https://doi.org/10.35805/BSK2022III040

Egizekov A.L.
orcid.org/0000-0001-7979-2239
Kuatbekov K.N.
orcid.org/0000-0002-2679-5097
Karakoishin K.E.
orcid.org/0000-0003-4013-4487
Mishin A.V.
orcid.org/0000-0003-2858-6181
Nurbekov A.M.
orcid.org/0000-0003-4192-8940

Corresponding author.
Mishin A.V. – Cardiac surgeon, Department of Pediatric Cardiac Surgery, Center for Modern Medicine «Mediterra» LLP «Institute of Surgery», Almaty, Kazakhstan
E-mail: avm_mishin@mail.ru

Conflict of interest
The authors declare that they have no conflicts of interest

Keywords:
CT scan, CT cardiography, congenital heart disease, cardiac surgery

COMPUTED TOMOGRAPHY IN THE DIAGNOSIS OF CONGENITAL HEART DISEASE

Egizekov A.L.[1], Kuatbekov K.N.[1], Karakoishin K.E.[1], Mishin A.V.[1], Nurbekov A.M.[2]

[1] Center of Modern Medicine «Mediterra», Institute of Surgery LLP, Almaty, Kazakhstan
[2] «S.D. Asfendiyarov Kazakh National Medical University» NC JSC Almaty, Kazakhstan

Abstract

Aim of the study – *Evaluate the value of multispiral computed tomography (MSCT) with intravenous contrast in the diagnosis of congenital heart disease (CHD) at the stage of preoperative preparation and choice of surgical tactics.*

Methods. *Between January 2021 and June 2022, 30 CT cardiographies were performed in our center, of different age and mediastinal pathology. A 64-slice Somaton Siemens sensation 64 CT scanner complete with digital processing systems was used. The main vessels of the heart were examined with intravenous bolus injection of contrast agent. Image analysis included study of anatomy of the defect by three-plane tomograms and construction of multiplanar 3-D reconstructions.*

Results. *Modern approaches to the imaging diagnosis of CHD in all age groups are presented. The role of CT-angiography with intravenous contrast in the diagnosis of congenital, acquired cardiovascular and thoracic pathology is shown. Qualitative assessment of CT-angiographic picture of CHD was performed.*

Conclusion. *Our experience with CT cardiography in the examination of patients with CHD, in contrast to traditional ultrasound and invasive techniques, in most cases allows to obtain more valuable diagnostic information, especially extracardiac structures, which determines its significance in the examination of CHD. It details anatomy of malformations in reliable morphometric indices, diagnosis of aortic, pulmonary artery, right ventricular pathology, including pathology of its outflow tract, to assess ventricular-artery connections and atrial-ventricular connections.*

Жүректің туа пайда болған ақауларын анықтаудағы компьютерлік томография

Егізеков А.Л.[1], Қуатбеков Қ.Н.[1], Каракойшин К.Е.[1], Мишин А.В.[1], Нұрбеков А.М.[2]

[1] Қазіргі заманғы медицина орталығы «Медитерра», ЖШС «Хирургия институты», Алматы қ., Қазақстан
[2] «С.Ж. Асфендияров атындағы Қазақ Ұлттық медицина университеті» Ке АҚ, Алматы қ., Қазақстан

Хат алысатын автор.
Мишин А.В. – «Хирургия институты» ЖШС «Медитерра» заманауи медицина орталығы, балалар кардиохирургиясы бөлімінің кардиохирургы, Алматы қ., Қазақстан
E-mail: avm_mishin@mail.ru

Мүдделер қақтығысы
Авторлар мүдделер қақтығысының жоқтығын мәлімдейді

Түйін сөздер:
компьютерлік томография, КТ-кардиография, туа біткен жүрек ақауы, кардиохирургия.

Аңдатпа

Мақсаты – *операция алдындағы дайындық және хирургиялық тактиканы таңдау кезеңінде туа біткен жүрек ақауларын (ТЖА) диагностикалауда тамыр ішіндегі контрасты бар мультиспиральды компьютерлік томографияның (MSKT) маңызын бағалау.*

Әдістер. *2021 жылғы қаңтар - 2022 жылғы маусым кезеңінде біздің орталықта көкірек патологиясы бар әртүрлі жастағы науқастарға 30 КТ-кардиография жүргізілді. 64-кесінді компьютерлік томограф Somaton Siemens sensation 64 сандық өңдеу жүйелерімен жиынтықта пайдаланылды. Жүректің магистральдық тамырларын зерттеу контрастылық затты тамырішілік болюсті енгізу арқылы жүргізілді. Бейнелерді талдау үш жазықтық томограммалар бойынша ақау атомиясын зерттеуді және мультипланарлық 3-D қайта жаңартуларды құруды қамтиды.*

Нәтижелер. *Барлық жас топтарының ТЖА визуализациялық диагностикасының заманауи тәсілдері ұсынылған. Туа біткен, пайда болған жүрек-қантамырлары және торакальды патологияны диагностикалауда тамырішіндегі контрасты бар КТ-кардиографияның рөлі көрсетілген. ТЖА КТ-ангиографиялық картинасын сапалы бағалау жүргізілді.*

Қорытынды. *Біз ТЖА бар науқастарды тексеру кезінде КТ-кардиографияны қолдану тәжірибеміз дәстүрлі ультрадыбыстық және инвазивті әдістемелерге қарағанда көп жағдайда неғұрлым құнды диагностикалық ақпаратты, әсіресе экстракардиалды құрылымдарды алуға мүмкіндік береді, бұл оның ТЖА-ны тексерудегі маңыздылығын айқындайды. Бұл ретте дұрыс морфометриялық көрсеткіштерде, аорта патологиясын, өкпе артериясын, оң жақ қарыншаны диагностикалауда, оның шығару бөлімінің патологиясын қоса алғанда, қарынша-артериялық байланыстарды және жүрекше-қарынша қосылыстарын бағалау үшін ақаулар анатомиясы нақтыланады.*

Компьютерная томография в диагностике врождённых пороков сердца

Егизеков А.Л.[1], Куатбеков К.Н.[1], Каракойшин К.Е.[1], Мишин А.В.[1], Нурбеков А.М.[2]

[1] Центр современной медицины «Mediterra», ТОО «Институт хирургии» г. Алматы, Казахстан
[2] НАО «Казахский Национальный медицинский университет имени С.Д. Асфендиярова», г. Алматы, Казахстан

Автор для корреспонденции.
Мишин А.В. *– кардиохирург, отделения детской кардиохирургии, Центр современной медицины «Mediterra» ТОО «Институт хирургии», г. Алматы, Казахстан*
E-mail: avm_mishin@mail.ru

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов

Аннотация

Цель – *оценить значение мультиспиральной компьютерной томографии (МСКТ) с внутривенным контрастированием в диагностике врождённых пороков сердца (ВПС) на этапе предоперационной подготовки и выбора хирургической тактики.*

Методы. *За период январь 2021 г – июнь 2022 г в нашем центре проведено 30 КТ-кардиографий, различного возраста и патологии средостения. Использовался 64-срезовый компьютерный томограф Somaton Siemens sensation 64 в комплекте с системами цифровой обработки. Исследование магистральных сосудов сердца проводилось с внутривенным болюсным введением контрастного вещества. Анализ изображений включал изучение анатомии порока по трёхплоскостным томограммам и построение мультипланарных3-Dреконструкций.*

Результаты. *Представлены современные подходы к визуализационной диагностике ВПС всех возрастных групп. Показана роль КТ-кардиографии с внутривенным контрастированием в диагностике врождённой, приобретённой сердечно-сосудистой и торакальной патологии. Проведена качественная оценка КТ-ангиографической картины ВПС.*

Заключение. *Наш опыт применения КТ-кардиографий при обследовании пациентов с ВПС, в отличие от традиционных ультразвуковых и инвазивных методик в большинстве случаев позволяет получить более ценную диагностическую информацию, особенно экстракардиальных структур, что определяет его значимость в обследовании ВПС. При этом детализируется анатомия пороков в достоверных морфометрических показателях, диагностике патологии аорты, легочной артерии, правого желудочка, включая патологию его выводного отдела, для оценки желудочково-артериальных связей и предсердно-желудочковых соединений.*

Ключевые слова:
компьютерная томография, КТ-кардиография, врождённый порок сердца, кардиохирургия

Introduction

Computed tomography (CT) of congenital heart disease (CHD) is now the leading standard in modern radiological diagnosis of complex CHD, with the paramount position of their extracardiac structures [1]. Before the era of the introduction of radiographic tomography, X-ray angiography was the "gold standard" diagnostic imaging of the vascular bed for a long time (Galperin M.D., 1950; Arutyunov A.I., Kornienko V.N., 1971; Pelz D.M., Fox A.J., 1985; Blatter D.D. et al., 1993). Computed tomography was proposed in 1972 by Godfrey Hounsfield and Allan Cormack. In 1992, the first two-spiral CT (MSCT) with two rows of detectors appeared, and in 1998, four-spiral, with four rows of detectors, respectively. In 2004-2005 32-, 64- and 128-slice MSCTs were introduced, including those with two X-ray tubes. In 2007, Toshiba introduced 320-slice CT scanners, and in 2013, 512-slice and 640-slice.

Significant progress achieved in the development of highly effective, primarily surgical methods of heart and vascular diseases treatment necessitates the introduction into clinical practice of new, more perfect and safe diagnostic technologies, which include spiral CT and magnetic resonance angiography (MRA). Their difference lies in noninvasiveness, as well as the possibility to study the state of the vascular wall and the changes occurring in it in diseases of various etiologies. A separate stage of CT development with a wide application field, including cardiological studies, can be called the era of electron-beam tomography (Ternovoy S., Sinitsyn V. et al, 2001).

The history of national CT diagnostics began in 1984, when Y.V. Grushin, after his training in Germany, started working in Alma-Ata on the first CT scanner in Central Asia and Trans-Ural part of the USSR on Siemens "Somatom DR2" apparatus. The minimally invasive method of vascular bed examination, which has been developed in the recent years, is spiral computer angiography. Development of clinical application and introduction of this method to the practice of republican medical centers in Kazakhstan began in Astana in 2003 for acquired heart disease (CHD), and in 2008 - for CHD.

Aim of the study

The aim of this article is to evaluate the value of multispiral computed tomography (MSCT) with intravenous contrast in the diagnosis of CHD during preoperative preparation and choice of surgical tactics.

Material and methods

Between January 2021 and June 2022, 30 CT cardiograms were performed in our Cardiology and Cardiac Surgery Department, in patients ranging in age from infants to 75 years old. Nosological units included: Fallot's tetrad - 12, partial-anomalous pulmonary vein drainage - 5, aortic recoarctation - 4, aortic coarctation - 2, thoracic bone structures - 2, coronary artery anomalies - 1, pulmonary artery stenosis - 1, total-anomalous pulmonary vein drainage combined with a single ventricle and pulmonary atresia - 1, double branching of the main vessels from the right ventricle - 1, hypoplasia of the aortic arch - 1. All patients underwent general clinical examination, CT scan with intravenous contrast. A 64-slice Somaton Siemens sensation 64 CT scanner complete with digital processing systems was used. Cardiac main vessels were examined with intravenous bolus injection of contrast agent. Image analysis included study of anatomy of the defect by three-plane tomograms and construction of multiplanar 3-D reconstructions.

Since CT is a source of ionizing radiation, we adapt our equipment and use safe "optimized pediatric protocols" in order to minimize radiation exposure, without compromising the health of the young patient and image quality. The study is performed in step-by-step scanning mode with mandatory prospective synchronization with ECG and intravenous bolus injection of a modern nonionic contrast agent, using an automatic injector "MEDRAD Stellant". Due to modern equipment with high resolution we are able to obtain informative images even in children of the first year of life, which provides a higher level of diagnostics of cardiovascular diseases and associated pathologies.

The starting point for CT diagnosis of CHD is slices in standard projections: axial, frontal and sagittal. All subsequent slices and reconstructions of areas of interest, as a rule, are of auxiliary importance for more clear presentation of results or calculations, 3D reconstructions are necessary for demonstration of spatial anatomy, mainly of the vascular bed, when planning surgical interventions or in dynamic observation in the postoperative period.

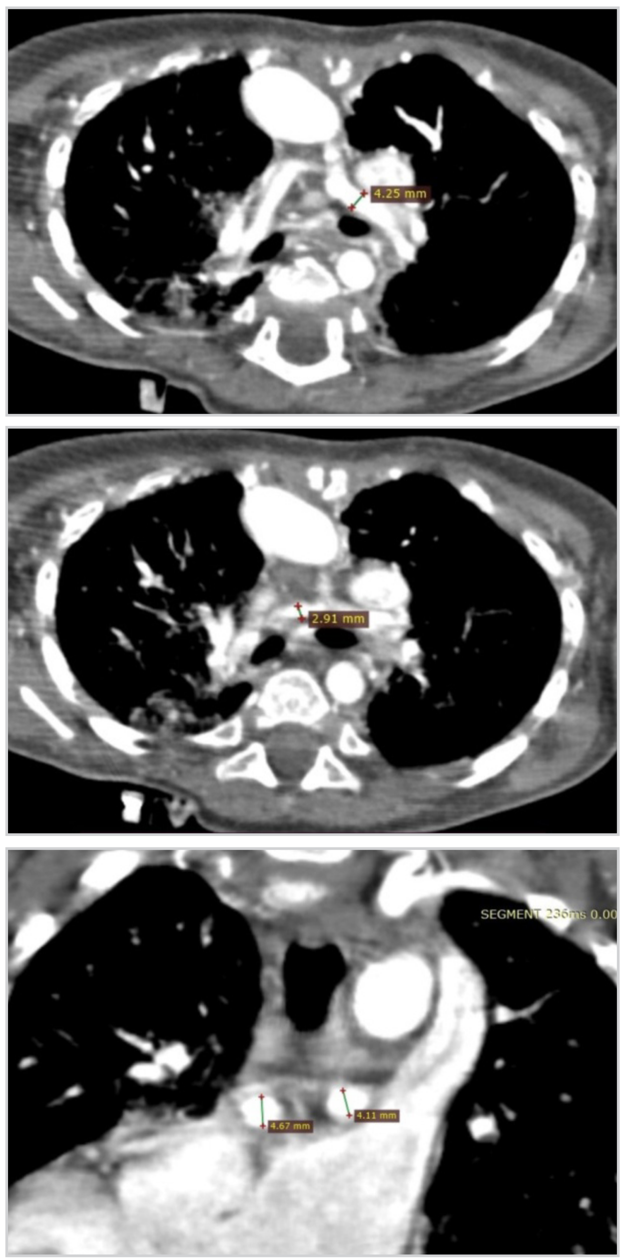


Figure 1.
Computer angiography:
A – Left branch of pulmonary artery with narrowing up to 2.9 mm (Z score – 3,75) in axial projection;
B – Right branch of the pulmonary artery with a diameter of 4.25 mm (Z score – 1,99) in axial projection;
C – maximal areas behind the bifurcation of pulmonary branches: right 4.67 mm, left 4.11 mm in frontal projection

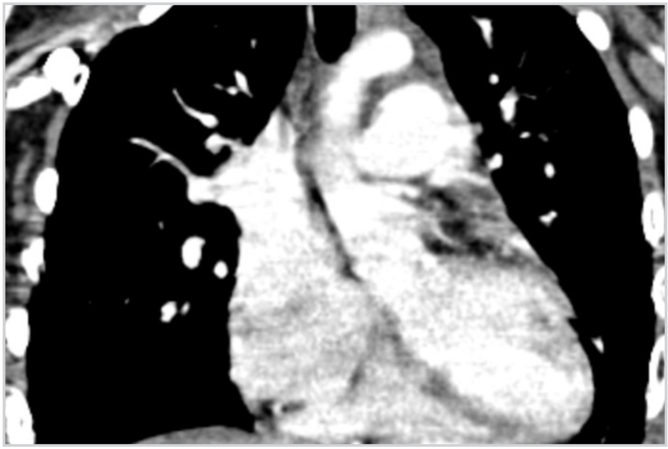


Figure 2.
Frontal CT-section angio-cardiography of the supracardiac form of PAPVD. The arrow shows the in flow of the right pulmonary veins into the SVC

A

B

C

Figure 3.
Computerized cardiography:
A – CT image of the thorax with the installed flow-vacuum system in axial view at the level of the aortic root.
B – CT image of the thorax with a flow-vacuum system installed in the sagittal projection at the level of the ascending aorta.
C – CT image of the thorax with a flow-vacuum system installed in the frontal projection at the level of the ascending aorta

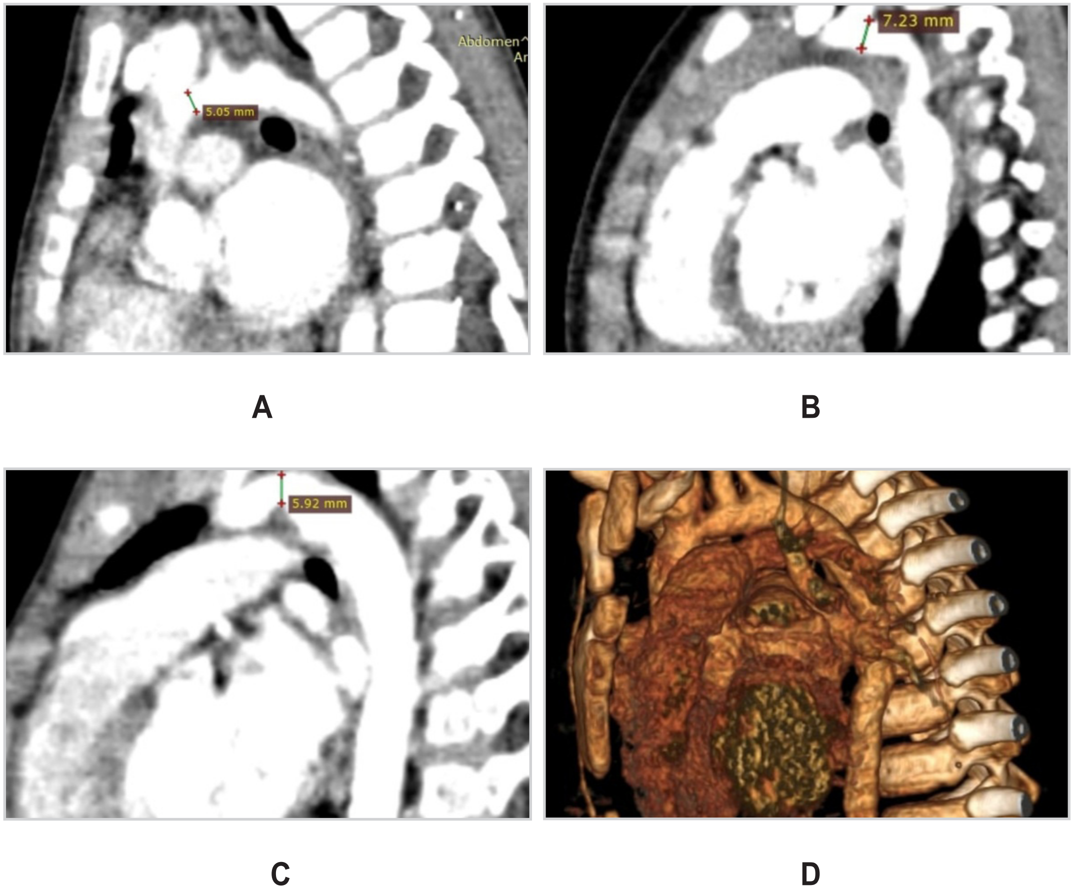


Figure 4.
Computer angiography:
A – Hypoplastic aortic arch in the segment C.
B – Hypoplastic aortic arch in the segment A.
C – Hypoplastic aortic arch in the segment B.
D – Hypoplasia of the aortic arch (3D reconstruction)

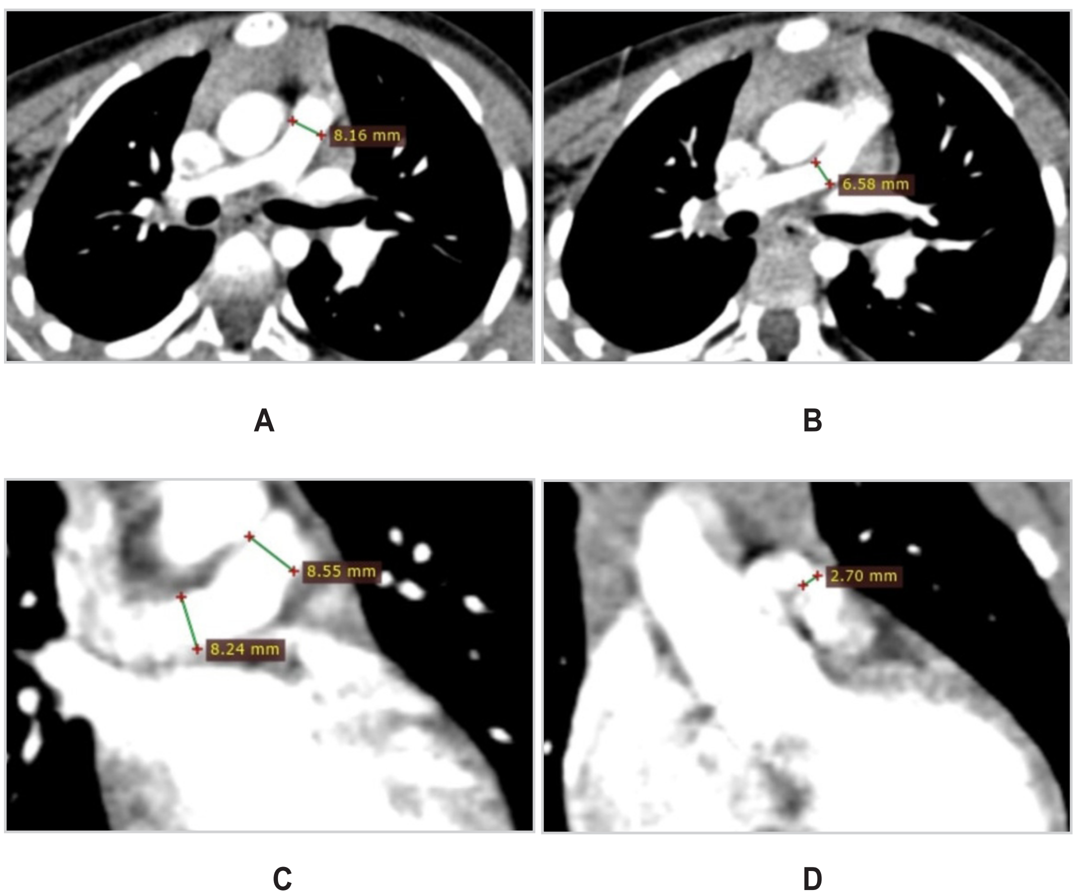
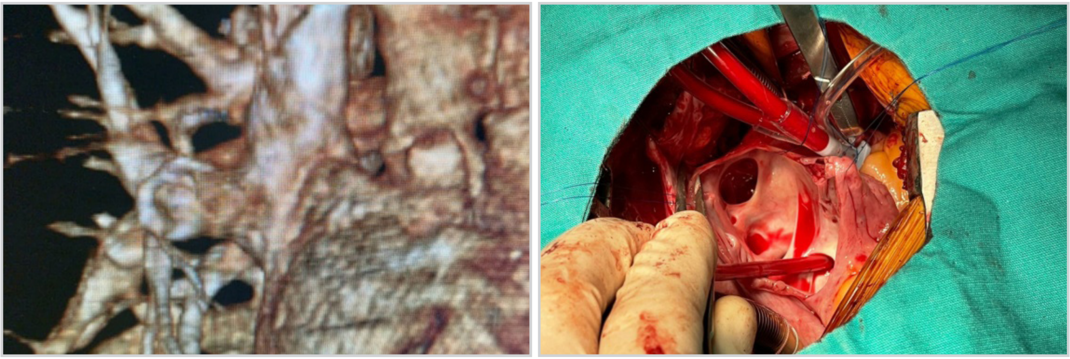


Figure 5.
Computerized cardiography Tetralogy of Fallot:
A –Hypoplastic pulmonary artery trunk.
B – Hypoplastic left pulmonary artery branch.
C – Pulmonary arteries at the bifurcation level.
D – Valvular stenosis of the pulmonary artery



A B

Figure 6.
Partial abnormal drainage of pulmonary veins:
A – Intraoperative photo.
B – 3D reconstruction

Discussion

Today this method has high resolution and allows to obtain qualitative information on the state of vessels of large vascular regions in arterial, parenchymatous and venous phases, as well as to assess the condition of the vessel wall (Nevsky G, Jacobs J.E. et al., 2011). The use of aortic CT techniques over the last 10 years has allowed, on the one hand, to expand the informative value of the obtained data, on the other hand, to radically reduce the number of invasive diagnostic methods required for decision-making on the volume of surgical intervention (Hoang JK et al., 2009; Vrtiska TJ et al., 2010; Hoey ED, 2010).

Modern approaches to the imaging diagnosis of CHD in all age groups are presented. The role of CT-angiography with intravenous contrast in the diagnosis of congenital, acquired cardiovascular and thoracic pathology is shown. A qualitative assessment of CT-angiographic pattern of CHD was performed. CT cardiography is necessary, especially to assess extracardiac anatomy or specific vascular connections or relationships, which can be complex in postoperative patients. Advances in the diagnosis and treatment of patients with CHD have led to improved survival and outcomes. Many patients require lifelong follow-up to monitor the effects of cardiac surgery or catheter interventions, as well as the development of complications. Noninvasive cardiac imaging plays a key role in the diagnosis and follow-up of such patients [2, 3, 4]. In complex congenital heart disease, defining the anatomy and using CT images as needed for three-dimensional modeling helps optimal surgical planning [5].

Cardiac CT completes the standard initial evaluation of infants with complex congenital heart pathology, providing a complete picture of the complex spatial relationships between anatomical and defective structures and is achievable with minimal radiation exposure.

MRI and CT scan play an important role in the examination of children with CHD when echocardiography is insufficient for surgical planning or postoperative follow-up [6, 7, 8, 9, 10]. The calculated effective dose of irradiation was calculated using conversion coefficient. The mean effective radiation dose for CT cardiography was 0.6 mSv. Cardiac CT in infants can be performed with a dose of less than 0.3 mSv. Cardiac CT completes the standard initial assessment of infants with CHD, providing a complete picture of the complex spatial relationships between anatomical and defective structures and is achievable with minimal radiation exposure. As our own experience of CT-angiography application in examination with CHD shows, in contrast to traditional techniques, this method in most cases provides more valuable diagnostic information, which determines its significance in the examination. It is about detailed anatomy of malformation, reliable morphometric indices, diagnosis of pathology of aorta, pulmonary artery, right ventricle, including pathology of its outflow tract, to assess ventricular-artery connections and atrial-ventricular connections.

Conclusions

Our experience with CT cardiography in the examination of patients with CHD, in contrast to traditional ultrasound and invasive techniques, in most cases allows to obtain more valuable diagnostic information, especially extracardiac structures, which determines its significance in the examination of CHD. It details anatomy of malformations in reliable morphometric indices, diagnosis of aortic, pulmonary artery, right ventricle pathology, including pathology of its outlet, to assess ventricular-artery connections and atrial-ventricular connections. Another convenient advantage of CT is the comprehensive coverage of all thoracic cavity organ complexes at one time, allowing a parallel diagnosis of thoracic and mediastinal organs.

The use of the “segmental approach” at all stages of chest and cardiac CT in patients with CHD fully meets the increased requirements for accurate preoperative diagnosis of all anatomical details of any heart defect, providing important systematic information on the heart structure and associated anomalies necessary for planning surgical treatment.

The combination of any of CT methods with catheter angiography increases the result up to 97%, and the combination of any of CT methods with echocardiography and catheter angiography up to 98%. The practical value of CT cardiography consists in: simultaneous evaluation of heart and bronchopulmonary pathology, possibility of examination of patients in severe or critical condition, diagnosis of vascular anomalies, dynamic monitoring in the early postoperative period, evaluation of microcalcinosis of patches and conduits in the remote follow-up after surgery.

A clear formulation of the clinical task determines the choice of the optimal algorithm for CT diagnostics of CHD, taking into account both anatomical and physiological features of the patient and possible accompanying extracardiac pathology, allowing to obtain all necessary information without unnecessary duplication of results, minimize the volume of catheter angiography, and in 67% of cases, to refuse to perform it at all.

References

1. Sachdeva R, Valente A, Armstrong A, et al. ACC/AHA/ASE/HRS/ISACHD/SCAI/SCCT/SCMR/SOPE 2020 Appropriate Use Criteria for Multimodality Imaging During the Follow-Up Care of Patients With Congenital Heart Disease. J Am CollCardiol. 2020 Feb, 75 (6) 657–703.https://doi.org/10.1016/j.jacc.2019.10.002.
2. Marelli A.J., Ionescu-Ittu R., Mackie A.S., et al. «Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010». Circulation 2014;130:749-756.
3. Gilboa S.M., Devine O.J., Kucik J.E., et al. «Congenital heart defects in the United States: estimating the magnitude of the affected population in 2010». Circulation 2016;134:101-109.
4. Warnes C.A. «The adult with congenital heart disease: born to be bad?»J Am CollCardiol2005;46:1-8.
5. Dodge-Khatami J, Adebo DA. Evaluation of complex congenital heart disease in infants using low dose cardiac computed tomography. Int J Cardiovasc Imaging. 2021 Apr;37(4):1455-1460. doi: 10.1007/s10554-020-02118-7. Epub 2021 Jan 3. PMID: 33392877.
6. Ramirez-Suarez KI, Tierradentro-García LO, Otero HJ, Rapp JB, White AM, Partington SL, Harris MA, Vatsky SA, Whitehead KK, Fogel MA, Biko DM. Optimizing neonatal cardiac imaging (magnetic resonance/computed tomography). PediatrRadiol. 2022 Apr;52(4):661-675. doi: 10.1007/s00247-021-05201-w. Epub 2021 Oct 17. PMID: 34657169.
7. John S, Schoeneberg L, Greenleaf CE, Salazar JD, Adebo DA. Pre- and post-operative cardiovascular CT in Stage I single ventricle palliation. J CardSurg. 2022 Feb;37(2):322-328. doi: 10.1111/jocs.16162. Epub 2021 Nov 29. PMID: 34845746.
8. Schindler P, Kehl HG, Wildgruber M, Heindel W, Schülke C. Cardiac CT in the Preoperative Diagnostics of Neonates with Congenital Heart Disease: Radiation Dose Optimization by Omitting Test Bolus or Bolus Tracking. AcadRadiol. 2020 May;27(5):e102-e108. doi: 10.1016/j.acra.2019.07.019. Epub 2019 Aug 20. PMID: 31444109.
9. Han BK, Overman DM, Grant K, Rosenthal K, Rutten-Ramos S, Cook D, Lesser JR. Non-sedated, free breathing cardiac CT for evaluation of complex congenital heart disease in neonates. J Cardiovasc Comput Tomogr. 2013 Nov-Dec;7(6):354-60. doi: 10.1016/j.jcct.2013.11.006. Epub 2013 Nov 7. PMID: 24331930.
10. Goitein O, Salem Y, Jacobson J, Goitein D, Mishali D, Hamdan A, Kuperstein R, Di Segni E, Konen E. The role of cardiac computed tomography in infants with congenital heart disease. IsrMedAssoc J. 2014 Mar;16(3):147-52. PMID: 24761701.