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Original Research Article

MSCT imaging of various shunts and grafts in post operative cases of congenital heart diseases

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ABSTRACT

Background: Multi-slice computed tomography (MSCT) plays an important role in clinical practice in assessing post-operative patients with complex CHD when echocardiography is not contributory. Despite the great capabilities of MR imaging for anatomic and functional assessment of the heart, it is time-consuming and may require a lengthy period of patient sedation; hence its use in seriously ill or uncooperative patients is often limited. CT has the advantages of widespread availability and short acquisition times. It is imperative for a radiologist to be aware of various palliative as well as corrective procedures and their various imaging findings. Aim of this article is to demonstrate and make one aware of various checklists and imaging findings in paediatric patients who have undergone various shunts and grafts at our tertiary cardiac care centre, their immediate as well as long term complications.
Methods: We studied a total of 100 paediatric patients (<12 years old), who had undergone some sort of palliative or corrective shunt or graft placement, on MSCT during the period 2014 to 2018 at our tertiary cardiac care centre.
Results: We try to outline details of various shunts and grafts used in congenital heart diseases correction, MSCT technique and imaging appearances and appearances of abnormal post-operative findings.
Conclusions: Advances in computed tomography (CT) scanners and electrocardiographic gating techniques have resulted in superior image quality of the aorta and pulmonary arteries for evaluating postoperative congenital heart disease. MSCT is an excellent non-invasive modality for post-operative evaluation of various shunts and grafts.

Keywords: Congenital heart disease, MSCT, Shunts and grafts

INTRODUCTION

Advances in surgical techniques have increased the life expectancy of patients with congenital heart disease. Thus, the population who may benefit from long-term follow-up with cross-sectional imaging is increasing.

Non-invasive imaging is pivotal in the follow-up of patients with congenital heart disease (CHD) who have undergone palliative or corrective surgical procedures. Trans-thoracic echocardiography is considered as an initial imaging modality of choice for assessment of CHD. However, it is limited in the reliable assessment of these procedures because of operator dependency, a small field of view and acoustic window, and poor assessment of the right heart, intra-cardiac baffle and extra-cardiac complex vascular anatomy.[1]

Cross-sectional imaging with magnetic resonance (MR) or computed tomography (CT) may help overcome the limitations of conventional angiography as well such as overlap of adjacent cardiovascular structures, difficulties in simultaneously depicting the systemic and the pulmonary vascular systems, and catheter-related complications.[2] Radiologists should understand and become familiar with the complex morphology and physiology of CHD, as well as with various palliative and corrective surgical procedures performed in these patients, to obtain CT angiograms with diagnostic quality and promptly recognise imaging features of normal post-operative anatomy and complications of these complex surgeries.

METHODS

We studied a total of 100 subjects (<12 years old) who had undergone any palliative or corrective procedure during the period 2014 to 2018. Echocardiography is the first line modality of choice in all the paediatric patients with congenital heart disease who have undergone any palliative procedure. MSCT imaging was done in only those patients in whom echocardiography was not completely informative or who required confirmation of echo findings or to determine the exact site of stenosis whenever there was gradient on echo.

We performed CT scan on 128 slice SOMATOM Definition AS+;(Siemens Healthcare, Germany) with non-ionic contrast medium, dosage of 2ml/kg followed by saline chaser (half that of contrast amount). The flow rate was 2-3ml/sec, with bolus tracking technique, Scan triggered at 100 HU; kV of 80/100 and effective mAs ~ 40-100. Whenever required, sedation was done by a trained anaesthesiologist.

Very small patients (<10kg weight, <1-month-old) were first admitted and then underwent MSCT imaging for sake of pre and post procedure observation. We found short acting anaesthesia helpful. Blood reports-HIV, HBsAg, serum creatinine of all patients were mandatory. Those who were given sedation were monitored for 4 hours. Patients who had fever or respiratory tract infection were given appropriate treatment and asked to come back for MSCT scan at a later date. Terminally sick patients or patients whose parents were not willing to consent were excluded from the study.

All image data were evaluated using Syngovia software (Siemens Healthcare). Various image reformatting techniques including curved planar reconstruction, maximum intensity projection (MIP), shaded surface display and 3D volume-rendering technique (VRT) are used to get all the clinically relevant information. It is imperative to examine source images as well apart from reconstructed images; as some information might be missed by interpreting only reconstructed images.

Total radiation dose varied from 5-7mSv. Following steps were addressed for minimizing radiation dose. A**)** most of the scans were performed non-ECG gated. B) automatic current modulation technique C) low kVp D) Justifying CT examination rigorously and eliminate inappropriate referrals E) reduce the number of multiple phase scans F) scan only the indicated area ("child-size" the scan) G) shielding H) monitoring dose indices [volumetric CT dose index (CTDIvol) and dose-length product (DLP)].

RESULTS

We found non-invasive MSCT to be 100% sensitive as well as specific for evaluation of shunts and grafts. With use of various sharp kernel reconstructions and post-processing techniques, intrastent lumen were clearly visible. This was a major step in eliminating the need of further invasive testing and providing valuable cardiac as well as extracardiac information like pulmonary artery thrombosis in branch pulmonary arteries. Out of 100 total subjects (Table 1); 40 were of modified BT shunt (Figure 1), 25 were of central shunts (Figure 2, 3B), 5 were of SANO shunts (Figure 3A), 15 were of RVOT-PA conduit/stents (Figure 4), 10 were of bidirectional Glenn shunts-complete Fontan shunts (Figure 4C, 5) and 5 were of PDA stents.

Table 1: Numbers of various grafts and shunts evaluated on MSCT.

Shunts/grafts	No.
Modified BT shunt	40
Central shunt	25
RVOT-PA conduit/RVOT stent	15
Bidirectional Glenn shunt	10
SANO shunt	5
PDA stent	5

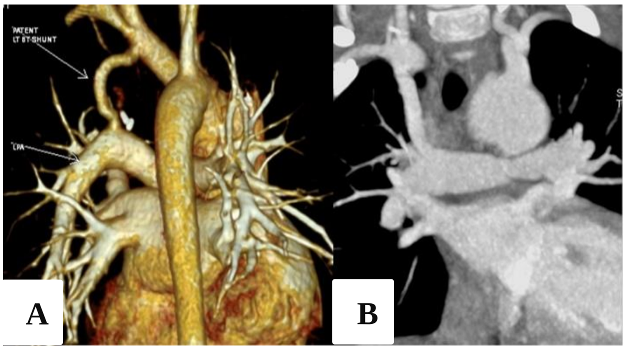

Figure 1: Patent modified BT shunt. (A): 3D VRT image of patent left BT shunt, (B): MPR image of patent right BT shunt.

Of the 40 modified BT shunt patients, 5 were completely occluded (Figure 6) with post-operative confirmation of the same. 2 subjects had seroma formation (Figure 7). Out of the 25 patients with central shunts, 2 were completely occluded with post-operative confirmation of the same. 1 subject had stenosis at anastomotic site. (Figure 8). Total 15 RVOT-PA conduit/stent were studied out of which 5 subjects had anastomotic site stenosis

(Figure 9). 1 subject had a small thrombus within conduit and branch pulmonary artery embolism as well. (Figure 10). Total 10 bidirectional Glenn shunts-complete Fontan shunts were studied of which none were occluded. Total 5 SANO shunts and PDA stents were studied out of which none were occluded.

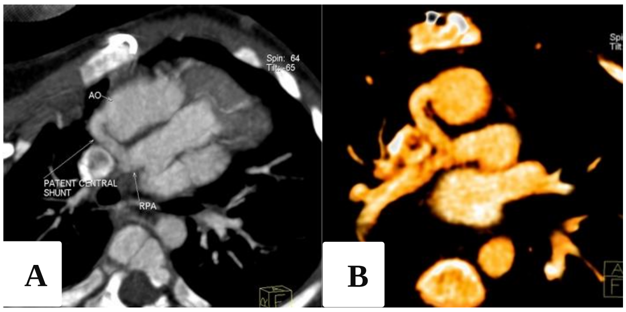

Figure 2: Patent central shunt. (A): MPR image of patent central shunt, (B): VRT thin image of patent central shunt.

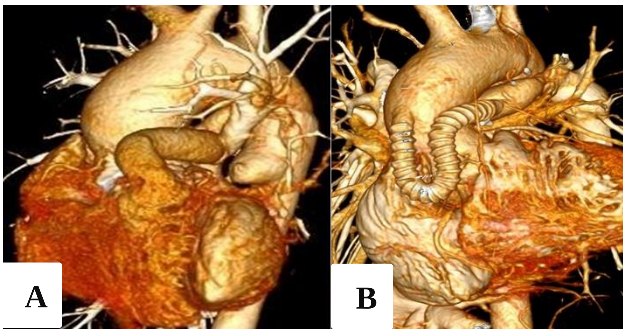

Figure 3: Patent sano and central shunts. (A): VRT image of patent sano shunt, (B): VRT image of patent central shunt.

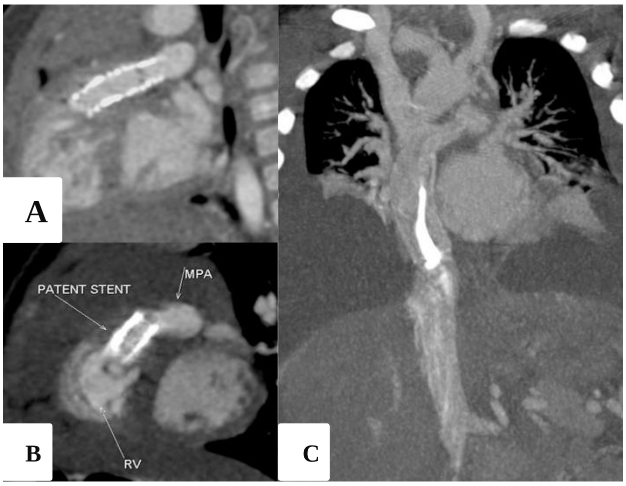

Figure 4: Patent RVOT stents in two patients and patent glenn and fontan shunts. (A): MPR image of patent stent in RVOT, (B): MPR image of another patient, also showing patent stent in RVOT, (C): Coronal MPR image of patent glenn and fontan shunts.

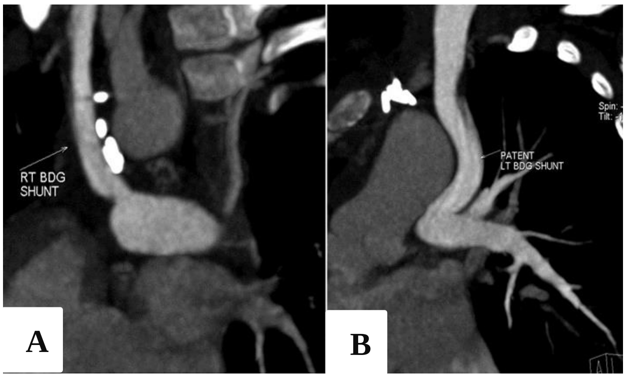

Figure 5: Patent bidirectional glenn shunts. (A): Curved MPR image of patent right bidirectional glenn shunt, (B): Curved MPR image of same patient showing patent left bidirectional glenn shunt.

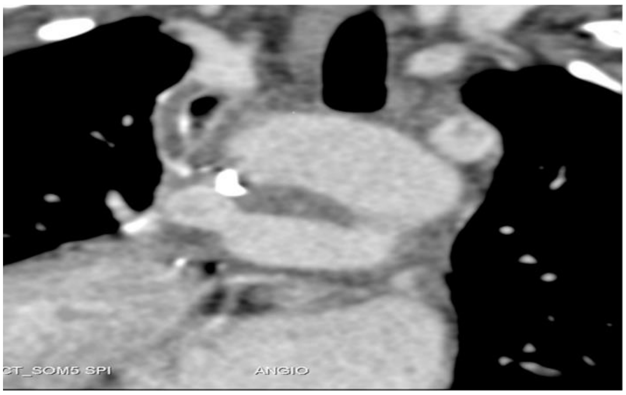

Figure 6: Curved MPR image of occluded modified right BT shunt.

Figure 7: Perigraft seroma formation. (A): MPR image of perigraft seroma formation, surrounding patent right BT shunt, (B): Axial image of same patient also showing perigraft seroma formation.

The complications rate were low in our study as shown in Table 2. Those patients with occluded shunts in whom pulmonary artery size had grown satisfactorily, directly underwent definitive cardiac repair but those in whom pulmonary size was not satisfactory, underwent other palliative procedure like for example BT shunt on opposite site. Patients with seromas were kept on follow-up only, and the seromas were found to regress gradually.

Patients with conduit stenosis were sent for re-surgery depending on severity of stenosis.

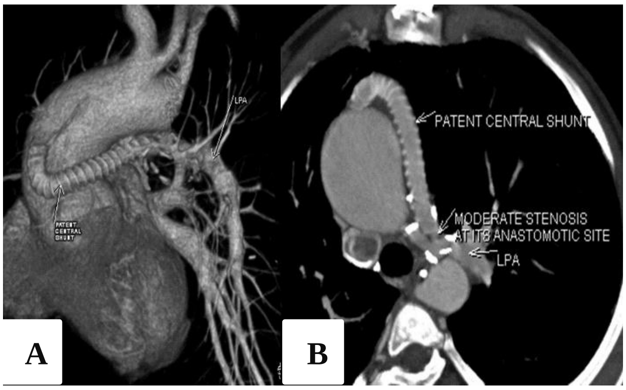

Figure 8: Central shunt with stenosis at anastomotic site. (A): VRT image of patent central shunt from ascending aorta to pulmonary artery, (B): MPR image of same patient showing moderate stenosis at anastomotic site.

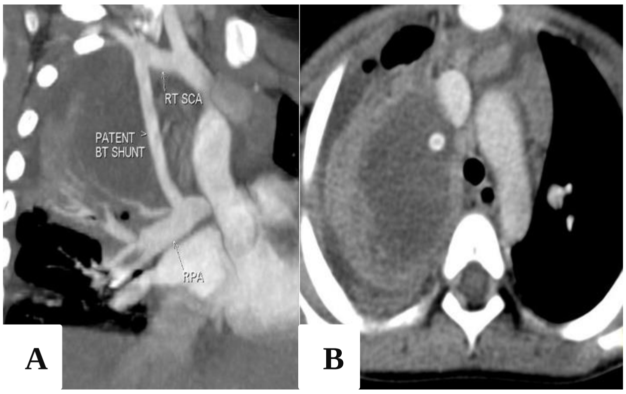

Figure 9: RVOT-PA conduit stenosis. (A): MPR images showing RVOT- PA conduit, (B): Axial image of same patient showing RVOT- PA conduit stenosis.

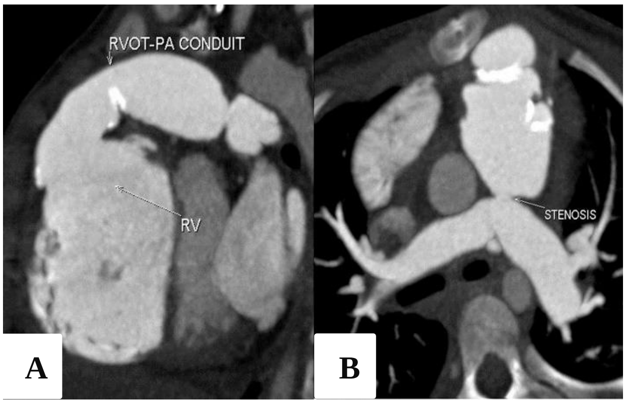

Figure 10: Thrombus in RVOT-PA conduit with branch pulmonary artery embolism. (A): MPR image of patent RVOT – PA conduit with small thrombus within, (B): MPR image of same patient with evident branch pulmonary artery embolism.

Table 2: Numbers of complications observed.

Type of complication	No.
Occluded BT shunt	5
Occluded Central shunt	2
RVOT-PA conduit anastomotic site stenosis	5
Seroma	2
Pulmonary artery thrombosis	5

DISCUSSION

Modified Blalock and Taussig shunt: An interposition polytetrafluoroethylene (PTFE, or Gore-Tex) graft between the subclavian artery and the pulmonary artery.[3] It prevents sacrifice of the subclavian artery and hence the ischemic sequelae in the ipsilateral upper limb. Pulmonary artery distortion and kinking is less likely. Its complication includes leakage of serous fluid through the PTFE in the chest or pseudoaneurysm formation, occasionally leads to massive hemoptysis.

Central shunt: A central shunt is a short PTFE connection between the ascending aorta and the main pulmonary artery.[4,5] Favoured if the pulmonary arteries are significantly hypoplastic. Its advantages include- avoidance of subclavian artery steal, lower occlusion rate (compared with the CBTS or MBTS techniques), provision of equal pulmonary blood flow to both lungs and relatively low incidence of congestive heart failure, acute occlusion, and pulmonary distortion.

SANO shunt-A sano shunt is a modification of Norwood procedure involves construction of a right ventricle to pulmonary artery (RV-PA) conduit as an alternative source of pulmonary blood flow. Compared with the Modified BT shunt, the RV-PA conduit provides a more stable hemodynamic state in the immediate postoperative period.[6,7] It is reported to be associated with lower interstage mortality in hypoplastic left heart syndrome.

Three-step surgical procedure called staged palliation is performed in hypoplastic left heart syndrome. Norwood procedure- performed shortly after birth. It converts the right ventricle into the main ventricle pumping blood to both the lungs and the body. The main pulmonary artery is cut off from the two branching pulmonary arteries, instead shunt (modified BT or sano) is placed between the pulmonary arteries and the aorta to supply blood to the lungs. Bidirectional Glenn shunt-performed six months after the Norwood. The superior vena cava (SVC) is divided from the right atrium. An incision is made on the pulmonary artery. The SVC is then sutured to the incision on the pulmonary artery. If the patient also has a left-sided SVC, the procedure is repeated on the left.[8] Fontan operation- 18 to 36 months after Glenn. IVC is channelled to pulmonary artery. At this stage, all deoxygenated blood flows passively through the lungs.[8,9]

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. 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.

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. The presence of an implanted pacemaker or defibrillator, other contraindication to MRI or vascular stents, which generally cause more artefacts with MRI than CT, will also influence the decision. Stent patency may be better assessed with CT than MRI due to metal artefacts.[10] It can also show stent fracture, separation from vessel wall, residual vessel narrowing and any pseudo aneurysm formation.

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.

Compared with the modified BT shunt, the RV-PA conduit (Sano shunt) provides a more stable hemodynamic state in the immediate postoperative period. Central shunt is preferable in significant hypoplastic pulmonary arteries and it provide equal flow to both the pulmonary arteries. Staged surgical palliation with Norwood, Glenn and fontan procedure is more effective than cardiac transplantation for hypoplastic left heart syndrome, because of the shortage of neonatal donor organs, the need for immunosuppression, and the limited durability of the transplant. Till date only very few studies have produced comparative data for MSCT versus catheter invasive angiography in literature. As in our study, Banderker E, Pretorius E, De Decker R. in their study “The role of cardiac CT angiography in the pre-and postoperative evaluation of tetralogy of Fallot” proved efficacy of MSCT in evaluation of shunts and grafts in TOF patients.[11]

Mohamed Helmy Nabo, Manal and Hayabuchi, Yasunobu and Inoue et al, in their study titled “Assessment of modified Blalock-Taussig shunt in children with congenital heart disease using multidetector-row computed tomography” concluded that there were excellent correlations between MDCT-and conventional angiography-based measurements of shunt diameter and that MDCT is a promising tool for the detection of lesions in B-T shunts.[12]

CONCLUSION

Advances in computed tomography (CT) scanners and electrocardio-graphic gating techniques have resulted in superior image quality of the aorta and pulmonary arteries with increased use of CT angiography for evaluating the postoperative congenital heart disease. Several abnormalities of the cyanotic heart disease often require surgery, and various open techniques and hence proper pre-operative mapping and evaluation is mandatory. Normal postoperative imaging findings, such as hyperattenuating felt pledgets, prosthetic conduits, and reanastomosis sites may mimic pathologic processes, thus a proper knowledge of all these procedures is imperative to avoid false positives. Familiarity with these procedures and their imaging features are required to identify normal postoperative appearances and complications.

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Ethical approval: Not required

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