

Induced apnea enhances image quality and visualization of cardiopulmonary anatomic during contrastenhanced cardiac computerized tomographic angiography in children

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ABSTRACT

Objective: The purpose of our study was to determine the effect of induced apnea on quality of cardiopulmonary structures during computerized tomographic (CT) angiography images in children with congenital heart diseases. **Methods:** Pediatric patients with congenital heart defects undergoing cardiac CT angiography at our facility in the past 3 years participated in this study. The earlier patients underwent cardiac CT angiography without induced apnea and while, later, apnea was induced in patients, which was followed by electrocardiogram gated cardiac CT angiography. General anesthesia was induced using sleep dose of intravenous propofol. After the initial check CT, on request by the radiologist, apnea was induced by the anesthesiologist by administering 1 mg/kg of intravenous suxamethonium. Soon after apnea ensued, the contrast was injected, and CT angiogram carried out. CT images in the “apnea group” were compared with those in “nonapnea group.” After the completion of the procedure, the patients were mask ventilated with 100% oxygen till the spontaneous ventilation was restored. **Results:** We studied 46 patients, of whom 36 with apnea and yet another 10 without. The quality of the image, visualization of structures such as cardiac wall, outflow tracts, lung field, aortopulmonary shunts, and coronary arteries were analyzed and subjected to statistical analysis (Mann–Whitney U, Fischer’s exact test and Pearson’s Chi-square test). In the induced apnea group, overall image quality was considered excellent in 89% ($n = 33$) of the studies, while in the “no apnea group,” only 30% of studies were excellent. Absent or minimal motion artifacts were seen in a majority of the studies in apnea group (94%). In the nonapnea group, the respiratory and body motion artifacts were severe in 50%, moderate in 30%, and minimal in 20%, but they were significantly lesser in the apnea group. All the studied parameters were statistically significant in the apnea group in contrast to nonapnea group ($P < 0.000$). **Conclusion:** The image quality of cardiac CT angiography greatly improves, and motion artifact significantly decreases with the use of induced apnea in pediatrics patients being evaluated for congenital heart disease. This technique poses no additional morbidity of significance.

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INTRODUCTION

For surgical management of patients with congenital heart disease, accurate evaluation of morphology of the heart and blood vessels

is critical. The shape and spatial relation of great arteries, pulmonary artery, its branches, anomalous pulmonary venous connection, shunts and anomalous coronary arteries are to be evaluated.

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The technical and clinical feasibility of multislice spiral computed tomography (CT) is confirmed in evaluating pediatric patients with complex congenital heart diseases.^[1] Multislice CT has benefits of faster scan time, high spatial and temporal resolution enabling the evaluation of cardiac structural abnormalities.^[2] CT accurately evaluates various forms of congenital cardiovascular disease in children. It is particularly valuable in the assessment of extracardiac vascular anomalies and in the evaluation of postoperative complications,^[3] thus answering most clinical questions of congenital cardiac defects and its management.

Cardiac CT angiography is sensitive to body and respiratory motions artifacts if severe, may render images non-diagnostic. Since the motion related artifacts caused by respiratory or body motions,^[4] it is impossible to avoid these artifacts in children, unlike in adults who could be requested to lie still and be relaxed. Deep sedation could control gross body motion artifacts but cannot cease respiratory motion artifact. General anesthesia is advantageous in children, as it protects the airway, prevents hypoxemia and gross body movements.^[5] However, general anesthesia does not decrease respiratory motion artifact due to spontaneous breathing.^[6,7] Ceasing spontaneous breathing could be carried out by the anesthesiologist without incurring significant morbidity in these patients, but might aid in improving the image quality. Mechanical ventilation with induced apnea during image acquisition has been described in children undergoing cardiac magnetic resonance imaging (MRI),^[8,9] but not during cardiac CT angiography.

Aims of the study

The aims of the study were to determine if induced apnea during diagnostic CT examination improved the image quality and aided in better evaluation of cardiac structural defects in congenital heart diseases in children.

METHODS

This nonrandomized prospective study was conducted in a tertiary care hospital, in children (neonates, infants, pediatric and adolescent) with congenital heart disease while they underwent diagnostic CT angiogram. Hospital ethical committee cleared the study. Written consent was obtained from the patient's parents or guardians for conducting the CT angiogram under induced apnea. A section of the cohort underwent CT angiogram under sedation (no apnea group); they

formed the studies done earlier, and yet another group of children underwent the same procedure under induced apnea and mechanical ventilation (apnea group). The patients in apnea group included those who underwent the procedure in the recent past. The quality of the image, visualization of structures such as cardiac wall, outflow tracts, lung field, aortopulmonary shunts, and coronary arteries were analyzed and subjected to statistical analysis. The aim of the study was to analyze the imaging characteristics using apnea in comparison to those breathing spontaneously during the CT study.

Anesthesia

Preanesthetic examination was performed prior to procedure. No premedication was advised for any of the patients unless they were apprehensive and irritable. In such cases, syrup triclofos 25 mg/kg was administered orally an hour prior to the procedure. The patients were kept fasting for at least 6 h prior to the procedure. The air conditioner in the CT room was temporarily turned down to prevent temperature loss due to low ambient temperature. The patients were kept normothermic by warm blankets covering them during the procedure. Intravenous line was secured with 20 gauge needle size and tested for line patency and function by administering 5 ml of normal saline using the mechanical injector. Monitoring included an electrocardiogram, pulse oximetry, and noninvasive blood pressure (BP) measurements. Oxygen face mask was used to administer oxygen. The children were anesthetized by administration of titrated dose of propofol by a slow intravenous injection (usually not more than 1 mg/kg). The patient was stabilized using pillows and positioned supine in the gantry once asleep. A nonenhanced check CT was performed prior to injection of contrast. After this, apnea was requested for by the radiologist; the anesthesiologist administered a bolus injection of 1 mg/kg suxamethonium intravenously. The child was ventilated with oxygen till induced apnea ensued. Following that, with an oxygen face mask in place (supplying 3–5 L of oxygen), the apneic child was subjected to noniodinated intravenous contrast and CT acquisitions done. Heart rate, BP and oxygen saturation were continuously monitored throughout the apneic period. After the CT study, the child was brought out of the CT gantry and mechanically ventilated using bag and mask till spontaneous ventilation returned. After complete recovery, the child was nursed in the pediatric intensive care unit and discharged by evening. In contrast, the children in the “no apnea” group breathed oxygen spontaneously via an oxygen

face mask while they underwent CT angiogram under sedation. They received up to 1 mg/kg propofol, 1 mg/kg fentanyl and 0.1 mg/kg midazolam intravenously. After the procedure, following their recovery, they were also nursed in the pediatric intensive care unit till full recovery and were discharged by evening. Complications related to anesthetic technique were noted.

Cardiac computerized tomographic angiogram protocol

All examinations were performed with 64 slice MDCT scanner (Philips brilliance 64 slice). Noncontrast chest CT scan was performed with a collimation of 64×0.625 and reconstruction thickness of 1 mm with an increment of 0.2. A voltage of 120 kv and 100 mA was used with scan thickness 0.9 mm. For CT angiogram, the locator and tracker were placed in the right ventricle with minimum delay of 3.2 s. A voltage of 120 kv and 350–400 mA exposure was used for contrast study. The resolution was standard, the pitch was 0.2, the field of view (FOV) was 250, the filter was cardiac sharp, rotation time was 0.4 s and window was 150–850. Trigger density threshold was 150 and postthreshold delay was 150. Non-ionic contrast medium was used - ultraviolet molecule – Iopromide - concentration of 769 mg/ml. Contrast medium was administered via the peripheral venous cannula using an automated pressure injector pump. The volume of the nonionic contrast was 1.5 ml/kg administered at a rate of 2.5 ml/s with 325 psi pressure.

Image evaluation

Qualitative evaluation was performed by the same radiologist, who was well-experienced in cardiac imaging. The evaluating radiologist had access to thin reconstructed images, multi-planar reformatted and three-dimensional volume rendered images. The images were subjectively scored for overall image quality and motion artifact as described by Saleh *et al.*^[9] [Table 1].

Vessel enhancement and sharpness were evaluated subjectively. For the assessment of lung arborization, up to fourth order pulmonary branches were evaluated

Table 1: Subjective scale for scoring image quality and/or motion artifacts on CT angiogram

Score 1 - Excellent images with absent motion artifacts (high diagnostic confidence)
Score 2 - Good images with mild motion artifacts (diagnostic quality image)
Score 3 - Fair images with moderate motion artifacts (indeterminate diagnosis)
Score 4 - Poor quality images due to severe motion artifacts (nondiagnostic)

CT: Computerized tomographic

with a four point subjective scale based on Saleh scoring method.^[9] Lung parenchyma and cardiac chambers were also assessed using the same method.

Statistical methods

Non-parametric variables were analyzed using Mann–Whitney U-test, Fischer’s exact test and Pearson’s Chi-square test SPSS 16 software (SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL) was used to analyze the data. $P < 0.05$ was considered as significant.

RESULTS

this was an observational study conducted during the period of 2010–2013. The study included 46 children who underwent diagnostic CT cardiac angiogram. The first 10 children underwent the procedure under “monitored anesthesia care” (sedation), and they breathed oxygen spontaneously via a face mask. The subsequent 36 patients were rendered apneic during the study. The age range was 2 days to 13 years 8 months 20 days; mean age was 4 years 6 months. The apnea lasted for about 10 ± 3 s (range 9–22 s). None of the patients required either endotracheal intubation or supraglottic airway to ventilate. The heart rate and saturation of the patients in either group were not significantly different.

A wide range of congenital cardiac abnormalities were seen in both control group and induced apnea group children [Table 2]. In the apnea group, the image quality was excellent in 89% in contrast to 30% in the non-apnea group. Absent or minimal motion artifacts were seen in majority of the studies in “apnea group” (94%) while in the non-apnea group, motion artifacts were severe in 50%, moderate in 30%, and minimal in 20%. In the apnea group, 100% of the images of the cardiac wall were good in contrast to 30% in the nonapnea group, which was statistically significant ($P < 0.000$). The images of the outflow tract in the apnea group were excellent; only in 30% of non-apnea group the image quality was good and the rest were fair [Figures 1 and 2]. All the above findings were statistically significant ($P < 0.000$). The image quality of lung fields was significantly different ($P < 0.000$) in the apnea group in contrast to the non-apnea group [Table 3]. Quality of imaging of coronary artery is shown in Table 4. It appears that coronary artery imaging does not seem to greatly improve with apnea unlike the other measurable considered in the study. There were only 15% of patients in the apnea group, who had image score of 1 while 26 had image of the score of 2. However in the non-apnea group, none had

Table 2: Findings in the induced apnea and control groups

Findings	Induced apnea	Control group
Aberrant right subclavian artery	2	1
Anomalous left anterior descending artery	1	0
Aortic isthmus narrowing	1	1
Atrial septal defect	4	0
Blalock-Taussig shunt	4	2
Coarctation of aorta	1	0
Double outlet left ventricle	1	0
Double outlet right ventricle	2	1
Major aorto pulmonary collaterals	2	1
Left superior venacava	1	1
Partial anomalous pulmonary venous return	2	1
Patent ductus arteriosus	3	0
Pulmonary atresia	8	4
Pulmonary stenosis	13	6
Right aortic arch	11	5
Right ventricle aneurysm	1	0
Total anomalous pulmonary venous return	2	0
Transposition of great arteries	3	1
Tricuspid atresia	2	1
Truncus arteriosus	1	0
Ventricular septal defect	10	6

Data is number of patients with different abnormalities. Many patients had more than 1 finding with complex congenital cardiac disease

Table 3: Lung field image quality score

Image quality score	Apnea group	No apnea group	Total
1	29	2	31
2	5	2	7
3	2	4	6
4	0	2	2
Total	36	10	46

$P < 0.000$

Table 4: Coronary artery delineation in the two groups

Image quality score	Apnea group	No apnea	Total
1	6	0	6
2	25	2	27
3	2	3	5
4	3	5	8
Total	36	10	46

Pearson's Chi-square test: $P = 0.001$

score of 1, 2 had 2, 3 had 3 and 5 had 4. Overall the scoring in the apnea group was better. It is interesting to note if reducing the heart rate that might occur by the use of suxamethonium might have any beneficial effect on imaging of coronary arteries.

DISCUSSION

An important component of the clinical management of congenital heart disease patient is good quality imaging of the heart and circulation. Imaging techniques are important to delineate anatomical structures with a high degree of detail. There are various imaging modalities to examine cardiothoracic structures with inherently relative advantages and limitations of each study.

Echocardiography including transesophageal approach is a routine primary modality used to examine children with congenital heart disease.^[10] The major disadvantage of echocardiography is its limited FOV and it cannot display the extracardiac structures like coronary and peripheral pulmonary anatomy, airway, and lungs. Currently, transesophageal echocardiography cannot be carried out in neonates and infants. Diagnostic cardiac catheterization is another modality, which is an invasive method performed if echo fails to provide a confident evaluation of the cardiac lesions and it is the only method to determine pulmonary vascular pressure and oxygen saturation,^[11] however, the disadvantages of cardiac catheterization are radiation burden,^[11] exposure to adverse effects of iodinated contrast,^[12] limitation in assessment of extracardiac structures, associated vascular and arrhythmic complications.^[13,14]

MRI is more appropriate for cardiac imaging, but drawbacks are prolonged acquisition time, decreased spatial resolution, less accessibility and limited use in assessing airways and lungs.^[15] CT is increasingly becoming important imaging technique for evaluation of congenital heart disease, because of greater access, faster scanning time and good spatial resolution of approximately 0.5 mm versus 1.5-2 mm for MR angiography, thus, demonstrating very fine structures including small aortopulmonary collaterals, lung arborization and coronary arteries^[16] without any artifact.

The use of general anesthesia and intravenous sedation in patients undergoing diagnostic procedures is increasing in the radiology department with more referrals for CT and MRI studies and with the use of safer drugs.^[17] Propofol, fentanyl, and midazolam are commonly used drugs for sedation in diagnostic procedures. For procedural sedation, they are administered intravenously to a spontaneously breathing child without respiratory assistance. This technique avoids airway instrumentation. There is a decrease in the frequency of respiratory events and airway intervention with the use of propofol.^[18] Intravenous suxamethonium is used as a neuromuscular

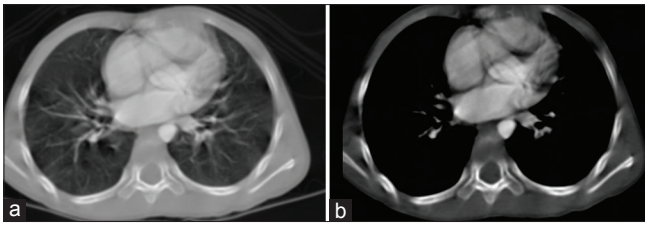


Figure 1: Control group without induced apnea; (a) Respiratory motion artifacts, blurring the branched pulmonary vessels. (b) Blurring of the cardiac chambers due to cardiac wall motion and respiratory artifact

blocking agent for rapid sequence induction because of its short-acting nature.^[19] Yet another benefit of using suxamethonium may be the decrease in the heart rate that is commonly seen following its administration. We have noted decrease in the heart rate from 20% to 30% after administration of suxamethonium. Decrease in the heart rate improves the image capture time and additionally the cardiac motion artifacts may also be reduced.

Fallot tetralogy is the most common abnormality in our study comprising various components of the disease entity. Assessment of pulmonary arterial anatomy is vitally important while deciding the treatment options in Tetralogy of Fallot.^[16] The spectrum of pulmonary malformations includes hypoplasia or atresia of the main or segmental pulmonary arteries, non-confluence of the left and right pulmonary arteries. In the majority of severe cases, multiple collateral vessels were seen arising from the descending thoracic aorta, brachiocephalic and subclavian arteries and occasionally from the abdominal aorta or coronary circulation.^[20] All the above said anatomical delineations are better visualized when apnea is induced, as observed in our study. Surgical attempts to gather these multiple vessels and pulmonary arteries requires meticulous preoperative planning based on individual patient anatomy.^[21]

Coronary anomalies are relatively frequent in the congenital heart disease population.^[22] In many cases, they are of little or no significance and may be normal for a particular condition. The one major exception to this is an anomalous left coronary artery or large branch passing directly in front of an enlarged right ventricle and running immediately posterior to the sternum, unsuspected there may be serious consequences at the time of sternotomy. The operating surgeon will appreciate if this finding is mentioned in the report before surgery.

Several other cardiac and extracardiac abnormalities were confidently evaluated with the use of induced apnea. The aorta, large arterial branches, and cardiac

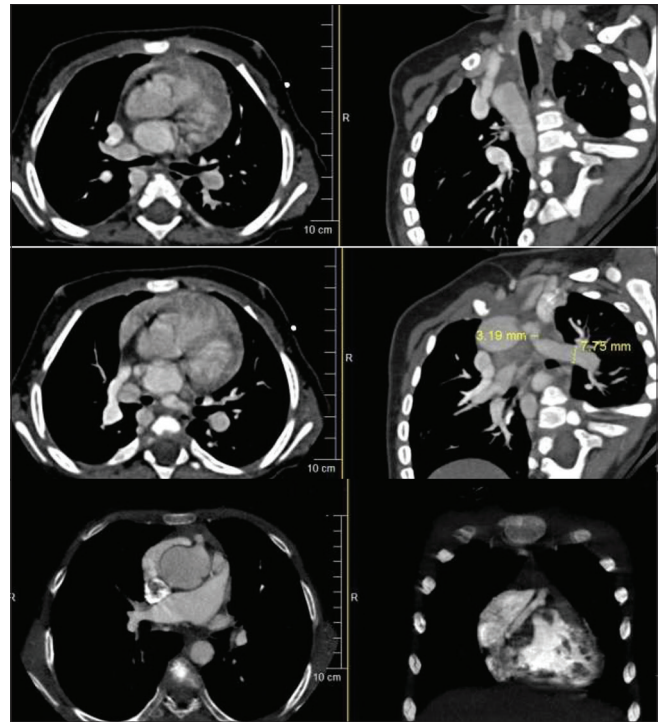


Figure 2: Induced apnea group, anomalous drainage of superior vena cava into right pulmonary artery. Images are of excellent diagnostic quality

chambers may be assessed without breath holding, whereas assessment of smaller vessels needs elimination of respiratory and body motion artifacts. As observed in our study, cardiac structures, major arterial tree, and pulmonary artery are well visualized by using apnea.

The limitations of our study is a small cohort of the control group. However, a considerable difference in image quality is appreciated between the control group and induced apnea group. Another drawback of the study is the radiation dose associated with a CT study; however, this is comparable to the annual dose received from natural sources of radiation.^[23] In spite of these limitations, the advantages of speed and high spatial resolution of the modality, multi-detector CT has an important role in evaluating congenital cardiac abnormalities in children.

Potential weakness of the study

The cohort was not matched. The number of participants is small, the data and the result may be skewed. A larger study with bigger cohort might be useful.

CONCLUSION

The overall image quality of cardiac CT angiography is greatly improved by eliminating respiratory and

body motions artifacts with the use of induced apnea in pediatrics patients being evaluated for congenital heart disease.

REFERENCES

- Lee T, Tsai IC, Fu YC, Jan SL, Wang CC, Chang Y, *et al.* Using multidetector-row CT in neonates with complex congenital heart disease to replace diagnostic cardiac catheterization for anatomical investigation: Initial experiences in technical and clinical feasibility. *Pediatr Radiol* 2006;36:1273-82.
- Ruan W, Yang M, Gong Y, Qiao L, Mo X, Teng G. Diagnosis of complicated congenital heart diseases in neonates and infants using 64-slice spiral CT. *Sci Res Essays* 2011;6:146-56.
- Dillman JR, Hernandez RJ. Role of CT in the evaluation of congenital cardiovascular disease in children. *Am J Roentgenol* 2009;192:1219-31.
- Choi HS, Choi BW, Choe KO, Choi D, Yoo KJ, Kim MI, *et al.* Pitfalls, artifacts, and remedies in multi-detector row CT coronary angiography. *Radiographics* 2004;24:787-800.
- Malviya S, Voepel-Lewis T, Eldevik OP, Rockwell DT, Wong JH, Tait AR. Sedation and general anaesthesia in children undergoing MRI and CT: Adverse events and outcomes. *Br J Anaesth* 2000;84:743-8.
- American Academy of Pediatrics Committee on Drugs. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures. *Pediatrics* 1992;89 (6 Pt 1):1110-5.
- Committee on Drugs. American Academy of Pediatrics. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: Addendum. *Pediatrics* 2002;110:836-8.
- Tsai-Goodman B, Geva T, Odegard KC, Sena LM, Powell AJ. Clinical role, accuracy, and technical aspects of cardiovascular magnetic resonance imaging in infants. *Am J Cardiol* 2004;94:69-74.
- Saleh RS, Patel S, Lee MH, Boechat MI, Ratib O, Saraiva CR, *et al.* Contrast-enhanced MR angiography of the chest and abdomen with use of controlled apnea in children. *Radiology*. 2007;243:837-46.
- Curtis SL, Stuart AG. Outcome in congenital heart disease. *Curr Paediatr* 2005;15:549-56.
- Bacher K, Bogaert E, Lapere R, De Wolf D, Thierens H. Patient-specific dose and radiation risk estimation in pediatric cardiac catheterization. *Circulation* 2005;111:83-9.
- Bettmann MA, Heeren T, Greenfield A, Goudey C. Adverse events with radiographic contrast agents: Results of the SCVIR Contrast Agent Registry. *Radiology* 1997;203:611-20.
- Vitiello R, McCrindle BW, Nykanen D, Freedom RM, Benson LN. Complications associated with pediatric cardiac catheterization. *J Am Coll Cardiol* 1998;32:1433-40.
- Tavli V, Kayhan B, Okur FF, Kirman M, Tekdogan M. Complications of pediatric cardiac catheterization: 18-month study. *Turk J Pediatr* 2000;42:294-7.
- Taylor AM. Cardiac imaging: MR or CT? Which to use when. *Pediatr Radiol* 2008;38 Suppl 3:S433-8.
- Crean A. Cardiovascular MR and CT in congenital heart disease. *Heart* 2007;93:1637-47.
- Patatas K, Koukkoulli A. The use of sedation in the radiology department. *Clin Radiol* 2009;64:655-63.
- Srinivasan M, Turmelle M, Depalma LM, Mao J, Carlson DW. Procedural sedation for diagnostic imaging in children by pediatric hospitalists using propofol: Analysis of the nature, frequency, and predictors of adverse events and interventions. *J Pediatr*. 2012;160:801-6.e1.
- Taha SK, El-Khatib MF, Baraka AS, Haidar YA, Abdallah FW, Zbeidy RA, *et al.* Effect of suxamethonium vs rocuronium on onset of oxygen desaturation during apnoea following rapid sequence induction. *Anaesthesia* 2010;65:358-61.
- Mohan A, Balat H, Vaghela D, Ninama G, Balat J, Damor S. Study of role of MDCT in pulmonary angiography in evaluation of pulmonary arteries patterns in children with tetralogy of Fallot. *Int J Res Med* 2013;2:13-6.
- Greil GF, Schoebinger M, Kuettner A, Schaefer JF, Dammann F, Claussen CD, *et al.* Imaging of aortopulmonary collateral arteries with high-resolution multidetector CT. *Pediatr Radiol* 2006;36:502-9.
- Tuzcu EM, Moodie DS, Chambers JL, Keyser P, Hobbs RE. Congenital heart diseases associated with coronary artery anomalies. *Cleve Clin J Med* 1990;57:147-52.
- Schindera ST, Nauer C, Treier R, Trueb P, von Allmen G, Vock P, *et al.* Strategies for reducing the CT radiation dose. *Radiologe*. 2010;50:1122-7.

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