Myocardial bridging analysis by coronary computed tomographic angiography in a Saudi population

Ragab Hani Donkol, Zizi Saad

Ragab Hani Donkol, Radiology Department, Aseer Central Hospital, Abha, Saudi Arabia and Faculty of Medicine, Cairo University, 11559, Cairo, Egypt
Ragab Hani Donkol, Department of Radiology, Faculty of Medicine, Cairo University and Assir Central Hospital, Abha 61321, Saudi Arabia
Zizi Saad, Cardiology Department, Aseer Central Hospital, Abha, Saudi Arabia and Faculty of Medicine, Zagazig University, 44519 Zagazig, Egypt

Author contributions: Donkol RH designed the study, performed CCTA studies, analyzed the data and wrote the manuscript; Saad Z shared in the manuscript writing, selection of cases, clinical and echocardiographic assessment, as well as collected data and interpreted CCTA scans.

Correspondence to: Ragab Hani Donkol, MD, Department of Radiology, Faculty of Medicine, Cairo University and Assir Central Hospital, PO Box 34, Abha 61321, Saudi Arabia. ragabhani@hotmail.com
Telephone: +966-72-291169 Fax: +966-38-552244
Received: April 24, 2013 Revised: October 11, 2013 Accepted: October 17, 2013
Published online: November 26, 2013

Abstract

AIM: To assess the incidence, location, morphology and clinical association of myocardial bridging in a Saudi population using coronary computed tomographic angiography (CCTA).

METHODS: A total of 350 CCTA of Saudi patients were included in this study (236 men, 114 women) with a mean age of 56.3 years. All patients were examined for appropriateness criteria of CCTA indications (typical chest pain, recent onset cardiomyopathy, left bundle branch block, etc.). The scans were retrospectively reviewed for the presence of myocardial bridging and any other pathological association.

RESULTS: Myocardial bridging was found in 89 of 350 (22.5%) patients. Most of the intramuscular segments were of the superficial type and found in the mid left anterior descending (LAD) (24.6%), followed by distal LAD (3.7%), diagonal branches (2%), ramus intermediate artery (1.4%) and obtuse marginal artery (0.8%). No myocardial bridging was detected in the right coronary or circumflex arteries. No significant differences were found between males and females ($P = 0.14$). Coronary artery atherosclerosis was found in 51 of 89 (57.3%) patients with MB. Atherosclerotic plaques were not detected in the intramuscular or distal segment of bridging arteries. Dynamic compression was observed in 35 (94.5%) patients with full encasement. No evidence of myocardial hypoperfusion was found in the territories supplied by the bridging arteries.

CONCLUSION: CCTA is excellent in analyzing myocardial bridging in a Saudi population and the results are comparable to other populations. However, finding the real incidence may need a large multicenter study.

Key words: Coronary heart disease; Myocardial bridging; Coronary computed tomographic angiography; Coronary arteries anatomy; Coronary atherosclerosis

Core tip: A great revolution has happened in imaging of coronary arteries with multi-detector computed tomography. Myocardial bridging is considered a benign anomaly, but in exceptional incidences, it is associated with clinical manifestations. By reviewing the current literature, there is no research studying the prevalence of myocardial bridging (MB) in a Saudi population. This study is considered the first to investigate the prevalence of MB in a Saudi population and its clinical significance in 350 patients. The study highlighted that coronary computed tomographic angiography offers an excellent way to detect and characterize MB and the national prevalence of MB and its anatomical and clinical findings in Saudi Arabia is comparable to worldwide prevalence.
INTRODUCTION

Myocardial bridging (MB) is an inborn abnormality. It occurs when a segment of a coronary artery or its major branch travels through the myocardium instead of on the surface of the myocardium, resulting in a tunneled arterial segment. In an autopsy study, Ferreira et al distinguished two types of MB: superficial bridges crossing the artery perpendicularly or at an acute angle towards the apex and deep bridges characterized by muscle bundles arising from the right ventricular apical trabeculae that cross the affected artery transversely, obliquely or helically before terminating in the interventricular septum. The clinical outcome of patients with MBs has been considered benign when it is not associated with hemodynamic changes. However, the relationship of MB and ischemia remains controversial. Myocardial bridging is considered clinically significant when it is associated with regional hemodynamic compression.

Atherosclerotic changes usually affect the segment immediately proximal to the myocardial bridge, whereas its occurrence in the tunneled coronary segment is still controversial.

Coronary angiography was considered the gold standard for the diagnosis of myocardial bridging. However, it is an invasive procedure and requires a great deal of experience for its interpretation. Also, a superficial type of myocardial bridges may be missed on angiography.

Recently, coronary computed tomographic angiography (CCTA) has been introduced as a noninvasive imaging of the coronary arteries. CCTA is able to visualize the lumens of coronary arteries as well as their walls and the neighboring myocardium in any plane. The depiction rate of MB is greater with 64-section multi-detector computed tomography (MDCT) than with conventional coronary angiography; the higher prevalence of MB on MDCT is considered to be due to the inclusion of partial and full encasement on CCTA, the use of short-axis images obtained perpendicular to the long axis of the left anterior descending (LAD) for all analysis and measurement, and the consistently high image quality of MDCT. Coronary CT Angiography is able to visualize myocardial bridging in a more sensitive and comprehensive way than conventional coronary angiography, in which the diagnosis is not made by the direct visualization of the intramuscular course but the indirect finding of systolic compression of the coronary artery indicated by the milking effect. Based on CCTA, Kim et al. classified myocardial bridging of LAD into three types. Type I is myocardial bridging with partial encasement with the artery within the interventricular gorge and in direct contact with left ventricular myocardium. Type II is myocardial bridging with full encasement of LAD by myocardium but without measurable overlying myocardium. Type III is myocardial bridging with full encasement of LAD by myocardium but with measurable overlying myocardium (> 0.7 mm).

The objective of the present study is to assess the incidence of myocardial bridging, as well as their location and morphology, in Saudi patients by using CCTA and comparing the national results to the international worldwide published studies. The clinical association and pathological changes in relationship to myocardial bridging will be also assessed.

MATERIALS AND METHODS

The study was designed to be a retrospective observational study. A total of 350 Saudi Caucasian subjects were included in this study. Patients of other ethnic groups were excluded from the study. The patients included 236 men and 114 women, with an average age of 56.3 ± 11 years. The patients were examined for different clinical cardiac conditions (Table 1). All CCTA studies were done between January 2010 and February 2013. Written informed consent was taken from all patients included in the study. The ethics committee in the hospital approved the use of the clinical and imaging data.

| Clinical presentations of the patients | Total patients | MB patients |
|---------------------------------------|----------------|-------------|
| Typical chest pain                     | 32 (9.1)       | 6 (6.8)     |
| Atypical chest pain                    | 138 (39.4)     | 44 (49.5)   |
| Known coronary artery disease          | 21 (6)         | 4 (4.5)     |
| Valvular lesions                       | 16 (4.5)       | 2 (2.3)     |
| New onset of heart failure symptoms    | 39 (11.2)      | 8 (8.9)     |
| Presence of risk factors               | 104 (29.8)     | 25 (28)     |

MB: Myocardial bridging.
or any other phase of the R-R interval according to the situation. All patients included in this study were in sinus rhythm and were always pre-medicated with nitroglycerin (5 mg sublingually 1 min before the examination) to dilate the coronary arteries. The heart rate ranged between 50 and 78 BPM with a mean of 65 BPM. Most patients received beta-blockers to control their heart rate within this range, as metoprolol tartrate (5 mg/mL IV bolus) can be repeated according to HR (Beloc ampule, AstraZeneca).

Image reconstruction and interpretation

Two experienced readers certified with level III CCTA blindly interpreted the CCTA images for all patients. Interpretation started with the axial resource images, then other multiplanar reconstructions. If myocardial bridging was detected, the depth and length of the tunneled segment were measured. Myocardial bridge was defined as a segment of a coronary artery that courses through the myocardium. Coronary artery disease (CAD) was defined as coronary wall atheromatous change (calcified and non-calcified plaque) with or without luminal reduction. Hemodynamically significant stenosis was defined as equal or greater than 50% reduction of the lumen diameter (10).

Each involved coronary artery was assessed for the presence of atherosclerotic changes and the location of those changes in relationship to the tunneled segment. The exact anatomy of a normal coronary artery or a tunneled segment was identified in both axial and reformatted images in all planes. The tunneled segment is considered superficial or deep if the depth of the covering myocardium is ≤ 1 or > 1 mm respectively (11).

Superficial MB was further subdivided into complete and incomplete based on the full or partial encasement of the LAD within the left ventricular myocardium (9).

The relationship between length, thickness of the bridge, and severity of the stenosis in the coronary artery proximal to the bridge was studied. The coronary CTA findings were classified as the following: no atheromatous changes or luminal narrowing as normal; atheromatous changes without luminal narrowing as mild disease; atheromatous changes with insignificant stenosis as moderate disease; and atheromatous changes with significant stenosis as severe disease. Because the LAD is the most common artery involved with MB, we compared coronary CTA findings in subjects with myocardial bridge with other patients without bridging.

Statistical analysis

The SPSS software package was used for the statistical data analysis. In the descriptive statistical analysis, quantitative variables were expressed as mean ± SDs, whereas categorical variables were expressed as a percentage. Statistical significance was set at P value < 0.05.

RESULTS

All CCTA scans interpreted in this study were of a good image quality and all involved tunneled segments were assessable. Myocardial bridging was found in 89 of 350 (22.5%) patients. No significant differences were found between males and females (P = 0.14). The total intramuscular segment was 96; thus, in 7 patients, more than 1 intramuscular segment was found. Most of the intramuscular segments were in the LAD artery. No myocardial bridging was detected in the right coronary artery or proximal LAD. The coronary arteries involved are presented in Table 2.

The length of the intramuscular segments ranged from 6 to 24 mm (average 15 ± 7 mm). The mean diameter of the intramuscular segments was 3 ± 3 mm and 1.6 ± 0.5 mm for LAD and the remaining arteries, respectively. The diameter of the proximal segments was significantly larger than that of the intramuscular segment, 2.8 ± 0.5 mm for the LAD and 1.8 ± 0.6 mm for the remaining arteries (P > 0.001). The depth of the intramuscular segments ranged from 1 to 6.2 mm and the mean thickness was 2.3 ± 3.9 mm.

Two anatomical patterns of intramuscular segments were identified according to the depth and the course of the intramuscular segment of LAD: the superficial type [46 segments (61.3%)] in which the intramuscular artery had a superficial course along the interventricular septum (Figure 1) and was covered by a thin layer of tissue (< 1 mm thick) and the deep type [29 segments (38.6%)] in which the intramuscular segment penetrated the interventricular septum at a depth between 1 and 6.2 mm (Figure 2).

Imaging evidence of coronary artery atherosclerosis was found in 51 of 89 (57.3%) patients and in 41 of 261 (15.7%) patients without bridging. Atherosclerotic plaques were not detected in the tunneled or distal segment to myocardial bridging in any case. No evidence of myocardial hypoperfusion was found in the myocardial territories subtended by the tunneled coronary arteries.

In 81 patients with a LAD-myocardial bridge, atherosclerotic changes were found in 37 subjects (45.7%) and were consistently localized in the coronary segment proximal to the bridge. Dynamic compression was observed in two patients with partial encasement (5.5%) and 35 patients with full encasement (94.5%). The results indicated that dynamic compression occurred almost exclusively in myocardial bridging with full encasement. In patients with MB of other coronary arteries, significant atherosclerotic

Table 2. Location and incidence of myocardial bridge in different coronary arteries in Saudi patients n (%)  

| Coronary artery                  | Patients |
|----------------------------------|----------|
| Mid LAD                          | 68 (24.6)|
| Distal LAD                       | 13 (3.7) |
| Diagonal                         | 7 (2)    |
| Ramus intermedius                | 5 (1.4)  |
| Obtuse marginal artery           | 3 (0.8)  |
| Left circumflex                  | 0 (0)    |
| Right coronary                   | 0 (0)    |

LAD: Left anterior descending.
anomaly but in exceptional cases, it is associated with clinical manifestations. Coronary angiography was considered the gold standard for the diagnosis of myocardial bridging\[^{[6,7]}\]. With the introduction of MDCT into clinical practice, a great revolution has happened in the imaging of coronary arteries and their diseases. By reviewing the current literature, there is no research studying the prevalence of MB in a Saudi population. This study is considered the first to investigate the prevalence of MB in a Saudi population and its clinical significance in a relatively big sample size (350 patients). There is a wide discrepancy in the reported prevalence of myocardial bridging between autopsy findings (average 33%, range 15% to 85%)\[^{[12,13]}\] and those of conventional angiography (average 5%, range 0.5% to 16%)\[^{[14-23]}\]. This discordance occurs because most patients with MB have unrelated overt symptoms that are rarely referred for CCA. Also, CCA is not sensitive enough to detect a milking effect (temporary occlusion of artery during systole) with superficial MB\[^{[16]}\]. Recently with an apparent increase in the detection rates of MB, a prevalence as high as 44% has been found\[^{[23]}\].

Multiple studies have reported myocardial bridging by coronary CTA, showing a wide range of frequencies. With the use of 16 slice CT frequencies of MB, 18.9% of 228 patients\[^{[24]}\], 48.7% of 235 patients\[^{[25]}\], 15.8% of 148 patients\[^{[26]}\] and 8.7% of 276 patients\[^{[27]}\] had MB, while frequencies of MB with 64 slice CT were 6.42%, 30%, 22.5%, 5.8%, 10.4%, 17%, 18.6%, 50%, 37%, 58%, 23%, 44% and 30.5%\[^{[9,11,28-38]}\]. On the other hand, by dual source MDCT, Ou\[^{[39]}\] detected 5.4% of 2530 patients with MB and the results by Hwang et al\[^{[7]}\] showed 46% of 1275 patients with MB. The worldwide prevalence of MB (if we exclude the lower and higher results) ranges from 17%-40%\[^{[37]}\]. In this study, the incidence of MB in Saudi patients is 22.5%, which lies within the worldwide prevalence range near its lower limit. Also, in the current study, there is no difference in prevalence of MB between male and female subjects. This observation is in agreement with other studies\[^{[40,41]}\].

The exact course of the coronary arteries was easily recognized on reformatted MDCT in all our cases together with the consequences of myocardial bridging making it possible for the clinician to see the problem and start the management plan. The length and depth of myocardial bridging in the current study are in agreement

DISCUSSION

Myocardial bridging is generally considered a benign anomaly but in exceptional cases, it is associated with clinical manifestations. Coronary angiography was considered the gold standard for the diagnosis of myocardial bridging\[^{[6,7]}\]. With the introduction of MDCT into clinical practice, a great revolution has happened in the imaging of coronary arteries and their diseases. By reviewing the current literature, there is no research studying the prevalence of MB in a Saudi population. This study is considered the first to investigate the prevalence of MB in a Saudi population and its clinical significance in a relatively big sample size (350 patients). There is a wide discrepancy in the reported prevalence of myocardial bridging between autopsy findings (average 33%, range 15% to 85%)\[^{[12,13]}\] and those of conventional angiography (average 5%, range 0.5% to 16%)\[^{[14-23]}\]. This discordance occurs because most patients with MB have unrelated overt symptoms that are rarely referred for CCA. Also, CCA is not sensitive enough to detect a milking effect (temporary occlusion of artery during systole) with superficial MB\[^{[16]}\]. Recently with an apparent increase in the detection rates of MB, a prevalence as high as 44% has been found\[^{[23]}\].

Multiple studies have reported myocardial bridging by coronary CTA, showing a wide range of frequencies. With the use of 16 slice CT frequencies of MB, 18.9% of 228 patients\[^{[24]}\], 48.7% of 235 patients\[^{[25]}\], 15.8% of 148 patients\[^{[26]}\] and 8.7% of 276 patients\[^{[27]}\] had MB, while frequencies of MB with 64 slice CT were 6.42%, 30%, 22.5%, 5.8%, 10.4%, 17%, 18.6%, 50%, 37%, 58%, 23%, 44% and 30.5%\[^{[9,11,28-38]}\]. On the other hand, by dual source MDCT, Ou\[^{[39]}\] detected 5.4% of 2530 patients with MB and the results by Hwang et al\[^{[7]}\] showed 46% of 1275 patients with MB. The worldwide prevalence of MB (if we exclude the lower and higher results) ranges from 17%-40%\[^{[37]}\]. In this study, the incidence of MB in Saudi patients is 22.5%, which lies within the worldwide prevalence range near its lower limit. Also, in the current study, there is no difference in prevalence of MB between male and female subjects. This observation is in agreement with other studies\[^{[40,41]}\].

The exact course of the coronary arteries was easily recognized on reformatted MDCT in all our cases together with the consequences of myocardial bridging making it possible for the clinician to see the problem and start the management plan. The length and depth of myocardial bridging in the current study are in agreement
with the results of many studies\textsuperscript{[7,42]}. In the vast majority of cases, angiographic localization of myocardial bridges is in the LAD\textsuperscript{[43]}. Localization other than the LAD is extremely rare\textsuperscript{[34].}

This study shows that the intramuscular course of coronary arteries most commonly involves the middle segment of LAD, followed by its distal segment, and no cases were reported to have MB of the proximal LAD, circumflex or right coronary arteries. These results are in contrast with Loukas et al\textsuperscript{[46]} who demonstrated that the presence of myocardial bridges appeared to be related to coronary dominance and it goes with their results in detecting MB in LAD, diagonals, OM and RCA in descending order. On the other hand, Arjomand et al\textsuperscript{[49]} reported the first case of myocardial bridging of the circumflex artery (mid-portion) association with acute myocardial infarction.

Also, Tuncer et al\textsuperscript{[60]} reported a 63-year-old man with myocardial bridging of the left circumflex coronary artery with significant systolic narrowing at the mid segment after the first obtuse marginal branch.

The length of the intramuscular segments and their mean diameters were clearly determined by CCTA in the current study. The diameter of the proximal segments and the depth of the intramuscular segments were also evaluated. The results revealed a significant decrease in the diameter of the intramuscular segment compared with the adjacent proximal segment. Similar observations were reported in other literature\textsuperscript{[60,67]}. These structural differences between intramuscular and epicardial segments and the reduced diameter of the intramuscular segments have been associated with the detection of atherosclerotic changes detected in our cases.

Depth criteria is not clear cut for the classification of MB into superficial or deep types depicted on CT. However, some research classified MB as superficial or deep depending on the thickness of the covering muscular layer, either $\leq 1$ mm or $\geq 1$ mm respectively\textsuperscript{[13]}. In addition, superficial MB can be classified as complete or incomplete in accordance with the extent of the vessel encasement by the myocardium\textsuperscript{[9]}. This subdivision of superficial MB into complete and incomplete types based on the full or partial encasement is in our study. The incidence of superficial MB (61.3\%) was higher than that of the deep type (38.6\%). Nearly the same results were illustrated by Hwang et al\textsuperscript{[4]} as they found that the prevalence of superficial MB (66\%) was higher than that of deep MB (34\%). This study illustrated that dynamic compression was detected in two patients with partial encasement (5.5\%) and 35 patients with full encasement (94.5\%). The results indicated that dynamic compression occurred almost exclusively in myocardial bridging with full encasement, which is in concordance with Kim et al\textsuperscript{[9]} who reported that dynamic compression occurred almost exclusively (97.5\%) in patients with full encasement of the LAD coronary artery regardless of the presence of overlying muscle\textsuperscript{[9].}

Atherosclerotic changes detected in our series are limited exclusively to the arteries proximal to the deep-tunneled segments. No atherosclerotic changes were found in the superficial type of bridging, which can be explained by the lower shear stress that may contribute to atherosclerosis at proximal segment of MB, whereas higher shear stress may protect it from atherosclerosis at the tunnelled segment of MB\textsuperscript{[46]}. Another explanation is that due to the high-pressure gradient at the proximal segment, the local wall tension and subsequent endothelial dysfunction will enhance atherosclerotic changes in that segment\textsuperscript{[46]}. This observation was in agreement with other investigators who reported that the tunnelled segments are free of atheroma\textsuperscript{[54].}

Duygu et al\textsuperscript{[51]} found a significant positive correlation between hs-CRP and the percentage of atherosclerotic stenosis on the IVUS study of patients with stable angina pectoris and detected MB in LAD. They concluded that their results indicate the presence of low-grade inflammation in patients with an atherosclerotic lesion in bridged segments.

On the other hand, Duygu et al\textsuperscript{[53]} studied 71 patients with MB diagnosed by coronary angiography and they concluded that a myocardial bridge may initiate the development of an atherosclerotic lesion or may facilitate progression of atherosclerosis in the proximal segment of the vessel. The risk of acute coronary syndrome rises when atherosclerosis is superimposed on MB.

Zoghi et al\textsuperscript{[53]} studied 50 patients with MB in LAD on coronary angiography. All coronary artery segments were evaluated by IVUS and endothelial function was assessed with measurement of flow mediated dilatation in the brachial artery. They concluded that endothelial function is impaired in patients with MB and there is an increased tendency for atherosclerosis proximal to the bridge in MB patients.

However, our results do not agree with other studies showing that the atherosclerotic process occurs in the tunneled coronary segment with the same severity and frequency as the epicardial coronary segments\textsuperscript{[44].}

Some studies showed that such instances of myocardial bridging are linked to clinical complications that include ischemia, acute coronary syndrome, coronary spasm, arrhythmia and sudden death, although in the vast majority of cases, myocardial bridging remains clinically silent\textsuperscript{[1,4,3,16]}. Because dynamic compression occurs almost exclusively in myocardial bridging with full encasement, the incidence of myocardial bridging with full encasement is considered to be more meaningful in the clinical setting\textsuperscript{[38].}

Finally, our results support the classic belief that myocardial bridging is a normal variant and has no clinical consequences as none of our patients required specific medical or invasive treatment for MB. These findings are supported by Kramer et al\textsuperscript{[59]} and Nakanishi et al\textsuperscript{[53]} who demonstrated that MB is an incidental finding associated with an excellent survival rate of 97\% at 5 years. They postulated that the clinical significance of a MB appears to be related to the anatomic properties of a tunneled...
segment of coronary artery, the presence of associated myocardial ischemia, and the presence of proximal and distal atherosclerotic disease. They concluded that medical treatment is the choice for symptomatic patients. Coronary stenting and surgery should be kept for resistant cases that have not responded well to medical therapy. Preoperative mapping of MB allows the surgeon to be ready to deal with myocardial bridging and this will shorten the surgery time and operative risks significantly.

**Limitations of the study**

This study is the first to investigate such a relatively large patient group in Saudi Arabia. However, this study has a few limitations, including that it is just a descriptive study; we do not compare CCTA with other techniques like coronary angiography for a radiation dose. Also, we did not correlate our results with the clinical outcome after treatment. These limitations can be avoided by including a wide spectrum of patients from different provinces of the country. Also, multicenter clinical studies of larger groups are required to determine the degree to which myocardial bridging is responsible for symptoms such as angina, myocardial infarction and life-threatening arrhythmias. Prospective multicenter studies of larger groups are definitely still required to determine the true national prevalence and whether myocardial bridging is responsible for cardiac symptoms or not.

In conclusion, the study shows clearly that CCTA offers an excellent non-invasive way to detect and characterize myocardial bridging. The national prevalence of MB in Saudi Arabia is comparable to worldwide prevalence. Also the anatomical and associated pathological findings of the tunneled arteries are similar to many other studies. However, multicenter clinical studies of larger groups are required to determine the true national incidence of MB, as well as the true clinical and physiological significance of myocardial bridging. However, it is still remains unclear which patients require further testing after the detection of myocardial bridging.

**REFERENCES**

1. Ge J, Jeremias A, Rupp A, Abels M, Baumgart D, Liu F, Haude M, Görg G, von Birgelen C, Sack S, Erbel R. New signs characteristic of myocardial bridging demonstrated by intracoronary ultrasound and Doppler. *Eur Heart J* 1999; 20: 1707-1716 [PMID: 10562478 DOI: 10.1053/eurhj.1999.1661]

2. Ferreira AG, Trotter SE, König B, Décourt LV, Fox K, Olsen EG. Myocardial bridges: morphological and functional aspects. *Br Heart J* 1991; 66: 364-367 [PMID: 1747296 DOI: 10.1136/hrt.66.5.364]

3. Morales AR, Romaneli R, Tate LG, Boucek RJ, de Marchena E. Intramural left anterior descending coronary artery: significance of the depth of the muscular tunnel. *Hum Pathol* 1993; 24: 693-701 [PMID: 8319950 DOI: 10.1016/0146-9438(93)90004-Z]

4. Noble J, Bourassa MG, Petitclerc R, Dyrra I. Myocardial bridging and milking effect of the left anterior descending coronary artery: normal variant or obstruction? *Am J Cardiol* 1976; 37: 993-999 [PMID: 1274883 DOI: 10.1016/0002-9149(76)90414-8]

5. Domínguez B, Valderrama V, Arrocha R, Lombana B. Myocardial bridging as a cause of coronary insufficiency. *Rev Med Panama* 1992; 17: 28-35 [PMID: 1603985]

6. Endo M, Lee YW, Hayashi H, Wada J. Angiographic evidence of myocardial squeezing accompanying tachyarrhythmias as a possible cause of myocardial infarction. *Chest* 1978; 73: 431-433 [PMID: 630950 DOI: 10.1378/chest.73.3.431]

7. Hwang JH, Ko SM, Roh HG, Song MG, Shin JK, Chee HK, Kim JS. Myocardial bridging of the left anterior descending coronary artery: depiction rate and morphologic features by dual-source CT coronary angiography. *Korean J Radiol* 2010; 11: 514-521 [PMID: 20808694 DOI: 10.3348/kjr.2010.11.5.514]

8. Leschka S, Koepfli P, Husmann L, Plass A, Vachenauer R, Gaemperli O, Schepis T, Genoni M, Marincek B, Eberli FR, Kaufmann PA, Alkadhi H. Myocardial bridging: depiction rate and morphology at CT coronary angiography—comparison with conventional coronary angiography. *Radiology* 2008; 246: 754-762 [PMID: 18223120 DOI: 10.1148/radiol.2463062071]

9. Kim PJ, Hur G, Kim SY, Namgung J, Hong SW, Kim YH, Lee WR. Frequency of myocardial bridges and dynamic compression of epicardial coronary arteries: a comparison between computed tomography and invasive coronary angiography. *Circulation* 2009; 119: 1408-1416 [PMID: 19253347 DOI: 10.1161/CIRCULATIONAHA.108.788901]

10. Ko BS, Cameron JD, Leung M, Meredith IT, Leong DP, Antonis FR, Crossett M, Troupis J, Harper R, Malaiayan Y, Seneviratne SK. Combined CT coronary angiography and stress myocardial perfusion imaging for hemodynamically significant stenoses in patients with suspected coronary artery disease: a comparison with fractional flow reserve. *JACC Cardiovasc Imaging* 2012; 5: 1097-1111 [PMID: 23153090 DOI: 10.1016/j.jcvi.2012.09.004]

11. Konen E, Goltsein O, Sternik L, Eshet Y, Shemesh J, Di Segni E. The prevalence and anatomical patterns of intramuscular coronary arteries: a coronary computed tomography angiographic study. *J Am Coll Cardiol* 2007; 49: 587-593 [PMID:
Myocardial bridging in a Saudi population

Donko RH et al. Myocardial bridging in a Saudi population

17276183 DOI: 10.1016/j.jacc.2006.09.039

Zeina AR, Odeh M, Blinder J, Rosenschein U, Barmir E. Myocardial bridge: evaluation on MDCT. AJR Am J Roentgenol 2007; 188: 1069-1073 [PMID: 17377049 DOI: 10.2214/ AJR.06.1714

Konen E, Goitzen O, Di Segni E. Myocardial bridging, a common anatomical variant rather than a congenital anomaly. Semin Ultrasound CT MR 2008; 29: 195-203 [PMID: 18564543 DOI: 10.1055/s-2008.1002.005

Okmen E, Oguz E, Erdinler I, Sanli A, Cam N. Left circumflex coronary artery bridging. Jpn Heart J 2002; 43: 423-427 [PMID: 12227718 DOI: 10.1536/jjh.43.423

Chiappa E, Vineis C. Sudden death during a game of soccer in a young adolescent with a myocardial muscle bridge. Ital Cardiol 1993; 23: 473-477 [PMID: 8339873

Möhlenkamp S, Hort W, Ge J, Erbel R. Update on myocardial bridging. Circulation 2002; 106: 2616-2622 [PMID: 12427660 DOI: 10.1161/01.CIR.0000048280.4867.7A

Faruqui AM, Maloy WC, Felner JM, Schlant RC, Logan WD, Symbas P. Symptomatic myocardial bridging of coronary artery. Am J Cardiol 1978; 41: 1305-1310 [PMID: 307341 DOI: 10.1016/0002-9149(78)90480-1

Amoroso G, Battolla L, Gemignani C, Panconi M, Petronio AS, Rondine P, Mariani M, Falaschi F. Myocardial bridging on coronary CTA: an innocent by-stander or a culprit in myocardial infarction? J Cardiovasc Comput Tomogr 2012; 6: 3-13 [PMID: 22264630 DOI: 10.1016/j.jcct.2011.09.015

Takamura K, Fujimoto S, Nanjo S, Nakashima M, Hisatou S, Namiaki A, Ishikawa Y, Ishii T, Yamazaki J. Anatomical characteristics of myocardial bridge in patients with myocardial infarction by multi-detector computed tomography. Circ J 2011; 75: 642-648 [PMID: 21282876 DOI: 10.1255/circ.11-0769

De Rossi R, Sacco M, Tedeschi C, Pepe R, Capogrosso P, Montemarano E, Rotondo A, Runza G, Midiri M, Cademartiri F. Prevalence of coronary artery intramyocardial course in a large population of clinical patients detected by multislice computed tomography coronary angiography. Acta Radiol 2008; 49: 895-901 [PMID: 18608013 DOI: 10.1080/028489850802199825

Kawawa Y, Ishikawa Y, Gomi T, Nagamoto M, Terada H, Ishii T, Kohda E. Detection of myocardial bridge and evaluation of its anatomical properties by coronary multislice spiral computed tomography. Eur J Radiol 2007; 61: 130-138 [PMID: 17045767 DOI: 10.1016/j.ejrad.2006.08.029

Chen YD, Wu MH, Sheu MH, Chang CY. Myocardial bridging in Taiwan: depiction by multidetector computed tomography coronary angiography. J Formos Med Assoc 2009; 108: 469-474 [PMID: 19515627 DOI: 10.1016/ S0029-6646(09)60094-2

Kim SY, Lee YS, Lee JB, Ryu JK, Choi JY, Chang SG, Kim KS. Evaluation of myocardial bridge with multidetector computed tomography. Cir C 2010; 74: 137-141 [PMID: 20966506 DOI: 10.1255/ari.circj.09-0407

La Grutta L, Runza G, Lo Re G, Gala M, Alaimo V, Grassel-Diono E, Bartolotta TV, Malago R, Tescheli C, Cademartiri F, De Maria M, Cardinale AE, Lagalla R, Midiri M. Prevalence of myocardial bridging and correlation with coronary atherosclerosis studied with 64-slice CT coronary angiography. Radiol Med 2009; 114: 1024-1036 [PMID: 19697702 DOI: 10.1007/s11547-009-0446-y

Bayrak F, Degertekin M, Ercelebi E, Gunesyu T, Sevinc D, Gemici G, Mutlu B, Aytaclar S. Evaluation of myocardial bridges with 64-slice computed tomography coronary angiography. Acta Cardiol 2009; 64: 341-346 [PMID: 1959344 DOI: 10.2143/AC.64.3.2038019

Liu H, Huang MP, Liang CH, Zheng JH, Wu ZB. Detection and its clinical value of myocardial bridging with 64-slice spiral CT coronary angiography. Nanjing Yike Daxue Xuebao 2009; 29: 236-238 [PMID: 19246287

Jacobs JE, Bod J, Kim DC, Hecht EM, Srichai MB. Myocardial bridging: evaluation using single- and dual-source multidetector cardiac computed tomographic angiography. J Comput Assist Tomogr 2008; 32: 242-243 [PMID: 18379310 DOI: 10.1097/RCT.0b013e31810756e3

Atar E, Kornowski R, Fuchs S, Naftali N, Bekeny GN. Prevalence of myocardial bridging detected with 64-slice multidetector computed coronary angiography in asymptomatic adults. J Cardiovasc Comput Tomogr 2007; 1: 78-83 [PMID: 17083883 DOI: 10.1016/j.jcct.2007.08.003

Yang L, Zhao LF, Li Y, Wang XJ, Zhao XH, Zhao H, Wu J, Liu X, Cai ZL. Multi-slice computed tomography of myocardial bridge and mural coronary artery and clinical significance thereof. Zhonghua Yi Xue Za zhi 2006; 86: 2858-2862 [PMID: 17300024

Chen CC, Chen MT, Lei MH, Hsu YC, Chung SL, Sung YJ. Assessing myocardial bridging and left ventricular configuration by 64-slice computed tomography in patients with apical hypertrophic cardiomyopathy presenting with chest pain. J Comput Assist Tomogr 2010; 34: 70-74 [PMID: 20118725 DOI: 10.1097/RCT.0b013e3181b66431

Koşar P, Ergun E, Ozttirk C, Koşar U. Anatomical variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance. Diag Interv Radiol 2009; 15: 275-283 [PMID: 19957241

Jodocy D, Aglan I, Friedrich G, Mallouhi A, Pachinger O, Jaschke W, Feuchtmann G. Left anterior descending coronary artery myocardial bridging by multislice computed tomography: correlation with clinical findings. Eur J Radiol 2010; 73: 89-95 [PMID: 19038513 DOI: 10.1016/j.ejrad.2008.10.004

Lubarsky L, Gupta MP, Hecht HS. Evaluation of myocardial bridging of the left anterior descending coronary artery by 64-slice multidetector computed tomographic angiography. Am J Cardiol 2007; 100: 1081-1082 [PMID: 17884365 DOI: 10.1016/j.amjcard.2007.05.029

Ou SX, Li XR, Peng GM, Zhang L, Li SN. Imaging of congenital coronary artery anomalies by dual-source computed tomography angiography. Zhongguo Yi Xue Ke Xue Yuan Xue Bao 2010; 32: 690-694 [PMID: 21219802

Ma ES, Wang W, Ma GL, Zheng T, Yu HW. Morphological and quantitative evaluation of myocardial bridge and mural coronary artery with 256-slice CT angiography: initial clini-
Myocardial infarction associated with sudden cardiac death. Eur Heart J 2009; 30: 1627-1634 [PMID: 19406869]

42 de Agustin JA, Marcos-Alberca P, Fernández-Golffin C, Bordes S, Feltes G, Almeria C, Rodrigo JL, Arrazola J, Pérez de Isla L, Macaya C, Zamorano J. Myocardial bridging assessed by multidetector computed tomography: likely cause of chest pain in younger patients with low prevalence of dyslipidemia. Rev Esp Cardiol (Engl Ed) 2012; 65: 885-890 [PMID: 22658689 DOI: 10.1016/j.rec.2012.02.013]

43 Bourassa MG, Butnaru A, Lespérance J, Tardif JC. Symptomatic myocardial bridges: overview of ischemic mechanisms and current diagnostic and treatment strategies. J Am Coll Cardiol 2003; 41: 351-359 [PMID: 12579660]

44 Loukas M, Curry B, Bowers M, Louis RG, Bartczak A, Kiedrowski M, Kamionek M, Fudalej M, Wagner T. The relationship of myocardial bridges to coronary artery dominance in the adult human heart. J Anat 2006; 209: 43-50 [PMID: 16822268 DOI: 10.1111/j.1469-7580.2006.00590.x]

45 Arjomand H, AlSalman J, Azain J, Amin D. Myocardial bridging of left circumflex coronary artery associated with acute myocardial infarction. J Invasive Cardiol 2000; 12: 431-434 [PMID: 10953110]

46 Tuncer C, Sökmen G, Acar G, Kороğlu S. A case of myocardial bridging of the left circumflex coronary artery. Turk Kardiyol Dern Ars 2008; 36: 562-563 [PMID: 19223726]

47 Hausleiter J, Meyer T, Hadamitzky M, Huber E, Zankl M, Martinoff S, Kastrati A, Schömig A. Radiation dose estimates from cardiac multislice computed tomography in daily practice: impact of different scanning protocols on effective dose estimates. Circulation 2006; 113: 1305-1310 [PMID: 16520411 DOI: 10.1161/CIRCULATIONAHA.105.602490]

48 Malek AM, Alper SL, Izumo S. Hemodynamic shear stress and its role in atherosclerosis. JAMA 1999; 282: 2035-2042 [PMID: 10591386 DOI: 10.1001/jama.282.21.2035]

49 Masuda T, Ishikawa Y, Akasaka Y, Iizho K, Kiguchi H, Ishii T. The effect of myocardial bridging of the coronary artery on vasoactive agents and atherosclerosis localization. J PaeDi 2001; 193: 484-414 [PMID: 11241423]

50 Wissler RW. The evolution of the atherosclerotic plaque and its complications. In: Connor WE, Bristow JD, eds. Coronary Heart Disease: Prevention, Complications, and Treatment. Philadelphia, Pa: Lippincott, 1985: 193–214

51 Duygu H, Zoghi M, Nalbantgil S, Ozerkan F, Cakir C, Ertas F, Yuksek U, Akilli A, Akin M, Ergene O. High-sensitivity C-reactive protein may be an indicator of the development of atherosclerosis in myocardial bridging. Int J Cardiol 2008; 124: 267-270 [PMID: 17953039]

52 Duygu H, Zoghi M, Nalbantgil S, Kirilmez B, Turk U, Ozerkan F, Akilli A, Akin M. Myocardial bridge: a bridge to atherosclerosis. Anadolu Kardiyol Derg 2007; 7: 12-16 [PMID: 17347068]

53 Zoghi M, Duygu H, Nalbantgil S, Kirilmez B, Turk U, Ozerkan F, Akilli A, Akin M. Myocardial bridge: a bridge to atherosclerosis. Cardioangiography 2006; 23: 577-581 [PMID: 16911331 DOI: 10.1111/j.1540-8175.2006.00279.x]

54 Waller BF. Nonatherosclerotic coronary heart disease. In: Fuster V, Alexander RW, O'Rourke RA, eds. Hurst’s the Heart. 11th ed. New York, NY: McGraw-Hill, 2004: 1173-1213

55 Tauth J, Sullebarger T. Myocardial infarction associated with myocardial bridging: case history and review of the literature. Cathet Cardiovasc Diagn 1997; 40: 364-367 [PMID: 9096936]

56 Kramer JR, Kitazume H, Proudfoot WL, Sones FM. Clinical significance of isolated coronary bridges: benign and frequent condition involving the left anterior descending artery. Am Heart J 1982; 103: 283-288 [PMID: 7055058 DOI: 10.1016/0002-8703(82)90500-2]

P- Reviewers: Celik T, Duygu H, Li J, Moreno R, Pascev R, Petix NR S- Editor: Wen LL L- Editor: Roemmele A E- Editor: Wang CH
