients or any given populations to decrease the cardiac morbidities and mortalities by predicting the time for early interventions either by medical, Percutaneous Coronary Arteries Interventions (PCIs); Catheterizations or surgical one's.

Acknowledgments:

I thank my GOD, "Allah", who made me performed this work, and I wish a benefit for every sufferer & people. Also I thank the AJSRP team for its effort from the start to the end.

Competing interests:

There are no competing interests.

The movies:

Movie 1: multiple views shown multiple coronary arteries from different windows, the blue segments are connector-like vessels, and it seeing with different lengths and shapes, stenosis is narrower and narrowest areas & dilatation is the widest area/areas, within segment/segments either with red/blue color, network-arteries are the areas with solid color either red or blue, and small, medium or large, mosaic color represent the turbulent flow in the pre & stenotic segments. In this movie there is E-figure that seen reversed to the right by 4-chamber view & corrected by 2-chamber view; this pointing to the vessel-walls relation, i.e. the anterior descending CA can be seen by 4-chambers, two chambers and long parasternal views.

Click here for file

[http://www.ajsrp.com/content/supplementary/ -S1.mov]

Movie 2: 4-chambers view shows Rt. To Lt. collateral circulation (vessels & blood pooling focuses), as seen two vessels flowing into B.P Focus in right ventricular wall, then to apex from which blood pumping into anterior (red vessels within LV field) and lateral walls (superficial & deep B.P.F; with delayed pumping via the deep one's), with separated B. P. focus for each.

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[http://www.ajsrp.com/content/supplementary/ -S2.mov]

Movie 3: four chambers view, shows Rt. To Rt. collateral circulation, as seen via the vessels and B.P. focuses medial and lateral to RV wall which flowing into basal firstly then laterally through arterial network and one red vessel and then forward through arterial red network and one vessel from basal focuses one for each like a mirror, but differentiated by the distal blue and red end for medial and forward flowing, and from these points into Lt. ventricle as seen by the apical to basal flow (inverted) in LV field.

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[http://www.ajsrp.com/content/supplementary/ -S3.mov]

Movie 4: Modified 4-chambers view shows left to right collateral circulation seen as solid color; blue and red, with scattered mosaic color, and arched red vessel with relation to lateral LV wall, and on the right side there is one red vessel with middle level obstruction and connecting blue and red vessels ends.

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[http://www.ajsrp.com/content/supplementary/ -S4.mov]

Movie 5: four chambers view, shows dilated LV chamber, blood vessels in middle and near to septum side of LV, near to free wall Rt. Septal side of right ventricle, with absent of blood vessels in lateral LV field, in the presence of Rt. To Lt. apical coronary artery flow with interruption, in both maneuvers; which pointing that the 2-MHz of 2-D mode permits to show the blood vessels separated (as seen firstly), while 4-MHz allowed visualization of solid color more than separated vessels, and this darkening is pointing to decrease of blood vessels in patients with dilated ischemic cardiomyopathy as the chronic atherosclerotic process obliterated even the collateral circulation (proximal/self and distal arterial rescuing vessels).

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[http://www.ajsrp.com/content/supplementary/ -S5.mov]

Movie 6: Long parasternal view, shows multiple arteries with different lengths, two longest arteries related to anterior and posterior left ventricular walls, tortuous have yellowish tent in some areas and met at distal ends, with connector-blue like vessel at middle of anterior vessel, other shorter artery in between them, and there are three blood pooling (B. P.) focuses two below posterior wall and one at mid-level of LV cavity surface, in addition to previously mentioned signs.

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[http://www.ajsrp.com/content/supplementary/ -S6.mov]

Movie 7: Long parasternal view, for left anterior descending coronary artery, shows four sites of obstruction; one's in the original artery and second in the first collateral artery, third in the original artery proximal to the connection of the second collateral artery with the original one's distal, and forth in the third collateral artery that connected the second collateral with original one's, and also shows stenosis in the third and fourth collateral arteries, (need controlled finger on/off motion for visualization it like in figure 12)

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[http://www.ajsrp.com/content/supplementary/ -S7.mov]

Movie 8: Long parasternal view; shows posterior descending coronary artery; the longitudinal vessel at posterior wall and it suffered of severe atherosclerosis with three obstruction sites (i.e. interrupted vessel course), first at mitral valve annulus, second at mid LV, and third at papillary muscle levels, with the appearance of many self-collateral vessels (Proximal collateral circulation), for the second and third sites, but the first was got collateral vessels from anterior LV vessel (seen as red vessels flowing from anterior to posterior, perpendicular to left atrium), other features are the three blood pooling focuses near to each other surrounded the posterior descending CA.

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[http://www.ajsrp.com/content/supplementary/ -S8.mov]

Movie 9: Short parasternal view, at level of Aortic Annulus, shows two main features; at level of left atrioventricular groove (left side) there are 5 buds of CA branches, one's of them run rightwards encircled the aortic artery at this level and it is decreased in lumen wideness gradually till the point of connection with blue artery which has a narrowest area before, there is mosaic color all along its course; which pointing to severe stenosis, the second one's is the right coronary artery stem with 8 parts or buds of their branches; three in red color and 5 in blue color, also there are other branches seen in the field.

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[http://www.ajsrp.com/content/supplementary/ -S9.mov]

Movie 10: Short Axis Parasternal view, at level of papillary muscles, shows coronary arteries all around the cardiac ventricle at level of papillary muscles, but they seen as if they inside the ventricles; because it lie in the smaller region of myocardium below the largest one's, parts of anterior and posterior descending coronary arteries seen in the related grooves with opposite flow, and in the right image the course of anterior descending CA seen interrupted, that pointing to obstruction and the reversed flow in the movie is due to collateral vessel.

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[http://www.ajsrp.com/content/supplementary/ -S10.mov]

Movie 11: short parasternal view modified to four chambers one's; shows alternated blood flowing into left and right ventricles, as seen by the timing of flow, and also shows tortuous, mosaic, dilated, narrowed vessels, blue and red vessels and networks.

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[http://www.ajsrp.com/content/supplementary/ -S11.mov]

Movie 12: Apical long parasternal view, shows multiple vessels blue and red; at level of aortic sinuses there is circular like blue vessels flows into two ways, basal level lateral upper corner of left atrium and pre-apical area of anterior wall, each of them connected with blood pooling focus in every vessel end, as seen by red-orange color, then from these B.P focuses into other areas suffered of poor or no blood flow, as indicated by the apical to basal flow (inverted flow) in anterior LV wall after blood reached to the anterior wall pre-apical blood pooling focus (anteriorly), (this is the same as what shown by catheterization; as in (movie 15) but with more details).

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[http://www.ajsrp.com/content/supplementary/ -S12.mov]

Movie 13: Long Subcostal view, shows multiple vessels on right and left sides; right coronary artery obstruction at multiple levels, Lt. to Rt. Collateral circulation with multiple blood pooling focuses, stenotic and dilated vessels, in addition to alternated time of blood flow between right and left (normal physiology).

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[http://www.ajsrp.com/content/supplementary/ -S13.mov]

Movie 14: Short subcostal view, shows multiple vessels with tortuosity, beaded, stenotic, dilated vessels, of blue and red vessels (original and collateral vessels which are the stages before occurrence of decreasing in numbers of blood vessels; paucity of blood vessels, by obliterations of proximal and distal collateral vessels of any myocardial region).

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[http://www.ajsrp.com/content/supplementary/ -S14.mov]

Movie 15: left anterior oblique 1.6^{o} and 29.9^{o} views of left main stem CA catheterization, shown vessels near to left stem black flow of angiographic contrast form a shape that like swirl, then it's arching to level perpendicular upon pre-apical area and flowing down of the contrast as a splash into the post stenotic areas, this black swirl and arc of collateral vessels is seen clearly, in addition to the blood pooling focuses by color flow echocardiogram in movie 8.

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[http://www.ajsrp.com/content/supplementary/ -S15.mov]

Movie 16: Subcostal view of 9 months neonate, shows beaded coronary arteries, connecting segments and small areas of arterial networks

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[http://www.ajsrp.com/content/supplementary/ -S16.mov]

Movie 17: Multiple cardiac views; of 5 years children show beaded arteries, more than one connecting blue segments, arterial networks

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[http://www.ajsrp.com/content/supplementary/ -S17.mov]

Movie 18: Subcostal long axis view shows Multiple CAs atherosclerotic changes as beading, large networks, white color due to original and collateral vessels connections, stenosis, dilation, and mosaic colors

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[http://www.ajsrp.com/content/supplementary/ -S18.mov]

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