Cardiac CT in Congenital Heart Disease

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Learning objectives

1. Uses and indications for CT scanning in congenital heart disease.

2. Advantages and disadvantages compared with other modalities will be considered.

3. Techniques and technical considerations will be briefly described with reference to specific indications.

4. Key specific conditions and situations will be discussed including the role in primary diagnosis, pre-operative assessment, post-operative review and identification of complications.

A detailed description of surgical technique and complications of cardiac support devices are outwith the scope of this poster.
Background

Recent advances in CT scanner technology have resulted in significant reduction in radiation doses and marked improvement in temporal resolution making scan duration significantly shorter. This has particular advantages for cardiac CT, resulting in less motion artefacts and therefore scans are more likely to be diagnostic even at fast heart rates. It is particularly useful for unstable patients, where rapid acquisition allows patients to be in the scanner for only a short period of time. The use of and advances in ECG gating permits good assessment of cardiac and coronary structures with removal of cardiac pulsation artefact. Combined with isotropic spatial resolution, this allows assessment of even very small coronary arteries and other vascular structures. Good anatomical depiction is obtained within seconds/split-seconds. The pulmonary parenchyma is well assessed with CT and can be interrogated in the same examination. Therefore, with a single examination, CT can assess cardiac structures, thoracic vessels, the lungs and tracheobronchial tree. However, functional information is much more limited compared with echo and MRI.

Increasingly these studies are performed in patients who are acutely unwell at initial presentation or have suddenly decompensated and require urgent imaging. Therefore, radiologists undertaking on-call in centres with cardiothoracic units may need a basic knowledge of the conditions and techniques they are likely to encounter.
Imaging findings OR Procedure details

Uses

In deciding the best modality to use to image a patient with congenital heart disease, a variety of factors need to be considered. However, most important is the clinical question to be answered and whether specific functional information is required or if a detailed over-view of the anatomy is the main goal. The age and co-operation of the patient may influence the decision about which modality to use (younger have naturally faster heart rates making temporal resolution important), as will equipment availability/accessibility. The presence of an implanted pacemaker or defibrillator, other contraindication to MRI or vascular stents, which generally cause more artefacts with MRI than CT [1], will also influence the decision. With access to modern CT scanners, the radiation dose is lower and the increased speed more likely to avoid the need for a general anaesthetic/sedation therefore the threshold for CT may be lower relative to MRI.

CT compared with echo

Echo is excellent for an overview of cardiac anatomy and functional information.

However, CT is better at delineating the great vessels, pulmonary veins and coronary arteries (anomalous or otherwise) and the exact course. On echo, the thoracic aorta is not always seen throughout its length and can be abnormal in association with other congenital heart disease or in isolation, for example, aortic coarctation. In the post-operative period, echo may have difficulty fully assessing the surgical repair, particularly if conduits have been inserted or extra-cardiac vessels repaired. CT is less operator dependant and is not limited by the available echo windows.

CT compared with MRI

MRI does not require ionising radiation and can provide a range of functional information.

However, CT is faster with shorter scanning times and breath-holds therefore better in unstable or uncooperative patients. It has better spatial resolution with potential for isotropic reconstruction. It is better at identifying the coronary arteries and anomalies, particularly in small patients and is universally applicable in patients with implantable cardiac devices. It may avoid sedation/anaesthetic and if this is the case, then CT is less labour intensive.

CT compared with invasive angiogram
A major advantage of invasive angiography is the ability to measure pressures. However, CT creates 3D rather than 2D images and can assess both the pulmonary and systemic circulations simultaneously and is non-invasive. It is much less likely to need a general anaesthetic or even sedation and avoids the associated procedural risks. CT radiation and contrast doses are generally smaller.

Considering the advantages and disadvantages of the various modalities, the uses vary with patient group, clinical diagnosis and question posed. This can be broadly divided into: preliminary diagnosis for cardiovascular abnormalities; pre operative evaluation; post operative review; acute indications; and assessment of associated non cardiac abnormalities in patients with congenital heart disease.

**Preliminary Diagnosis**

In patients with suspected congenital cardiovascular anomalies, CT can provide a specific diagnosis and anatomical detail. For example, if a vascular ring is suspected clinically eg double aortic arch, right aortic arch with aberrant left subclavian artery (the ring is completed by a PDA or ligamentum arteriosum) or a pulmonary sling. These may not have been identified at echo and can occur in isolation or in conjunction with more complex congenital heart disease. Their presence may influence operative approach or hamper post-operative recovery if there is airway compromise.

**Pre operative**

The complexity of the anatomy means that even with a labelled form of congenital heart disease, there are numerous anatomical variations, which can influence treatment and survival. Several conditions are much more likely to benefit from pre-operative CT imaging and will be discussed individually below. However the specific information commonly requested includes:

- The anatomy and sizes of the pulmonary arteries with regards to surgical planning
- The anatomy and dimensions of the aorta and relationship of any abnormalities to head and neck vessels.
- Anomalous coronary arteries are more common in the congenital heart disease population than the general population and the anatomy may be important prior to palliative or corrective surgery. CT may be requested to guide surgical technique, assess associated specific conditions or occasionally, to further assess a possible anomalous coronary identified at echo.
- Major aortopulmonary collateral arteries (MAPCAs) may occur in patients with severe right ventricular outflow tract obstruction and CT is important to identify and describe these pre-operatively.
Post Operative

As with all operations, there are general complications, which can be divided into acute and chronic.

- Immediate failure to wean from the ventilator may be due to vascular compression on the airway either as a result of altered anatomy following surgery or a previously unrecognised vascular or airway anomaly. CT can assess this.
- Mediastinitis and osteomyelitis: CT is useful to delineate post-operative collections, which may need further intervention. Wound infection may progress to osteomyelitis and CT is good at depicting the bony erosion.
- Shunt/conduit thrombosis or stenosis: particularly extra-cardiac shunts are well assessed with CT.
- Stent patency may be better assessed with CT than MRI due to metal artefacts. It can also show stent fracture, separation from vessel wall, residual vessel narrowing and any pseudo aneurysm formation.
- Seromas may occur in the post-operative period and generally have no clinical significance, rarely, they can become large enough to compress cardiovascular or airway structures.
- Arteriovenous malformations and fistula: Pulmonary AVMs have been described following bi-directional Glenn shunts and the Fontan procedure.
- MAPCAs may not have been identified prior to initial stage palliative surgery, but may be addressed at subsequent operations

Acute decompensation

This can happen prior to surgical correction or post surgically. Generally in the pre and post-operative settings, the indications are similar to those outlined above, but the clinical condition of the patient may favour CT.

Technique

Previous articles have extensively discussed the technical details of image acquisition and important considerations, therefore only key points will be highlighted in this section. To ensure the appropriate protocol, it is very important to have as much information on the patient's congenital heart disease from other imaging modalities, plus details on previous surgical intervention and what specific questions are to be answered. This may require multidisciplinary input as often these patients are under joint care eg cardiology and respiratory and it is preferable to perform a single examination where possible.

Optimal post contrast images are important, but the techniques will vary by patient and condition. It is important to consider the route of administration of contrast eg peripheral cannula, central line, ECMO (extracorporeal membrane oxygenation) cannula, ventricular assist device cannula. With most conditions, the site of injection is not relevant,
but certain indications require site-specific injection, such as simultaneous infusion through the arm and leg to assess the Fontan pathways. The dose and rate of injection can be variable. In general, we continue to use the conventional 2.0 ml/kg of 300mg/ml iodinated contrast, although some centres advocate lower contrast doses.

Prior to any injection, the patency of the cannula is tested. Care is taken to ensure bubbles are removed from the syringes and tubing to avoid potential systemic air embolism.

The decision whether to use hand or pump injection, is often dictated by the contrast volume, amounts over 20mls generally being injected by a pump. With a hand injection, the scan should be started as soon as the injection has finished. If this is done under general anaesthetic, the anaesthetist is requested to breath hold in inspiration just prior to the end of the injection. However, with faster scanner, anaesthesia may not be required and the scan may be performed in free breathing. If utilising a pump with smaller cannula, the rate is likely to be limited to between 1-2ml/s where as with a larger cannula 3-4mls/s may be a more realistic maximum. As a general rule, with the pump, we tend to use a bolus tracking method with a region of interest placed over the structure being principally assessed, commonly the aorta or pulmonary artery. The scan triggers at 125Hu and there is a 4 second delay. Occasionally a test bolus method is useful, particularly with more complex abnormalities for example when shunts exist.

**ECG gating or not**

In our practice, if specific information about the coronary arteries or intra-cardiac structures is required then the scans are gated. However this has a radiation penalty and is therefore not utilised for all patients.

*Non gated:*

For paediatric patient we utilise 2mm slice thickness with a 1mm pitch. Finer reconstructions can be performed during post-processing if required.

*Gated:*

In addition to improving coronary visualisation, this can allow basic functional information such as ejection fractions to be calculated and chambers to be measures at specific points in the cardiac cycle. Our protocol applies a 0.75mm slice thickness with 0.5mm pitch.

Bearing in mind the radiation and contrast penalty that will be incurred from a non-diagnostic scan, erring on the side of caution with scan protocoling is advised (eg erring on the side of higher contrast doses and utilisation of sedation). For all indications, users should familiarise themselves with radiation reducing techniques on their scanner.
Post processing

Care and attention in the post processing is important to assist with accurate interpretation and measurements of the structures of interest and to display the findings to clinicians and surgeons. Multiplanar reformats along the structures of interest are performed, for example, perpendicular to the right and left ventricular outflow tract or in the cardiac short and long axes. Additionally, 3D maximum-intensity-projection and volume-rendered images are often useful. [1] Often lung reconstructions performed on the CT angiogram images are sufficient to assess the pulmonary parenchyma and airways. Rarely, additional images will be acquired, such as selected slices in expiration.

Specific conditions:

AORTA

- **Coarctation:**

Echo is good at detecting associated defects such as a ventricular septal defect (VSD) or aortic valve pathology (commonly a bicuspid valve), but views of the ascending aorta, aberrant vessels and assessment of the coarctation itself may be limited.

CT pre surgery is useful particularly in unstable patients when anatomical information is more important than flow and functional assessment. It should assess size and position of stenosis with particular focus on the relationship to head and neck arteries, the presence of an aberrant right subclavian artery and whether the arch is hypoplastic. (See Figure 1)

CT and MRI can be used post treatment to assess any recurrent or residual stenosis, pseudoaneurysms formation (particularly if an earlier graft was used) or a residual hypoplastic arch. If a stent has been deployed, then CT currently may have fewer artefacts than MRI. [1]

- **Interrupted aortic arch:**

Almost all patients presents critically unwell in the neonatal period with flow to the distal aorta maintained by a patent ductus arteriosus (PDA). Associated aortic and subaortic stenoses are common, as is a VSD. If sufficient information is not obtained at echo, a CT is useful particularly to distinguish between interruption, tubular hypoplasia and coarctation. [4] The narrowest dimension of the left ventricular outflow tract (LVOT) is important, as are the distance between the proximal and distal segments and the size of the PDA. [3]

Post surgery, CT is useful to identify stenosis and (pseudo)aneurysm formation at the repair site. (See Figure 2). Bronchial compression either on the left or right can also occur. [4]
• **Aortic stenosis**

Aortic stenosis can usually be adequately treated with valvuloplasty or surgical valvotomy and pre-operative CT is not required unless there is concern of associated aortopathy. However with significant regurgitation and or compromised left ventricular (LV) function, repair or replacement may become necessary.

Some procedures have complications for example, following a Ross procedure, which involves implanting a pulmonary homograft (ie valve and proximal pulmonary artery) into the aortic position, the neo-aortic root can dilate and lead to valve insufficiency. Aortic dissection and pseudoaneurysm formation at the anastomosis sites have also been reported. [5] (See Figure 3).

• **Double Aortic Arch:**

This is a type of vascular ring, which can compress the trachea and as mentioned above may cause difficulties with weaning from ventilation if not identified. It can occur in isolation or combination with other forms of congenital heart disease. One of the lumens may be atretic and therefore will not opacify with contrast. [1] CT can identify the condition and help surgical planning, therefore discrepancies between size of the arches and the position of the head and neck vessels need to be described. (See figures 4 and 5)

**GREAT VESSELS**

• **Truncus arteriosus/aortopulmonary window**

Truncus arteriosus results in a single vessel supplying the pulmonary and systemic circulation including the coronary arteries. In contrast, an aortopulmonary window has separate great vessel origins but a communication between the aorta and main pulmonary artery. The valve morphology and function in truncus is variable and there is often an associated VSD and various coronary morphologies are possible. Problems arise when pulmonary artery (PA) pressures fall in the 1st week of life and therefore often repair is required early in life and CT may be the safest most accessibly anatomical test. (See Figures 6-8). Anomalous coronary arteries are common. Notably, a high, posterior origin of the left coronary artery may lie just below the pulmonary artery origin and therefore complicate surgical repair with the risk of postoperative coronary artery stenosis or occlusion. [6]

Post surgical CT may be useful to assess the right ventricle (RV) to PA conduit, which often needs to be replaced, the branch pulmonary arteries for repair morphology and the coronaries. Valvular dysfunction is also common, but this is generally well assessed with echo.
- **Transposition of the great arteries (TGA):**

The most common form of TGA has atrioventricular concordance and ventriculoarterial discordance i.e. the switch is at the level of the great vessels only therefore, the systemic blood returns to the right atrium (RA), passes to the RV and out into the aorta rather than the pulmonary artery (PA); conversely pulmonary blood returns to the left atrium (LA), passes to the left ventricle (LV) and into the pulmonary artery rather than the aorta. This creates parallel independent circuits, which need to mix through an atrial septal defect (ASD), VSD, PDA or combination thereof.

Pre-operatively, CT is useful to provide anatomical delineation prior to surgery including aorta and arch, PA size and position and origin of coronaries. Most corrective surgery for TGA will now involve the Jatene arterial switch. Patients with anomalous coronaries may not be candidates for the Jatene or may have increased surgical risk. It is important to describe the full course of the coronaries including whether there is an intramural course (the artery runs within the myocardium). Attention should also be paid to whether the LVOT appears stenotic.

Post-operatively, supravalvular pulmonary stenosis can occur, which may in part be due to distortion from adjacent aorta, as can stenosis/occlusion of coronaries and "incidental" dilatation of the neo-aorta (uncommonly associated with significant regurgitation). CT can be used to assess the RVOT, neo-aorta and coronaries. [1, 7] (See Figures 9-11).

- **Pulmonary arteries**

The right heart and pulmonary arteries become more difficult to assess in older children at echo. Therefore, CT is often utilised to assess the pulmonary arteries when contemplating specific surgical repairs. In addition, pulmonary anomalies can create a vascular ring causing airway compromise, most commonly a pulmonary sling, when the left pulmonary artery arises from the right pulmonary artery and compresses the trachea. CT is ideal to assess both the vessels and the airway.

- **Patent ductus arteriosus (PDA)**

The PDA lies between the proximal descending aorta and the origin of the left pulmonary artery. Some conditions are duct dependant and therefore treatment is give to maintain duct patency, but it can remain patent in pathological circumstances either in isolation or as part of other complex congenital cardiac conditions. This should therefore be a point of review for any congenital cardiovascular CT. (See Figure 12)
• **Hypoplastic left heart:**

The left heart structures are hypoplastic and most of the blood to the proximal aorta is retrograde through a PDA, therefore the root, ascending aorta and aortic arch are small. Pre surgery, echo may be sufficient to assess anatomy, but CT or MRI may be performed as adjuvants to assess particularly the aorta.

Surgery is typically performed as the 3-stage Norwood procedure with the ultimate aim to utilise the right ventricle as the systemic pump, ensure unobstructed pulmonary venous return and reroute systemic venous return to the lungs. The first stage involves fashioning a neo-aorta principally from the main PA and hypoplastic aorta; atrial septectomy and either a modified Blalock Taussig (BT) shunt (subclavian artery to pulmonary artery) or an RV to PA (Sano) shunt. (see Figures 13-15) The second stage aims to start separating the pulmonary from the systemic circulation: a bi-directional Glenn shunt involves an anastomosis of the superior vena cava (SVC) to right PA or the hemi-Fontan uses an atrio caval incision and anastomosis of the SVC to the pulmonary artery. At this stage the modified BT/sano shunt is eliminated. Stage 3 reroutes IVC blood to the pulmonary arteries either via an intracardiac tunnel (inferior vena cava (IVC) via right atrium to pulmonary artery) or extracardiac Fontan (IVC to PA). [8]

Like other forms of congenital heart disease, CT may be required pre-operatively to assess extracardiac anatomy in complex cases. Post-operatively, the most common indication is to assess for obstruction or stenosis of an extracardiac shunt or pulmonary Arteriovenous malformations (AVMs), which can be a complication of the Fontan procedure. Depending on the stage of repair, the site of injection or region of interest may need to be varied, therefore this information should be established prior to performing the CT.

**RIGHT PREDOMINANT**

• **Tetralogy of Fallot**

This is a combination of pulmonary outflow tract, a VSD, an aorta which over-rides both ventricles and RV hypertrophy. Often there is hypoplasia of the pulmonary valve and pulmonary artery. The condition has several anatomical types and pulmonary atresia of the Fallot type is often considered a severe form.

Treatment is palliation with a modified Blalock-Taussig shunt to improve pulmonary flow independent of a patent ductus arteriosus. A conduit is placed between the left or right subclavian artery and the respective pulmonary artery. Corrective surgery may also be performed. This requires closure of the VSD, resecting or relieving the right ventricular outflow tract obstruction and closing any associated anomalies such as ASD/patent foramen ovale (PFO).
Pre surgery, CT is particularly useful to identify anomalous coronaries and the RV outflow tract and pulmonary artery anatomy. Right ventriculotomy is usually performed in corrective surgery, therefore if a major coronary passes across the right ventricular outflow tract (RVOT), surgical technique may need to be modified. Other coronary abnormalities include an anomalous or accessory left anterior descending artery, prominent conal branch or a single origin coronary artery. With severe outflow obstruction, MAPCAs can be present and assessed with CT. (See figures 16-18).

Post-surgery: if a palliative BT shunt has been used, CT is occasionally required to assess patency. Following corrective surgery it may be requested to review the RVOT and pulmonary arteries. The aorta is often abnormal in tetralogy therefore CT may be requested to assess for aortopathy. [7]

- **Pulmonary atresia (including Tetralogy type)**

Pulmonary atresia can occur with or without a VSD. When pulmonary atresia with VSD has normal atrioventricular concordance, it has characteristics of a severe Fallot with no pulmonary flow from either ventricle. It can also take the form of a double-outlet right ventricle or transposition of the great arteries. Pulmonary circulation in pulmonary atresia with VSD is extremely variable. Pulmonary arteries may be present or absent, of varying sizes, branch pulmonary arteries may or may not be confluent and additional sources of pulmonary blood flow may be present eg through a PDA or MAPCA. CT may be able to demonstrate atretic or stenotic pulmonary arteries not demonstrated at cardiac catheterisation and MAPCAs may be small therefore better demonstrated on CT than MRI. These variations impact on surgical management and provide the main role for CT in pre-operative work up. There may be an associated aortopathy, anomalous coronaries, anomalous pulmonary or systemic venous drainage and these should also be reviewed. [9] (See figures 19-21).

MAPCAs can be differentiated from dilated bronchial arteries in several ways. Usually, MAPCAs do not branch in their mediastinal course, unlike bronchial arteries. MAPCAs typically anastomose with the pulmonary arteries close to the hilum rather than in the periphery and are virtually never connected to intercostal arteries. [9]

**SEPTAL DEFECTS**

CT is not required solely to assess an atrial or ventricular septal defect, but they are often demonstrated in conjunction with other conditions.

- **ASD.** Sinus venosus ASDs are associated with partial anomalous pulmonary venous drainage. Therefore, if this type of ASD is demonstrated on echo, a CT may be requested to assess for anomalous pulmonary veins.
• **VSD.** These can occur singularly or multiply and in various locations in the septum. CT can often give good anatomical delineation of the size and location of the defects. (See Figure 22)

**VEINS**

• **Systemic Veins**

Left SVC is more common in patients with congenital heart disease, but patients often also have a right SVC, which may or may not communicate via an innominate vein. Most left SVCS drain to the coronary sinus and then to right atrium, but occasionally they drain to the left atrium and cause hypoxia. Recognition is important for planning a right superior cavopulmonary connection or bidirectional cavopulmonary connection. [3] (See Figure 23)

• **Inferior Systemic Veins**

Most notably, in heterotaxy syndromes and left sided isomerism, the inferior vena cava (IVC) can be interrupted with azygos or hemiazygos continuity. The IVC is not demonstrated going into the RA at echo [10] and this can cause difficulty at right heart catheterisation.

• **Pulmonary veins**

These can be anomalous in isolation or combination with other cardiac defects, can become stenosed following surgery.

• **Total Anomalous Pulmonary Venous Drainage (TAPVD)**

This occurs when there is connection of the pulmonary veins from both lungs to form a confluence behind the left atrium and the common venous channel drains to a systemic vein, the right atrium or both. These can be obstructed or non-obstructed. The former causes pulmonary oedema at birth. CT can confirm the exact anatomy to help surgical planning and may detect obstruction of the common draining vein. Complications of repair include pulmonary veno-stenosis and pulmonary hypertension. (See figure 24). The condition can be associated with diffuse pulmonary lymphangiectasis. (See Figure 26).

• **Partial Anomalous Pulmonary Venous Drainage (PAPVD)**

PAPVD is common and not infrequently picked up as an incidental finding in routine non cardiovascular CT. In PAPVD part of the venous return connects to the SVC or right atrium and may be associated with an ASD. In Scimitar syndrome, the right pulmonary vein drains to the IVC and may be detected on chest radiograph.
CORONARIES

- Anomalous coronaries

CT is often the modality of choice to non-invasively investigate anomalous coronaries, which can be present in isolation but are more common in the congenital heart disease population, particularly those with conotruncal defects. Given the nature of the anomalous coronaries, they can be difficult to locate at angiogram. To solely identify the origin, often this can be done adequately with MRI, particularly with older co-operative patients. However for smaller vessels including coronary origins in babies and fistulous connections, this is much more difficult. CT is therefore useful in depicting coronary anatomy pre-surgery and helps plan surgical versus endoluminal treatment for fistulae.

The spectrum of abnormalities include: anomalous origin, course, termination, connections, or size. Examples include, fistulous arteries, coronaries arising from the wrong coronary sinus, an abnormal location in the aorta or even from the pulmonary trunk (commonly the left pulmonary artery). Particular attention should be paid to whether the anomalous coronary passes between the aorta and the pulmonary artery, the so-called "malignant course" and if there is a slit-like orifice and acute take-off from the aorta as these are associated with a higher risk of sudden cardiac death. Origin of the coronary artery from the pulmonary artery and a coronary artery fistula are also significant anomalies. In the congenital heart disease population, even the so-called benign anomalies may have clinical significance. For example if there is high take-off, aortic clamping during cardiopulmonary bypass may reduce coronary flow; single origin of the coronaries may increase the risks with reimplantation at the Jatene arterial switch; multiple ostia may complicate the arterial switch; anomalous left coronary or a large conus branch passing in front of an enlarged RV will run immediately posterior to the sternum and clearly could become important at time of sternotomy. Recognising anomalous coronaries is particularly important in patients with transposition of the great arteries, truncus arteriosus, tetralogy of Fallot and pulmonary atresia with or without intact ventricular septum as it may alter surgical technique.

Airways

The airways should always be reviewed on pre and post-operative CTs. Dilated or anomalous cardiovascular structures may compromise the airway (see Figure 5) and hamper post-operative recovery. The most common sites of compression are the trachea and left main bronchus with the right main bronchus and other sites less commonly affected.

Lungs

Similar to any CT scan, the images should be reviewed on different windowing settings. Pulmonary disorder may co-exist with congenital cardiovascular abnormalities, for
example pulmonary lymphangiectasia with total anomalous pulmonary venous drainage. (See Figure 26).

**Other findings**

There can be many additional associated congenital abnormalities which should be reviewed at time of scanning, for example duplication cysts and oesophageal atresia.

Vertebral anomalies may also be demonstrated on congenital cardiac CTs, particularly in children with the VACTREL syndrome.
Images for this section:

Fig. 1: Coarctation. Volume rendered image demonstrating a relatively long segment coarctation at the junction of the arch of the aorta and involving the left common carotid and left subclavian arteries.

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**Fig. 2:**Interrupted aortic arch. An oblique multiplanar reformat demonstrates stenosis at the site of repair of an interrupted aortic arch.

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Fig. 3: Aortic stenosis. This patient developed a pseudoaneurysm following the Ross procedure (pulmonary homograft) for aortic stenosis.

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**Fig. 4:** Double aortic arch. VR image demonstrates a double aortic arch with mirror image vessels and similarly sized arches.

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**Fig. 5:** Double aortic arch. This airway reformat demonstrates the severe tracheal stenosis the vascular ring is causing.

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Fig. 7: Truncus Arteriosus. A sagittal oblique MIP shows the common origin of the pulmonary artery and aorta with superior separation and the aortic arch passing superior to the left pulmonary artery.

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**Fig. 8:** Truncus Arteriosus. A VR image again demonstrating the common origin of the aorta and pulmonary artery causing the truncus arteriosus abnormality.

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Fig. 6: Truncus Arteriosus. Axial slice demonstrating the common origin of the pulmonary artery and aorta.

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Fig. 10: Transposition of the great arteries. A VR image demonstrated a common origin of the coronary arteries whereby the left coronary artery passes anterior to the RVOT.

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Fig. 9: Transposition of the great arteries. Axial CT slice demonstrating abnormal branching of the pulmonary artery around the aortic route in a patient following correction for transposition of the great arteries.

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**Fig. 11:** Transposition of the great arteries. A further VR image demonstrates the dilatation of the aortic root; the CT was performed to aid surgical planning for this and particularly to map the coronaries.

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**Fig. 12:** Patent ductus arteriosus. A sagittal oblique reformat demonstrates a small patent ductus arteriosus. Note the cardiac pulsation artefact on this non-gated scan, although the quality was sufficient for diagnostic purposes.

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**Fig. 13:** Hypoplastic left heart syndrome. This VR image demonstrates the neoaorta which is dilated relative to the descending aorta and the adjacent RVOT to PA conduit.

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Fig. 14: Hypoplastic left heart syndrome. A different VR projection from the posterior aspect showing the relationship of the neo-aorta to the pulmonary conduit.

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Fig. 15: Hypoplastic left heart syndrome. A sagittal oblique MIP demonstrates good patency of the pulmonary conduit with minimal stenosis at the aortic repair margin.

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**Fig. 16:** Tetralogy of Fallot. Sagittal oblique MIP demonstrates a VSD with overriding aorta.

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Fig. 17: Tetralogy of Fallot. Oblique image along the RVOT demonstrated narrowing of the RVOT with a shelf of supravalvular soft tissue.

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**Fig. 18:** Tetralogy of Fallot. The normal coronary origins are shown which is helpful for surgical planning.

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Fig. 19: Pulmonary atresia. Anterior VR with only the aorta visible and no discernible MPA is demonstrated.

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**Fig. 20:** Pulmonary atresia. Posterior VR image demonstrating a large MAPCA which is the principle supply to small branch pulmonary arteries

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**Fig. 21:** Pulmonary atresia. A coronal oblique MIP demonstrates the MAPCA passing from the aorta to the pulmonary artery and indeed is almost the same size and the pulmonary arteries.

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Fig. 22: ASD and VSD. An axial image of the heart demonstrating both an ASD and a VSD.

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**Fig. 23:** Bilateral SVCs. These are demonstrated either side of the aortic arch.

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Fig. 24: Total anomalous pulmonary venous drainage. A VR image following repair of total anomalous pulmonary venous drainage with re-stenosis of the left pulmonary veins. Only the right pulmonary veins are demonstrated inferior to the pulmonary arteries and anterior to the descending aorta.

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Fig. 25: Anomalous coronary. The circumflex is demonstrated taking a non malignant course from the right coronary artery between the posterior aorta and the left atrium.

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Fig. 26: Pulmonary lymphangiectasia. Diffuse interstitial opacification demonstrated on this CT scan was suggestive of pulmonary lymphangiectasia which is associated with TPAVD

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Conclusion

CT is useful to delineate the anatomy not only of the heart but of other (associated) congenital abnormalities. As CT radiation doses reduce, this will become an even more useful tool and CT has become invaluable in assessment of congenital heart disease. It is performed quickly which minimises the number of cases requiring anaesthetic and avoids the risks of invasive coronary angiography.

In the pre-operative period, it is particularly useful for depicting the coronary arteries, the whole of the aorta, the pulmonary arteries, veins and detecting the presence of MAPCAs.

Post-operatively the anatomy of shunts can be assessed, plus impingement on tracheobronchial tree.

CT is also excellent at detecting associated non-cardiovascular abnormalities.
References


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