Kardiologia Polska 2015; 73, 4: 261–266; DOI: 10.5603/KP.a2014.0207 ISSN 0022–9032

ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Shepherd's crook right coronary artery: a multidetector computed tomography coronary angiography study

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Abstract

Background: Shepherd's crook deformity of the right coronary artery (RCA) is considered a haemodynamically non-significant course anomaly. It may be challenging for cardiologists during percutaneous transluminal coronary angioplasty.

Aim: To investigate the radiological anatomy of the high riding course of the proximal segment of the RCA, especially focused on the Shepherd's crook RCA (SCRCA), on multidetector computed tomography (MDCT) coronary angiography.

Methods: A total of 1,118 MDCT coronary angiography examinations were reviewed retrospectively (349 [31.2%] male; 769 [68.8%] female, age range from 18 to 88 years [54.4 ± 14.7 years, mean ± standard deviation]). We classified the segments that had a higher course than RCA ostium (high riding RCA) into two types: type 1 — courses turning inferior with an angle equal to or more than 90 degrees, type 2 (SCRCA) — courses turning inferior with an angle less than 90 degrees. The origin of the sinoatrial node artery (SANA) and conus artery were also noted.

Results: High riding RCA was detected in 146 (13%) patients. Of them, 105 (71%) had type 1 and 41 (29%) had type 2. Atherosclerotic plaque formations, to varying degrees, were presented in 10 (24.3%) of the patients with SCRCA. Approximately half of SANA originated from the SCRCA segment of the RCA in SCRCA cases.

Conclusions: This is the first study about SCRCA that has been performed with MDCT coronary angiography. This study brings important anatomical knowledge to cardiologists. To have knowledge about the origin of the SANA prior to PTCA procedures is important to prevent possible arrhythmias and infarcts.

Key words: coronary disease, multidetector computed tomography coronary angiography, sinoatrial node, catheterisation, angioplasty

Kardiol Pol 2015; 73, 4: 261–266

INTRODUCTION

Shepherd's crook deformity of the right coronary artery (SCRCA) is considered a haemodynamically non-significant course anomaly [1]. In our study, we investigated the diameter, length, angle, and level of SCRCA, which is one of the right coronary artery (RCA)'s proximal segment course anomalies, and these segment's coronary atherosclerosis features in multidetector computed tomography (MDCT) coronary angiography examinations.

Our aim was to investigate the radiological anatomy of the high riding course of the proximal segment of the RCA, especially focused on the SCRCA and possible association with coronary atherosclerosis and origin of the sinoatrial node artery (SANA) and conus artery, on MDCT coronary angiography examinations.

METHODS

A total of 1,260 consecutive MDCT coronary angiography examinations were performed in our department between

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Received: 13.06.2014 **Accepted:** 18.09.2014 **Available as AoP:** 14.10.2014

October 2009 and February 2013, and the images of the patients were reviewed retrospectively to evaluate the course of the proximal segment of the RCA. A total of 142 patients were excluded from the study for the following reasons: coronary calcium scoring (n = 97), presence of metal artefacts such as surgical clips or pacemaker leads (n = 21), electrocardiography (ECG) dysrhythmias (n = 16), and movement artefacts (n = 8).

The institutional ethics committee had approved this retrospective study (No: 2013-12, GATA Haydarpasa Teaching Hospital, Istanbul, Turkey). Written informed consent was obtained from all patients.

Patients

Of 1,118 patients, 349 (31.2%) were male and 769 (68.8%) were female, with ages ranging from 18 to 88 years (54.4 ± 14.7 years, mean ± standard deviation [SD]). The indications for MDCT coronary angiography were: suspected coronary artery disease (n = 985), coronary artery anomaly (n = 46), coronary artery stent patency (n = 30), and coronary artery bypass graft assessment (n = 57). Detection of the proximal segment of the RCAs was performed according to the classification of the American Heart Association [2].

MDCT imaging examinations

The MDCT coronary angiography examinations were performed using a 64-MDCT scanner (Brilliance-64, Phillips Medical Systems, Eindhoven, The Netherlands or LightSpeed VCT, GE Healthcare, Milwaukee, USA). A volume of dataset was acquired from the level of the carina through the diaphragm by using thin collimation and ECG gating. Image acquisition was performed after an intravenous injection of 50–100 mL of 350–400 mgI/mL non-ionic contrast material (either iohexol [Omnipaque 350, GE Healthcare Ireland, Cork, Ireland] or iopromide [Iomeron 400, Bracco, Milano, Italy]) administered at a rate of 5–6 mL/s via a power injector.

Image analysis

The images were reviewed on a three-dimensional workstation equipped with multiplanar and maximum-intensity-projection reformations to visualise the heart along the cardiac axes. We examined the course of the RCA's proximal segment in regard to the ostium of the RCA in coronal views. We accepted the course of proximal RCA segment that is at the same level or lower than the RCA's ostium as the normal course. We classified the segments that have a higher course than the RCA's ostium (high riding RCA) into two types: type 1 — courses turning inferior with an angle equal to or more than 90 degrees (Fig. 1); type 2 — courses turning inferior with an angle less than 90 degrees. We assigned type 2 courses as SCRCA (Fig. 2A, B). We measured the angle between the ascending aorta and SCRCA's proximal segment in the coronal plane (Fig. 3). If we were unable to view the ascending aorta and SCRCA's proximal segment in one image, we used multi-planar reconstruction images. On the axial plane, we measured the angle between the SCRCA and a line drawn tangentially to the ascending aorta at the level of the RCA's ostium (Fig. 4). We set the angle between

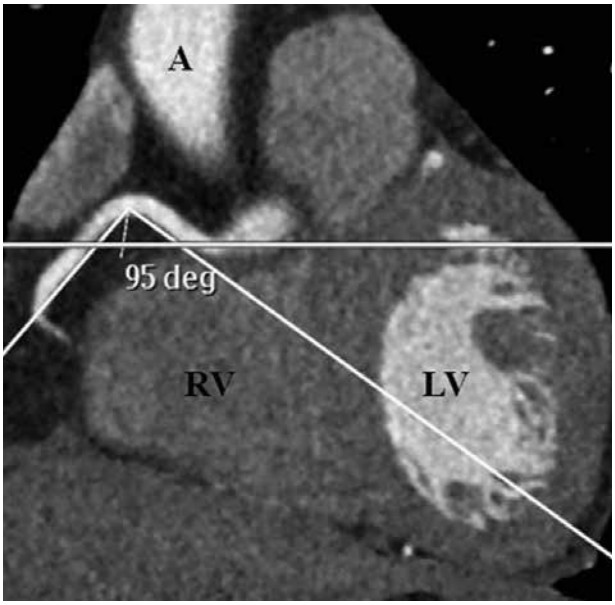

Figure 1. Type 1 high riding right coronary artery (RCA). Oblique coronal multi-planar reconstruction image shows proximal segment of the RCA coursing above the baseline that is drawn parallel to the horizontal axis at the RCA origin. This course was called "high riding RCA". Because the angle was greater than 90 degrees, it was called type 1 high riding RCA; A — aorta; LV — left ventricle; RV — right ventricle

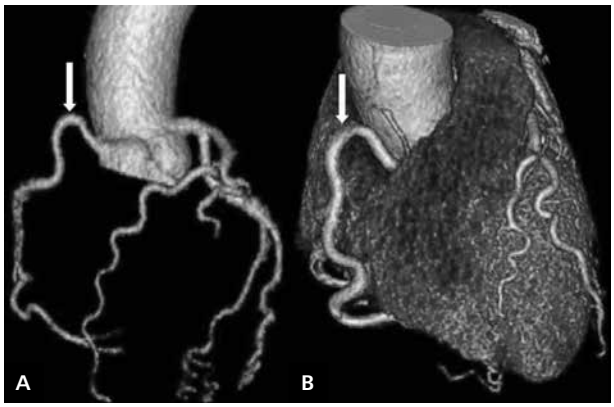

Figure 2. **A**. Three-dimensional, volume-rendered image of the coronary tree shows Shepherd's crook morphology of the proximal right coronary artery (arrow); **B**. Shepherd's crook right coronary artery course adjacent to the right atrium above the atrioventricular groove is well illustrated on volume rendered image (arrow)

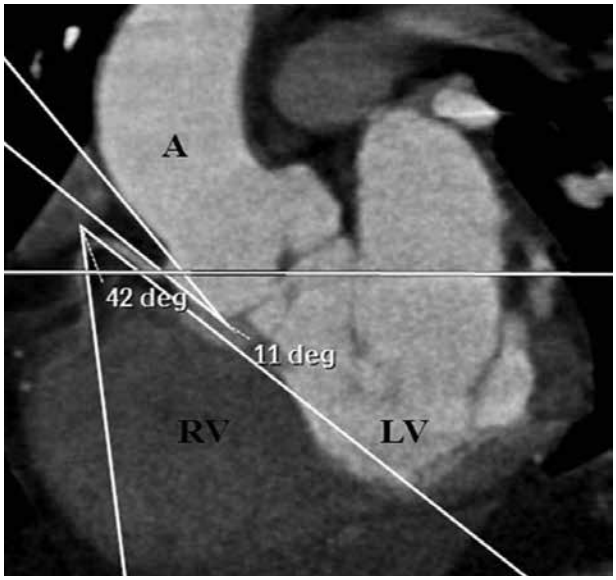

Figure 3. Shepherd's crook angle is measured by drawing two lines that are parallel to the proximal and distal part of the Shepherd's crook right coronary artery (SCRCA). Angle between the ascending aorta and SCRCA on oblique coronal plane is also illustrated; A — aorta; LV — left ventricle; RV — right ventricle

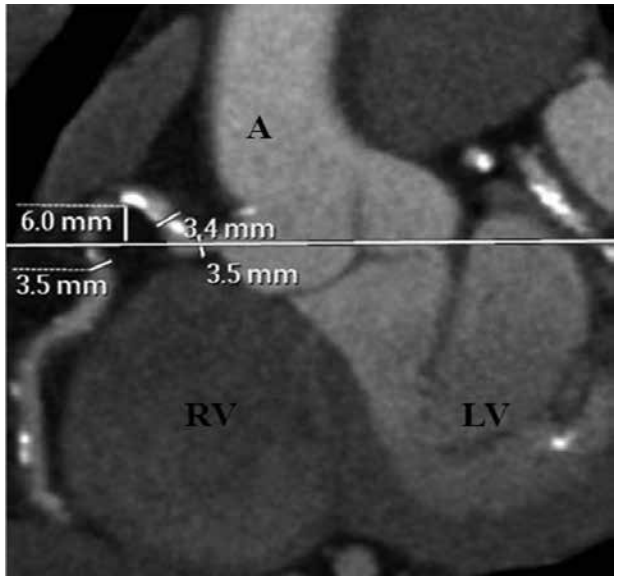

Figure 5. Oblique coronal multi-planar reconstruction image; a Shepherd's crook right coronary artery (RCA) is seen with 3.4 mm proximal diameter and 3.5 mm distal diameter. Proximal RCA prior to the Shepherd's crook segment has a diameter of 3.5 mm. Height of the Shepherd's crook RCA from the baseline drawn parallel to the horizontal axis at the RCA origin is 6 mm. Note also diffuse fibrocalcific plaques along the course of the RCA; A — aorta; LV — left ventricle; RV — right ventricle

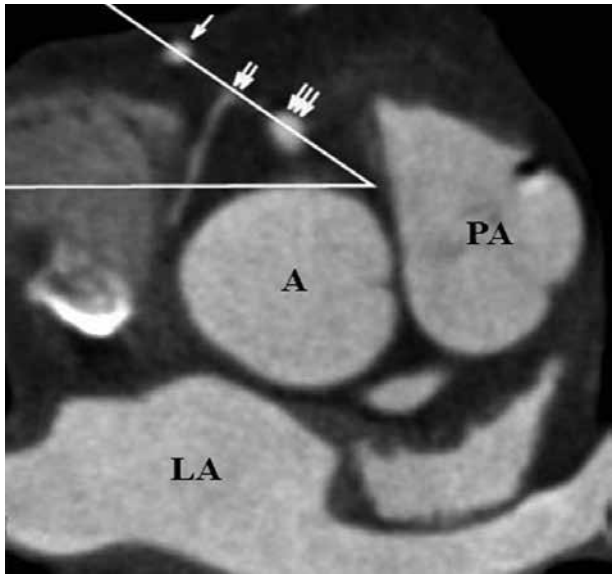

Figure 4. Axial multi-planar reconstruction image; Axial angle between Shepherd's crook segment and ascendant aorta was measured by drawing a line tangentially to the aorta and a line including proximal (triple arrow) and distal (arrow) part of the Shepherd's crook right coronary artery (SCRCA). A sinoatrial node artery arising from the SCRCA is clearly seen (double arrow); A — aorta; LA — left artrium; PA — pulmonary artery

the proximal and distal segments of the SCRCA as the "SCRCA angle" (Fig. 3). We recorded atherosclerotic plaque frequency and morphology, degree of stenosis, and content of plaque causing stenosis at SCRCA. Coronary artery stenosis was defined as follows: mild < 50%, moderate > 50%, and severe > 75% narrowing in luminal diameter. The length and calibration of the SCRCA and calibration of the RCA near the ostium were measured. Then, we examined height of the SCRCA (Fig. 5). We recorded the SCRCA's height as the distance between the RCA's ostium and SCRCA's peak point on coronal views. We measured the SCRCA's diameter at four points: adjacent to the RCA's ostium, proximal, middle, and distal segments. For length measurement we took the distance between the segment upturning sharply and the distal point of the segment coursing inferior. We also examined the origin of the SANA and conus artery in SCRCA patients.

Statistical analysis

Descriptive statistics were used to analyse the data. The relationship between the presence of high riding RCA and coronary atherosclerosis was examined with the χ^2 test. We also analysed the relationship between atherosclerosis and type 1 SCRCA and normal RCA by Spearman's correlation test. Statistical significance was interpreted when p values were below 0.05. All statistical analyses were performed using SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA).

Table 1. Diameter of proximal-middle and distal segments, length of segment, axial angle, coronal angle, crook angle, height, and RCA diameter in patients with SCRCA.

	N	Minimum [mm]	Maximum [mm]	Mean [mm]	SD
RCA diameter	41	2.50	5.40	4.0122	0.74270
SCRCA proximal diameter	41	2.50	6.90	4.0512	0.97394
SCRCA middle diameter	41	2.40	6.90	4.0463	0.96231
SCRCA distal diameter	41	2.20	6.80	3.9537	0.97419
SCRCA length	41	26.00	54.00	37.5122	6.77909
Axial angle	41	23.00	97.00	64.4878	17.46586
Coronal angle	41	–3.00	44.00	13.5854	11.53251
SCRCA angle	41	9.00	68.00	36.1463	17.69401
SCRCA height	41	6.00	52.00	13.0000	7.26980

N — number of patients; RCA — right coronary artery; SCRCA — Shepherd's crook right coronary artery; SD — standard deviation

RESULTS

High riding RCA was detected in 146 (13%) patients from the total of 1,118 patients. Of them, 105 (71%) had type 1 and 41 (29%) had type 2 (SCRCA). Proportion of type 1 in the whole patient group was 9.3% and the SCRCA was 3.6%. Anatomical properties of the SCRCA patients are listed in Table 1. Varying degrees of atherosclerotic plaque formations were present in 279 of 1,118 (24%) patients. The relationship between the presence of high riding RCA and coronary atherosclerosis was examined with the χ^2 test. No statistically significant relation was detected between these two parameters ($p = 0.465$).

The mean age of the 105 patients with type 1 was 61.2 ± 11.3 years (mean ± SD; range 35–84 years). Fifty-eight (55.2%) of these patients were male and 47 (44.8%) were female. Varying degrees of atherosclerotic plaque formations were seen in 31 (29.5%) patients.

The mean age of the 41 patients with SCRCA was 63 ± 12.8 years (mean ± SD; range 30–88 years). Of these patients, 18 (42.9%) were male and 23 (54.8%) were female. Paired samples test was used to find differences between the ages of the type 1 and SCRCA patients. There was not a statistically significant difference in ages between type 1 and SCRCA patients ($p = 0.728$). Varying degrees of atherosclerotic plaque formations were seen in 10 (24.3%) patients.

Incidences of atherosclerotic disease were similar between high riding RCA and RCA with normal course patients, and a statistically significant difference was not detected ($p = 0.486$).

Of the patients with SCRCA, 31 (75%) were normal calibre, 5 (12%) had mild stenosis, 4 (9%) had moderate stenosis, and 1 (2%) had severe stenosis. Furthermore, of the 10 patients with atherosclerotic disease, 9 (90%) were fibrocalcific and 1 (10%) was calcified. Of the patients with type 1, 74 (70,4%) were normal calibre, 17 (16.1%) had mild stenosis, 6 (5.7%) had moderate stenosis, 7 (6.7%) had severe stenosis, and 1 (0.9%) had occlusion. Of the 31 patients with atherosclerosis, 22 (70.9%) had fibrocalcific plaque and 9 (29%) had calcified plaque.

The origin of the SANA in the patients with SCRCA was: 14 (34.1%) from circumflex artery (LCx), six (14.6%) from RCA, 20 (48.7%) from SCRCA (Fig. 4), and one (2.4%) from both LCx and SCRCA. In SCRCA, SANA originated most frequently from the SCRCA segment of the RCA.

The origin of the conus artery in the patients with SCRCA was as follows: 14 (34.1%) from aorta, 18 (43.9%) from RCA, and nine (21.9%) from SCRCA. In this type, the conus artery originated most frequently from the RCA.

The mean length of RCA segment before SCRCA was 5.26 ± 3.2 mm (mean ± SD; range 0–18 mm).

DISCUSSION

Shepherd's crook deformity of the RCA is a dramatic upturn with a near-180° switchback turn. It is a haemodynamically non-significant course anomaly [1]. In this study, we aimed to investigate the radiological anatomy of the high riding course of the proximal segment of the RCA, especially focused on the SCRCA in MDCT coronary angiography examinations.

MDCT coronary angiography is an excellent noninvasive diagnostic tool for coronary artery evaluation [3, 4]. Moreover, it can demonstrate the small arteries in detail, such as the SANA and conus artery [5]. According to a study in which coronary artery angiography was performed in 1,041 patients, the frequency of SCRCA was 4.9% [6]. As far as we know, there is no MDCT coronary angiography study in the literature. According to our results, SCRCA was seen in 41 of

1,118 patients and the frequency was 3.6%. Compared to coronary artery angiography results, we come across this course anomaly in MDCT coronary angiography examinations less frequently. However, we think that our results could reflect the population better, since MDCT coronary angiography is performed in more patients and for more indications. The aetiology of SCRCA is unknown. In our study, the incidence of atherosclerotic disease was similar in patients with and without SCRCA. There was no statistically significant difference detected; however, we frequently detected SCRCA in elderly patients (mean age 63 ± 12.8 years [mean ± SD; range 30–88 years]). So, it seems that it is not a congenital variation, and it probably occurs secondarily to the age-related degenerative processes. The relation between course anomaly and atherosclerosis frequency was not investigated in literature before, and according to our results there is not any significant correlation between them.

RCA proximal segment is an origin site for the SANA and conus artery in some cases. Transient and permanent occlusions of these arteries with balloons and stents during percutaneous transluminal coronary angioplasty in these cases may cause arrhythmias and infarcts. Therefore, it is important to be aware of the origin of these arteries. In our study, approximately half of SANA originated from the SCRCA segment of the RCA in SCRCA cases. However, we experienced no such relationship for the conus artery, and it predominantly originated from the proximal horizontal segment of the RCA.

Limitations of the study

Our study had several limitations. Firstly, our cases were identified by a retrospective review of the images from MDCT coronary angiographic studies, so we did not know whether the asymptomatic population had SCRCA and we had no data about their coronary artery angiography. Thus, our prevalence does not reflect the general population ratio. Secondly, the software was unavailable to perform prospective imaging; therefore, we used retrospective imaging for MDCT coronary angiography. This kind of imaging method increases the radiation doses received by the patients. Thirdly, we performed the study in an adult group and did not have any paediatric patients. Fourthly, MDCT coronary angiography was the only diagnostic tool, and invasive coronary artery angiography data were not available. A comparison could not be made between these modalities. Finally, several measurements were only performed in the group of patients with SCRCA. It would be of interest to make a comparison between patients with SCRCA and without SCRCA.

CONCLUSIONS

In our study, the incidence of SCRCA is similar to that found in the literature. There was no significant relation or correlation between atherosclerosis and type 1 and SCRCA course. Approximately half of SANA originated from the SCRCA segment of the RCA in SCRCA cases. So, to have three-dimensional images and knowledge about the origin and course of the SANA prior to percutaneous transluminal coronary angioplasty procedures may help to prevent possible arrhythmias and infarcts.

Conflict of interest: *none declared*

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Deformacja prawej tętnicy wieńcowej: angiografia wieńcowa metodą wielorzędowej tomografii komputerowej

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Streszczenie

Wstęp: Deformacja prawej tętnicy wieńcowej (RCA) w kształcie laski pasterza jest uważana za anomalię nieistotną hemodynamicznie. Jednak może ona stanowić problem dla kardiologa w trakcie przeprowadzania przezskórnej śródnaczyniowej angioplastyki wieńcowej.

Cel: Badanie przeprowadzono w celu radiologicznej oceny anatomicznej przebiegającego wysoko proksymalnego segmentu RCA, ze szczególnym uwzględnieniem deformacji RCA w kształcie laski pasterza (SCRCA, *Shepherd's crook right coronary artery*), za pomocą angiografii wieńcowej metodą wielorzędowej tomografii komputerowej (MDCT).

Metody: Oceniono retrospektywnie 1118 obrazów angiografii wieńcowej MDCT [349 (31,2%) mężczyzn; 769 (68,8%) kobiet, w wieku 18–88 lat (średnia ± odchylenie standardowe: 54,4 ± 14,7 roku)]. Segmenty przebiegające powyżej ujścia RCA (RCA przebiegająca wysoko) podzielono na dwie kategorie: typ 1 — tętnica zagina się ku dołowi pod kątem wynoszącym 90° lub więcej, typ 2 (SCRCA) — tętnica zagina się ku dołowi pod kątem wynoszącym mniej niż 90°. Odnotowano również odejście tętnicy zaopatrujący węzeł zatokowo-przedsionkowy (SANA, *sinoatrial node artery*) i tętnicy stożka.

Wyniki: Przebiegającą wysoko RCA stwierdzono u 146 (13%) chorych. Spośród nich u 105 (71%) występował typ 1, a u 41 (29%) typ 2. Blaszki miażdżycowe w różnym stopniu zaawansowania wykryto u 10 (24,3%) osób z SCRCA. U około połowy pacjentów SANA odchodziła od segmentu SCRCA prawej tętnicy wieńcowej (typ 2).

Wnioski: Jest to pierwsze badanie dotyczące SCRCA przeprowadzone z wykorzystaniem angiografii wieńcowej MDCT. W badaniu tym uzyskano informacje anatomiczne mające ważne znaczenie dla kardiologów. Wiedza na temat miejsca odejścia SANA przed zabiegami przezskórnej śródnaczyniowej angioplastyki wieńcowej pomaga zapobiegać wystąpieniu arytmii i zawału serca.

Słowa kluczowe: choroba wieńcowa, angiografia wieńcowa metodą wielorzędowej tomografii komputerowej, węzeł zatokowo-przedsionkowy, cewnikowanie, angioplastyka

Kardiol Pol 2015; 73, 4: 261–266

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Praca wpłynęła: 13.06.2014 r. **Zaakceptowana do druku:** 18.09.2014 r. **Data publikacji AoP:** 14.10.2014 r.