



**Universiteit
Leiden**
The Netherlands

The Leiden Convention coronary coding system: translation from the surgical to the universal view

Koppel, C.J.; Vliegen, H.W.; Bokenkamp, R.; Harkel, A.D.J. ten; Kies, P.; Egorova, A.D.; ... ; Jongbloed, M.R.M.

Citation

Koppel, C. J., Vliegen, H. W., Bokenkamp, R., Harkel, A. D. J. ten, Kies, P., Egorova, A. D., ... Jongbloed, M. R. M. (2021). The Leiden Convention coronary coding system: translation from the surgical to the universal view. *European Heart Journal - Cardiovascular Imaging*, 23(3), 412-422. doi:10.1093/ehjci/jeab012

Version: Publisher's Version

License: [Creative Commons CC BY-NC 4.0 license](#)

Downloaded from: <https://hdl.handle.net/1887/3276113>

Note: To cite this publication please use the final published version (if applicable).

The Leiden Convention coronary coding system: translation from the surgical to the universal view

Claire J. Koppel ¹, Hubert W. Vliegen¹, Regina Bökenkamp²,
A. Derk Jan ten Harkel², Philippine Kiès¹, Anastasia D. Egorova¹,
J. Wouter Jukema¹, Mark G. Hazekamp³, Martin J. Schalij¹,
Adriana C. Gittenberger-de Groot¹, and Monique R.M. Jongbloed^{1,4*}

¹Department of Cardiology, Leiden University Medical Center, Albinusdreef 2, PO Box 9600, Postal zone B-04-P, 2300 RC Leiden, The Netherlands; ²Department of Pediatric Cardiology, Leiden University Medical Center, Albinusdreef 2, PO Box 9600, Postal zone J-6-S, 2300 RC Leiden, The Netherlands; ³Department of Cardiothoracic Surgery, Leiden University Medical Center, Albinusdreef 2, PO Box 9600, Postal zone K-06-S, 2300 RC Leiden, The Netherlands; and ⁴Department of Anatomy and Embryology, Leiden University Medical Center, Einthovenweg 20, PO Box 9600, Postal zone: S-1-P, 2300 RC Leiden, The Netherlands

Received 22 October 2020; editorial decision 12 January 2021; accepted 21 January 2021; online publish-ahead-of-print 15 February 2021

Aims

The Leiden Convention coronary coding system structures the large variety of coronary anatomical patterns; isolated and in congenital heart disease. It is widely used by surgeons but not by cardiologists as the system uses a surgeons' cranial view. Since thoracic surgeons and cardiologists work closely together, a coronary coding system practical for both disciplines is mandatory. To this purpose, the 'surgical' coronary coding system was adapted to an 'imaging' system, extending its applicability to different cardiac imaging techniques.

Methods and results

The physician takes place in the non-facing sinus of the aortic valve, oriented with the back towards the pulmonary valve, looking outward from the sinus. From this position, the right-hand sinus is sinus 1, and the left-hand sinus is sinus 2. Next, a clockwise rotation is adopted starting at sinus 1 and the encountered coronary branches described. Annotation of the normal anatomical pattern is 1R-2LCx, corresponding to the 'surgical' coding system. The 'imaging' coding system was made applicable for Computed Tomography (CT), Magnetic Resonance Imaging (MRI), echocardiography, and coronary angiography, thus facilitating interdisciplinary use. To assess applicability in daily clinical practice, images from different imaging modalities were annotated by cardiologists and cardiology residents and results scored. The average score upon evaluation was 87.5%, with the highest scores for CT and MRI images (average 90%).

Conclusion

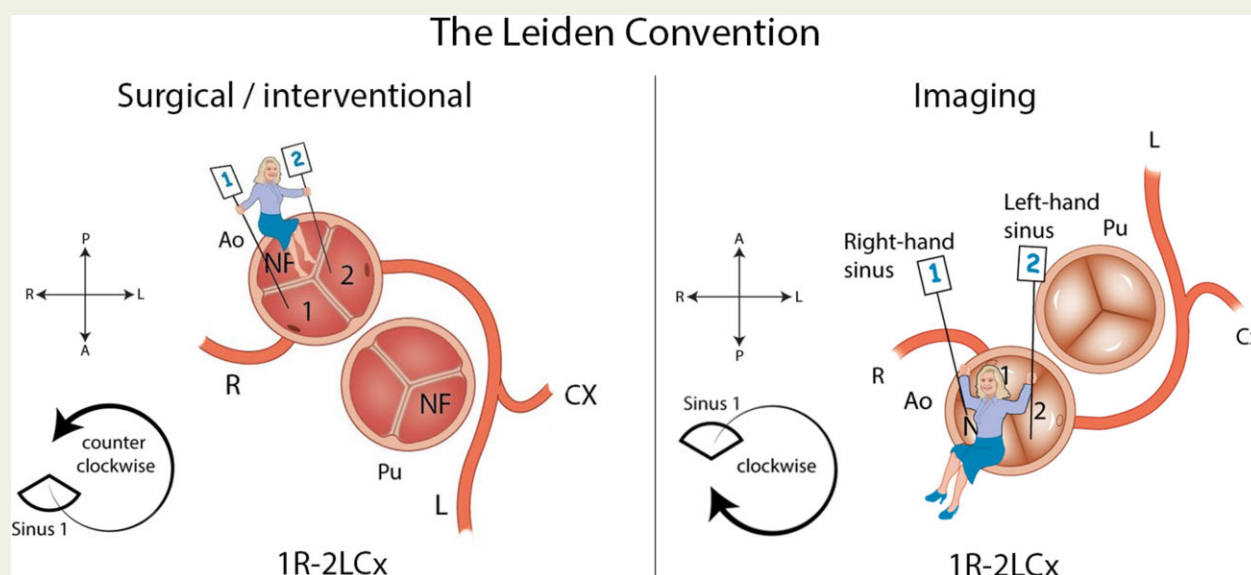
The imaging Leiden Convention is a coronary coding system that unifies the annotation of coronary anatomy for thoracic surgeons, cardiologists, and radiologists. Validation of the coding system shows it can be easily and reliably applied in clinical practice.

* Corresponding author. Tel: +31 71526 9380. E-mail: m.r.m.jongbloed@lumc.nl

© The Author(s) 2021. Published by Oxford University Press on behalf of the European Society of Cardiology.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact journals.permissions@oup.com

Graphical Abstract



Keywords

• Leiden Convention • coronary anatomy • coronary coding system • cardiac imaging • coronary angiography •

Introduction

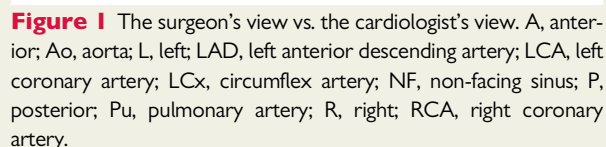
The coronary circulation can have an array of patterns. Where in most cases two orifices give rise to three main coronary arterial branches, more complex patterns, including single sinus coronary arteries, are also encountered. Especially when the great arteries are abnormally aligned, as is the case in different forms of congenital heart disease, e.g. transposition of the great arteries (TGA) and tetralogy of Fallot, it may be challenging to systematically describe the coronary anatomy. Over the past years, several classification systems have been developed to describe the origin and patterning of the coronary arteries.^{1–4} Unfortunately, these methodologies are not applicable irrespective of the position of the great arteries. In 1983, a coding system (dubbed ‘the Leiden Convention’) was designed which is independent of the position of the great arteries, thus rendering it also applicable to hearts with a different relationship of the great arteries relative to each other, such as TGA.^{5,6} In 2018, Gittenberger-de Groot et al.⁷ proposed the ‘modified Leiden Convention’, which also includes the course of the coronary branches around the great arteries. This coding system is applicable to (anomalous) coronary arteries and bicuspid aortic valves (BAV) irrespective of the position of the great arteries. In this way, the coronary anatomy can be uniformly described in all cases, independently of the cardiac anatomy.⁷

Over the past decades, the Leiden Convention has been widely used among surgeons.^{3,8–10} The coding system considers the coronary anatomy from a cranial view, as encountered during cardiac surgery (Figure 1). This is, however, not the view derived from imaging

techniques in use by (paediatric) cardiologists. In both computed tomography (CT) angiography and transthoracic echocardiography (TTE), the preferred tools for delineation of the coronary artery anatomy in (paediatric) cardiology, the physician’s view is from caudal to cranial, and the coronary anatomy is viewed from the base of the aorta upward (Figure 1). Using the modified Leiden Convention (i.e. from a surgical point of view, Figure 2, left panels) for CT or TTE may result in inadequate anatomical descriptions.^{10,11}

Correct diagnosis of the coronary anatomy is especially important prior to surgery in patients with congenital heart disease to facilitate the identification of patients at high-risk for surgery. In adults, a CT scan is preferred to magnetic resonance imaging (MRI) or TTE because of better spatial resolution.^{12–14} Another advantage of CT is that the results are operator-independent.¹¹ In paediatric cardiology, TTE (using the parasternal short axis) is more often used to visualize the coronary anatomy. Children often have better echocardiographic windows than adults and TTE has the additional advantage of no radiation exposure, in contrast to CT scanning.¹⁴ Coronary artery anomalies after arterial switch operation are encountered frequently after surgery¹⁵ justifying repeated imaging with CT-angiography and TTE for follow-up by (paediatric) cardiologists after surgery.^{16,17}

Since cardiac surgeons and cardiologists work closely together, it is important that they can use the same coding system when describing coronary anatomy. The feasibility for clinical use of a coronary coding system is largely determined by whether or not the coronary anatomy can be uniformly noted and easily preterd. Here, we present the ‘imaging Leiden Convention’ (Figure 2, right panels), a coding system designed for uniform use in CT scans, MRI scans, and the TTE



Methods and results

An important aspect of the surgical Leiden Convention is the terminology of the aortic sinuses. Rather than indicated as left coronary sinus, right coronary sinus, and non-coronary sinus according to the coronary artery originating from it, an unambiguous classification was made.⁷ In this way, the ambiguity that arises in case of malposition of the great arteries is avoided. In all hearts, as a general rule, two of the aortic sinuses face the pulmonary valve and one does not. The sinus that does not face the pulmonary valve is accordingly named 'non-facing sinus'. The annotation of the coronary arteries is carried out in three simple steps (*Figure 2*, left panels). In Step 1, the physician takes place in the non-facing sinus, looking towards the pulmonary valve. In

Translation to the imaging Leiden Convention

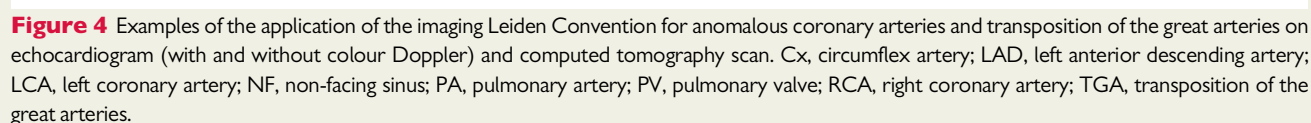
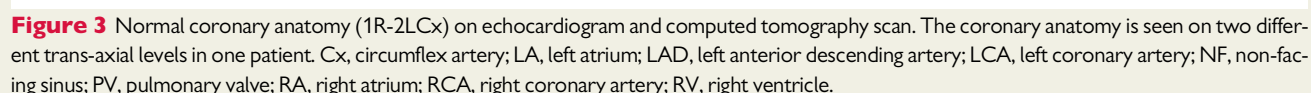
The imaging Leiden Convention for CT, MRI, and TTE

Application of the coronary coding system

Figure 3 shows the results of applying the imaging Leiden Convention to TTE and CT images.



To correctly describe an interarterial, pre-pulmonary, retro-aortic, or intra-septal course in Step 3 or as additional characteristic, the 'dot and eye method' from Serota *et al.*¹⁹ can be used. Examples of coronary anomalies are shown for normally related great arteries in *Figure 7*. A vessel seen 'on end' during CAG will appear as a 'dot'. This is the case in the non-angulated RAO 30° view of an interarterial RCA (*Figure 7A*) and a retro-aortic or



coronary artery course can be determined. For example, when the LCA forms the inferior part and the LCx the superior part, the left main stem originating from sinus 1 courses intra-septal (Figure 7C).

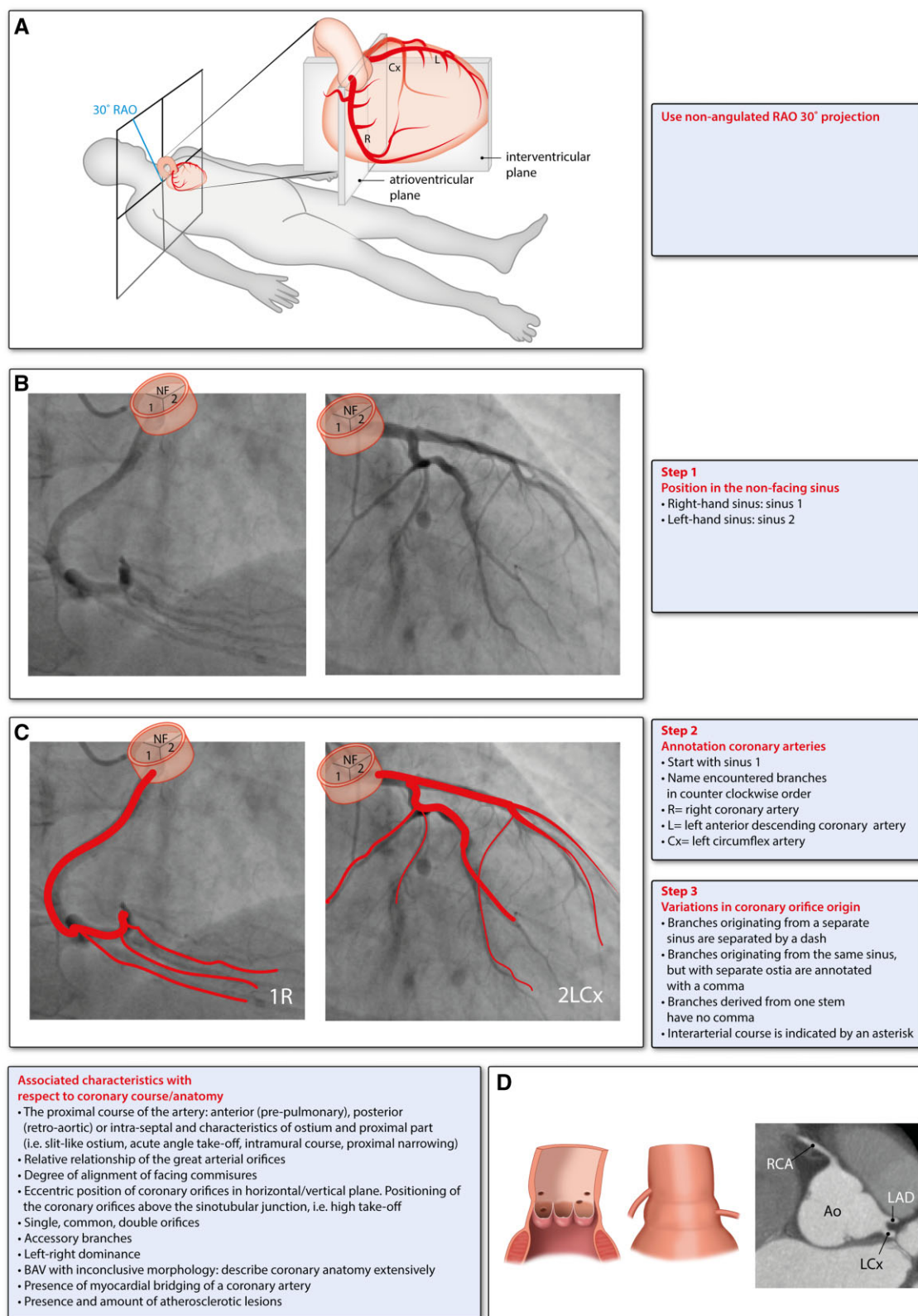
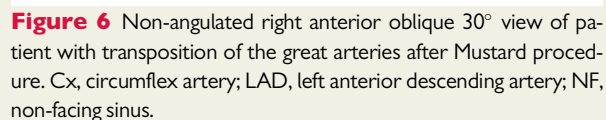


Figure 5 The surgical Leiden Convention for coronary angiography. Ao, aorta; BAV, bicuspid aortic valve; LAD, left anterior descending artery; LCx, circumflex artery; RAO, right anterior oblique; RCA, right coronary artery; NF, non-facing sinus. The bottom panels are derived and modified with permission from Gittenberger-de Groot et al.⁷



Description of associated characteristics with respect to coronary course and anatomy

- (1) The proximal course of the artery: anterior (pre-pulmonary), posterior (retro-aortic), or intra-septal. An interarterial course is already specified in Step 3 by an asterisk. In case of an interarterial

- (2) Additional information on the proximal course of the coronary artery, i.e. shape of the coronary orifice, acute angle take-off, intramural course, and proximal narrowing. This information is especially important for arteries that follow an interarterial course, as this has implications for the risk of sudden cardiac death.^{12–14} Definitions for the shape of the coronary orifice are provided by the Texas Children's Hospital: round (anterior–posterior diameter is the same as the transverse diameter), oval (transverse diameter is 50–90% of anterior–posterior diameter), and slit-like (transverse diameter is <50% of anterior–posterior diameter).²⁰
- (3) Eccentric position of coronary orifices within the sinus and positioning of the coronary orifices relative to the sinotubular junction, i.e. high take-off. For a more detailed description of these characteristics, the topography map from the Texas Children's Hospital can be used.²¹
- (4) Presence of single, common, or double orifices (this can also be derived from the annotation, from the presence, or absence of the comma).
- (5) Presence of accessory branches originating from the coronary sinuses, this includes the sinoatrial node branch and a potential conus artery.
- (6) Coronary artery system dominance: right, left, or co-dominant system.
- (7) Presence of myocardial bridging of a coronary artery.
- (8) Presence and degree of atherosclerotic lesions.
- (9) The position of the great arteries relative to each other and the alignment of the facing commissures. This is important in an arterial switch procedure to determine the site of relocation of the buttons of the new coronary orifices.

Separate attention needs to be paid to BAV (Figure 8). Three main morphological BAV types can be distinguished based on which leaflets are conjoined: (i) Type 1 in which the leaflets of sinus 1 and 2 are conjoined; (ii) Type 2 in which the leaflets of sinus 1 and the non-facing sinus are conjoined; and (iii) Type 3 in which the leaflets of sinus 2 and the non-facing sinus are conjoined. The types can be further subdivided in types with and without a raphe (the latter referred to as 'strictly bicuspid').

In case the type of BAV cannot be determined, a descriptive approach is advised.

To assess practical applicability and feasibility in clinical practice of the imaging Leiden Convention, the coding system was tested using images of the various imaging modalities. Two congenital cardiologists and four cardiology residents assessed CT and MRI images. Two

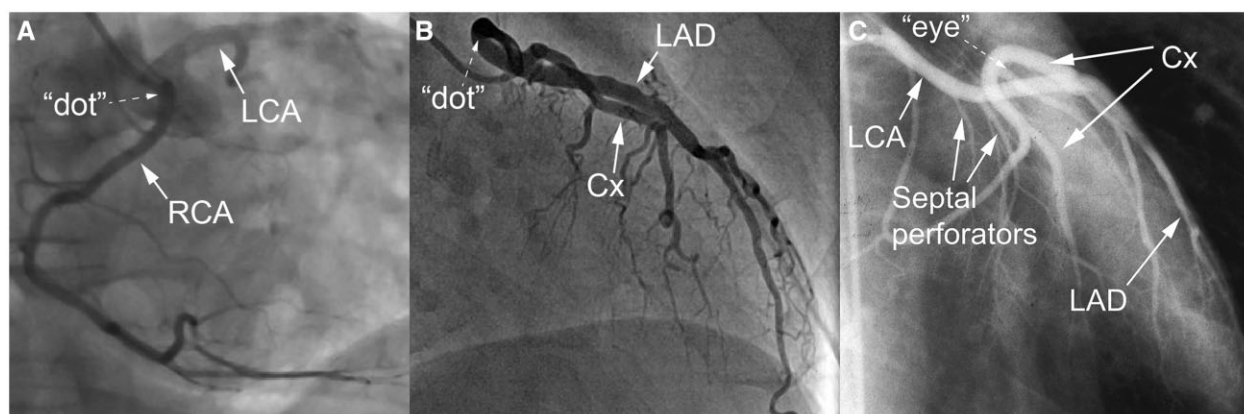


Figure 7 (A) RCA from sinus 2 with interarterial course. Note more intense contrast proximally, because vessel is seen on end ('dot'). (B) LCA from sinus 1 with interarterial course (RCA not visualized). Note more intense contrast proximally, because vessel is seen on end ('dot'). (C) LCA from sinus 1 with septal course (RCA not visualized). Cx, circumflex artery; LAD, left anterior descending artery; LCA, left coronary artery; RCA, right coronary artery. Images derived and modified with permission from Vliegen et al.¹⁸

Table 1 Assistance table for translating the coronary angiography images to a description according to the Leiden Convention, Dot = vessel seen 'on end', eye = LCA or LAD and LCx form an ellipse^{18,19}

Anomalous coronary artery	Course	Appearance
<u>RCA from sinus 2</u>		
Anterior	Anterior to pulmonary artery	Coursing slightly forward, then turning backwards to atrioventricular groove
2R _o /LCx		
Posterior	Posterior to aorta	'Dot', turning around the aorta in the direction of the spine
2LCx _o /R		Very uncommon variation
Interarterial	Between aorta and pulmonary artery	'Dot', seen in proximal course of RCA (Figure 7A)
2R _o */LCx	At, below or above level of pulmonary valve	
<u>LCA/LAD from sinus 1</u>		
Anterior	Anterior to pulmonary artery	'Eye' configuration with LCx in atrioventricular groove
1R _o /LCx		
1R _o /L-2Cx		
Posterior	Posterior to aorta	'Dot', originating close to RCA and turning posterior to aorta
1LCx _o /R		
Interarterial	Between aorta and pulmonary artery	'Dot', seen in proximal course of LCA (Figure 7B)
1R _o /LCx*	At, below or above level of pulmonary valve	
1R _o /L*-2Cx		
Intra-septal	Through inter-ventricular septum	'Hammock' appearance of left main stem, 'eye' formed by LCx and left main stem, 1st septal branch arises from proximal left main stem (Figure 7C)
1R _o /LCx		
1R _o /L-2Cx		
<u>LCx from sinus 1</u>		
Posterior	Posterior to aorta	Posterior course with 'dot'
1Cx _o /R-2L		

LAD, left anterior descending artery; LCA, left coronary artery; LCx, circumflex artery; RCA, right coronary artery.

paediatric cardiologists and two cardiology residents assessed TTE images, and one interventional cardiologists and two cardiology residents assessed CAG images in RAO 30° view. All physicians received a brief explanation of the coronary coding system, followed by one

exercise case, after which the physicians were asked to score 5 or 6 images according to the Leiden Convention coding system. Figures 2 and 5 and Table 1 were provided as instruction manuals for assessing the images.

Test results

The average score on all three modalities was 87.5%. For CT and MRI, average score was 90%. On TTE participants scored an average percentage of 83%, and for CAG 88%. The scores on all imaging modalities were consistently high (Figure 9). Figure 9 also shows the average score per rater per modality and the mean scores per case per modality. Most mistakes were made in Step 3 (67% of all mistakes). Usually, this was the incorrect placement of the comma or forgetting to use the asterisk.

Discussion of applicability and limitations

In this study, we introduce an extrapolation of the Leiden Convention coronary coding system. This system is already widely implemented in surgical practice and has now been modified for use in cardiac imaging techniques. Assessment of the applicability and feasibility of the imaging Leiden Convention shows that it can easily be implemented by colleagues of various experience after uniform short introduction and the results are likely to further improve with an increasing learning curve.

Applicability for CT and MRI

For CT and MRI, the imaging Leiden Convention is practically applicable. There was a clear learning curve: after the first few cases, the results during the test improved with each case, as shown in Figure 9.

Applicability for TTE

For TTE still frames were used. However, all participating cardiologists and residents are used to looking at moving images on TTE and the possibility of searching for the best view. Also, colour Doppler is often used to improve coronary artery visibility which was not available on all images presented. We therefore expect the application of the coding system to be even more feasible in daily practice than it already proved to be in the test. It is advised to use colour Doppler with a low Nyquist limit (e.g. 0.14) to optimize coronary artery visibility. Finding the coronary arteries using echocardiography can be challenging, especially in adults. However, if the coronary arteries are adequately visualized, such as in children, application of the imaging Leiden Convention proved well feasible.

Applicability for CAG

The applicability for CAG was tested on one interventional cardiologist and two cardiology residents. The interventional cardiologist could describe the coronary anatomy based on the RAO 30° view. Due to his experience, he used a 'reversed method' to describe the anatomy according to the Leiden Convention. He recognized the anatomy and anomalies, and then wrote down the correct annotation, scoring a maximum of 100%. In clinical practice, this is how most experienced cardiologists will use the coding system. For the cardiology residents with different amounts of experience with CAG, assessment based on the still frame images alone, proved difficult because of their inexperience with TGA (Cases 4 and 5) and coronary anomalies on CAG. With the assistance of Table 1, description of the coronary anatomy annotation was feasible. It was commented by the participants that moving CAG images and the possibility of looking from different angles

would make using the Leiden Convention easier for CAG, but that in principle the method can be adequately applied. In clinical practice, clinicians will have the availability of moving images to interpret the anatomy, likely rendering its applicability more feasible than during the test cases.

Overall, it can be concluded that the applicability and feasibility of the Leiden Convention in daily practice are high and the methods can be easily mastered.

Limitations

The great advantage of the Leiden Convention coronary coding system lies in the applicability in different forms of congenital heart disease, as it can be applied irrespective of the position of the great arteries. However, there are a few limitations to the system. The Leiden Convention is not applicable in the absence of a pulmonary artery (i.e. in pulmonary atresia), in truncus arteriosus communis, quadricuspid aortic valves, and in cases where the aortic valve morphology cannot be adequately distinguished. In these anomalies, a descriptive approach is recommended. If a coronary artery arises from the pulmonary artery, the Leiden Convention can be applied to the normally arising artery and description of the coronary artery from the pulmonary artery should be done as an associated characteristic.

Of note, the Leiden Convention coronary coding system is not meant to replace direct contact and discussion between cardiologists and cardiac surgeons. Rather, it is a tool to render communications unambiguous for written reports and to support the discussion whilst reviewing images of patients.

Conclusions

The imaging Leiden Convention is a simple coronary coding system that unifies the annotation of the coronary anatomy for cardiac surgeons, cardiologists, and radiologists. Reviewing the applicability and feasibility of the coding system shows that it can be easily and reliably applied and mastered in clinical practice. It is applicable to CT, MRI, and TTE. For CAG, the surgical Leiden Convention can be applied and also proved to be reliably applicable. Reviewing dynamic images is recommended to facilitate the use of the coding system. The Leiden Convention has the potential to improve the communication between cardiac surgeons and (paediatric) cardiologists by providing in a systematic interdisciplinary coronary artery coding system.

Acknowledgements

We greatly acknowledge Mr. Slagter for drawing the graphical abstract and Figures 1, 2, 5, 6, and 8.

In respectful memory of Adriana C. Gittenberger-de Groot, without whom the Leiden Convention coronary coding system would not have existed.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

Conflict of interest: none declared.

References

- Chiu IS, Wu CS, Wang JK, Wu MH, Chu SH, Hung CR et al. Influence of aortopulmonary rotation on the anomalous coronary artery pattern in tetralogy of Fallot. *Am J Cardiol* 2000;**85**:780–4.a9.
- Chiu IS, Wu S-J, Chen S-J, Wang J-K, Wu M-H, Lue H-C. Sequential diagnosis of coronary arterial anatomy in congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 2003;**75**:422–9.
- Suzuki T. Modification of the arterial switch operation for transposition of the great arteries with complex coronary artery patterns. *Gen Thorac Cardiovasc Surg* 2009;**57**:281–92.
- Sithamparanathan S, Padley SPG, Rubens MB, Gatzoulis MA, Ho SY, Nicol ED. Great vessel and coronary artery anatomy in transposition and other coronary anomalies. *JACC Cardiovasc Imaging* 2013;**6**:624–30.
- Gittenberger-de Groot AC, Sauer U, Oppenheimer-Dekker A, Quaegebeur JM. Coronary arterial anatomy in transposition of the great arteries: a morphologic study. *Pediatr Cardiol* 1983;**4**:15–24.
- Gittenberger-De Groot AC, Bogers AJJC, Bartelings MM. Aspects of normal and abnormal development of the main coronary arteries. In: JAE Spaan, AVG Bruschke, AC Gittenberger-De Groot, eds. *Coronary Circulation: From Basic Mechanisms to Clinical Implications*. Dordrecht: Springer Netherlands; 1987. p32–41.
- Gittenberger-de Groot AC, Koenraadt WMC, Bartelings MM, Bokenkamp R, DeRuiter MC, Hazekamp MG et al. Coding of coronary arterial origin and branching in congenital heart disease: the modified Leiden Convention. *J Thorac Cardiovasc Surg* 2018;**156**:2260–9.
- Al Anani S, Fughhi I, Taqatqa A, Elzein C, Ilbawi MN, Polimenakos AC. Transposition of great arteries with complex coronary artery variants: time-related events following arterial switch operation. *Pediatr Cardiol* 2017;**38**: 513–24.
- Baslaim GM. Is preoperative delineation of coronary artery pattern a prerequisite for arterial switch operation? *J Cardiac Surg* 2006;**21**:465–70.
- Jaggers JJ, Cameron DE, Herlong JR, Ungerleider RM. Congenital heart surgery nomenclature and database project: transposition of the great arteries. *Ann Thorac Surg* 2000;**69**:205–35.
- Goo HW. Identification of coronary artery anatomy on dual-source cardiac computed tomography before arterial switch operation in newborns and young infants: comparison with transthoracic echocardiography. *Pediatr Radiol* 2018;**48**: 176–85.
- Brothers JA, Frommelt MA, Jaquiss RDB, Myerburg RJ, Fraser CD Jr, Tweddell JS. Expert consensus guidelines: anomalous aortic origin of a coronary artery. *J Thorac Cardiovasc Surg* 2017;**153**:1440–57.
- Cheezum MK, Liberthson RR, Shah NR, Villines TC, O'Gara PT, Landzberg MJ et al. Anomalous aortic origin of a coronary artery from the inappropriate sinus of valsalva. *J Am Coll Cardiol* 2017;**69**:1592–608.
- Gräni C, Buechel RR, Kaufmann PA, Kwong RY. Multimodality imaging in individuals with anomalous coronary arteries. *JACC Cardiovasc Imaging* 2017;**10**:471–81.
- Veltman CE, Beeres SLMA, Kalkman DN, Kelder TP, Kiës P, Vliegen HW et al. Variation in coronary anatomy in adult patients late after arterial switch operation: a computed tomography coronary angiography study. *Ann Thorac Surg* 2013;**96**:1390–7.
- Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM et al. 2018 AHA/ACC guideline for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 2019;**139**: e698–e800.
- Baumgartner H, De Backer J, Babu-Narayan SV, Budts W, Chessa M, Diller G-P et al. 2020 ESC guidelines for the management of adult congenital heart disease: the task force for the management of adult congenital heart disease of the European Society of Cardiology (ESC). *Eur Heart J* 2020:1–83.
- Vliegen HW, Jukema JW, Bruschke AVG. Congenital coronary artery anomalies. In: Vliegen HW, Jukema JW, Bruschke AVG, eds. *Congenital Coronary Artery Anomalies, Anatomy, Diagnosis, and Management*. 2nd ed. Leiden: TTMA BV; 2012.
- Serota H, Barth CW, Seuc CA, Vandormael M, Aguirre F, Kern MJ. Rapid identification of the course of anomalous coronary arteries in adults: the "dot and eye" method. *Am J Cardiol* 1990;**65**:891–8.
- Agrawal H, Mery CM, Krishnamurthy R, Molossi S. Anatomic types of anomalous aortic origin of a coronary artery: a pictorial summary. *Congenit Heart Dis* 2017; **12**:603–6.
- Mery CM, Lawrence SM, Krishnamurthy R, Sexson-Tejtel SK, Carberry KE, McKenzie ED et al. Anomalous aortic origin of a coronary artery: toward a standardized approach. *Semin Thorac Cardiovasc Surg* 2014;**26**:110–22.