Original Article

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# Prevalence of myocardium bridging in Thai population and the effect of myocardium bridging on hemodynamic changes.

# ความชุกของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจในประชากรไทยและผลต่อการเปลี่ยนแปลงของระบบไหลเวียนโลหิต

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## Abstract

**Objective:** To assess the prevalence and characteristics of myocardial bridging in Thai population and to evaluate the effect of myocardial bridging on hemodynamic alterations by using gross cardiac parameters.

**Materials and Methods:** The study was performed in 318 Thai cadavers sent for autopsy in the Department of Forensic Medicine, Siriraj Hospital between May 2012 and June 2013. In each case, sex, age, gross cardiac parameters including heart weight and left ventricular wall thickness (LV), and myocardial bridging findings including location, length and depth was evaluated. Pearson's chi square test and student paired t-test were performed to assess the correlation between cardiac parameters and myocardial bridging.

**Results:** The overall prevalence of myocardial bridging in Thai population was 17.0% and was found more predominantly in male than in female about 3 times. All of myocardial bridging segments were located in the segments of left anterior descending artery (LAD) and myocardial bridging segments were mostly existed in the mid-segment of LAD. The existence of myocardial bridging had the effect on both heart weights and left ventricular wall thickness parameters ($p < 0.05$) and this effect was evidently found more in female group than in male group. The length of myocardial bridging ≥ 1.5 cm (15 mm) and the depth of myocardial bridging ≥ 0.3 cm (3 mm) had the more effect on LV parameter than the length of myocardial bridging < 1.5 cm (15 mm) and the depth of myocardial bridging < 0.3 cm (3 mm) ($p < 0.05$).

**Conclusion:** The overall prevalence of myocardial bridging in Thai population was 17.0%. The length of myocardial bridging ≥ 1.5 cm (15 mm)and the depth of myocardial bridging ≥ 0.3 cm (3 mm) were the well-predicted parameters for hemodynamic changes of hearts.

**Keywords:** Myocardial bridging, prevalence, hemodynamic changes.

## บทคัดย่อ

**วัตถุประสงค์**: เพื่อหาความชุกของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจในประชากรไทยและประเมินผลกระทบของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจต่อการเปลี่ยนแปลงของหัวใจ

**วัสดุและวิธีการศึกษา**: ทำการศึกษาในศพคนไทยจำนวน 318 ศพซึ่งถูกส่งมาผ่าชันสูตรในภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาลระหว่างเดือนพฤษภาคม พ.ศ. 2555 ถึงมิถุนายน พ.ศ. 2556โดยเก็บข้อมูลได้แก่ เพศ, อายุ, ลักษณะของหัวใจ ได้แก่ น้ำหนักหัวใจ และความหนาของหัวใจห้องล่างซ้าย และการมีอยู่ของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจ โ ดยทำการบันทึกตำแหน่ง, ความยาว และความลึกไว้ จากนั้นจึงทำการวิเคราะห์ทางสถิติด้วยวิธี Pearson's chi square test และ student paired t-test เพื่อหาความสัมพันธ์ระหว่างลักษณะของหัวใจและภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจ

**ผลการศึกษา**: ความชุกของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจในประชากรไทยโดยรวมเท่ากับ 17.0% และพบในเพศชายมากกว่าเพศหญิงประมาณ 3 เท่า ภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจอยู่ที่หลอดเลือดแดงเลี้ยงหัวใจด้านซ้ายหน้า (LAD) และส่วนใหญ่จะอยู่ที่ส่วนกลางของหลอดเลือด (mid-segment of LAD) ภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจมีผลต่อน้ำหนักหัวใจและความหนาของผนังหัวใจห้องซ้ายล่าง ($p < 0.05$) และผลกระทบนี้เห็นได้ชัดในเพศหญิงมากกว่าในเพศชาย กลุ่มที่มีความยาวของหลอดเลือดแดงเลี้ยงหัวใจซึ่งแทรกตัวในชั้นกล้ามเนื้อหัวใจที่ยาวตั้งแต่ 1.5ซม. (15มม.)ขึ้นไปและความลึกของหลอดเลือดแดงเลี้ยงหัวใจซึ่งแทรกตัวในชั้นกล้ามเนื้อหัวใจที่ลึกตั้งแต่0.3ซม. (3มม.)ขึ้นไปมีผลต่อความหนาของผนังหัวใจห้องซ้ายล่างมากกว่ากลุ่มที่มีความยาวและความลึกน้อยกว่า ($p < 0.05$)

**สรุป**: ความชุกของภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจในประชากรไทยโดยรวมเท่ากับ 17.0%โดยความยาวของหลอดเลือดแดงเลี้ยงหัวใจซึ่งแทรกตัวในชั้นกล้ามเนื้อหัวใจที่ยาวตั้งแต่ 1.5ซม. (15มม.)ขึ้นไปและความลึกของหลอดเลือดแดงเลี้ยงหัวใจซึ่งแทรกตัวในชั้นกล้ามเนื้อหัวใจที่ลึกตั้งแต่0.3ซม. (3มม.)ขึ้นไป เป็นตัวชี้วัดที่ดีในการใช้ประเมินผลกระทบของภาวะดังกล่าวต่อการเปลี่ยนแปลงของหัวใจ

**คำสำคัญ**: ภาวะหลอดเลือดแดงเลี้ยงหัวใจแทรกตัวในชั้นกล้ามเนื้อหัวใจ, ความชุก, การเปลี่ยนแปลงของหัวใจ

## Introduction

Myocardial bridging is defined as a segment of a major epicardial coronary artery, the 'tunnelled artery', that goes intramurally through the myocardium beneath the muscle bridge. It was firstly recognized at the autopsy by Reyman in 1737 [1]and firstly described in angiography by Portmann and Iwig in 1960[2]. Though myocardial bridging can be detected at all three coronary arteries, the most common site of myocardial bridging is generally found at the mid-segment of left anterior descending artery(mid-LAD)[3-5]. The prevalence that has been reported from coronary angiography varies from 0.5% to 33%[6-13],but the prevalence in autopsy series seems to behigher, ranging from 5 to 86%[14-18].

Although myocardial bridging has generally been considered the benign condition, the complications such as myocardial ischemia, acute coronary syndrome, coronary vasospasm, cardiac arrhythmia and even sudden cardiac death can occur and have been reported in some literatures[19-23]. These complications demonstrate that myocardial bridging tends to have some significant hemodynamic implications to the heart. These cardiac events are related to stenosis of myocardial bridging segment during systolic myocardial contraction and lead to decreased myocardial perfusion. Theoretically, myocardial bridging can lead to cardiac remodeling and myocardial ischemia because of this reduction of coronary blood flow.

This study aimed to assess the prevalence and characteristics of myocardial bridging in Thai population and to evaluate the effect of myocardial bridging on hemodynamic alterations by using gross cardiac parameters.

## Material and methods

The collection for prevalence of myocardial bridging was performed in 318 cadavers those were sent for autopsy in the Department of Forensic Medicine, Siriraj Hospital between May 2012 and June 2013.Cadavers were selected based on the following eligible criteria: postmortem interval of all cadavers less than 24 hours (no signs of decomposition), no cardiac injuries in all cadavers and no previous cardiac operations or procedures in all cadavers.

When hearts were examined in autopsy procedures, all of three branches of coronary arteries were cut in cross sectional about 3-5 millimeters interval along the whole length of coronary arteries. Myocardial bridging was defined in terms of segments of coronary arteries which were grossly surrounded by myocardium at all sides. Branches of coronary arteries which were presented with myocardial bridging were recorded. The location of myocardial bridging was defined as the distance from the coronary origin. The depth of myocardial bridging was measured at the point of maximal

depth. Finally, the total length of myocardial bridging was measured. Heart weights were measured after the removal of root of aorta and other vessels proximal to atria and the removal of blood clot in cardiac chambers. Measurement of left ventricular wall thickness was conducted at septal area below the mitral valve 1 cm.Degree of stenosis of each coronary artery was recorded in terms of percent stenosis. Demographic information was recorded including forensic number, sex, age, body weight, body height and cause of death.

Statistical analysis

The prevalence of myocardial bridging regarding to gender and each age group was analyzed by descriptive statistical analysis.Pearson's Chi-Square test was performed to determine statistical significant of gender and age group. The location of myocardial bridging on coronary arteries was defined by descriptive statistical analysis.

Student paired t-test analysis was performed for comparison of heart weights and left ventricular wall thickness (LV) between myocardial bridging group and non-myocardial bridging group. Furthermore, student paired t-test analysis was performed to determine the effect of the length and depth of myocardial bridging on heart size and left ventricular wall thickness (LV).

All statistical analyses wereperformed with SPSS software version 18. For all statistical analyses, $p < 0.05$ was considered statistically significant.

## Results

A total of 318 adult hearts were examined in autopsy procedures. There were 234 males and 84 females with age range from 15 to 84 years old. The average age for males was 40.97 years old and for female was 39.05 years old, respectively. All of myocardial bridging segments were located in the segments of left anterior descending arteries (LAD).

The overall prevalence of LAD myocardial bridging in the studied population was 17.0%. When sex was taken into account, it was found that the prevalence of LAD myocardial bridging in men was 20.5% and in women was 7.1%, respectively (Table 1). It was statistically demonstrated that LAD coronary bridging was found more significantly in Thai men than Thai women ($p < 0.01$).

| Gender | Myocardial bridging | | Total | p-value |
|---|---|---|---|---|
| | No myocardial bridging | Myocardial bridging | | |
| Female | 78 (92.9%) | 6 (7.1%) | 84 (100%) | |
| Male | 186 (79.5%) | 48 (20.5%) | 234 (100%) | p = 0.005 |
| Total | 264 (83.0%) | 54 (17.0%) | 318 (100%) | |

Table 1 Prevalence of myocardial bridging in Thai population regarding to gender

The prevalence of LAD myocardial bridging regarding to age group and dividing by sex was demonstrated in the following table (table 2). According to statistical analysis by Pearson's Chi-Square test, it was illustrated that the prevalence of LAD myocardial bridging was not difference in each age group ($p > 0.05$). Hence, age group did not have any influences in the existence of myocardial bridging.

| Age group | Myocardial bridging | | Total | p-value |
|---|---|---|---|---|
| | No myocardial bridging | Myocardial bridging | | |
| Female< 30 yrs | 28 (96.6%) | 1 (3.4%) | 29 (100%) | |
| Female 30-44 yrs | 22 (91.7%) | 2 (8.3%) | 24 (100%) | p > 0.05 |
| Female 45-59 yrs | 21 (91.3%) | 2 (8.7%) | 23 (100%) | p > 0.05 |
| Female ≥ 60 yrs | 7 (87.5%) | 1 (12.5%) | 8 (100%) | p > 0.05 |
| Male < 30 yrs | 50 (83.3%) | 10 (16.7%) | 60 (100%) | |
| Male 30-44 yrs | 57 (82.6%) | 12 (17.4%) | 69 (100%) | p > 0.05 |
| Male 45-59 yrs | 62 (74.7%) | 21 (25.3%) | 83 (100%) | p > 0.05 |
| Male ≥ 60 yrs | 17 (77.3%) | 5 (22.7%) | 22 (100%) | p > 0.05 |
| Total | 186 (79.5%) | 48 (20.5%) | 234 (100%) | |

Table 2 Prevalence of myocardial bridging in Thai population regarding to age group

The location of myocardial bridging was mostly existed in the mid-segment of LAD and averagely located in 3.991 ±1.218 cm from left coronary artery (LCA) origin (median = 3.900 cm).

To assess the effect of myocardial bridging on the hemodynamic change of hearts, 94 cases which had significant coronary atherosclerosis (the level of coronary stenosis were at least or more than 50% in any branches of coronary arteries) and had structural heart diseases such as valvular heart diseases or undefined cardiomegaly were excluded. Hence, 224 cases were brought to analyze to establish the relationship between myocardial bridging and gross cardiac parameters indicating hemodynamic alterations including heart weights and left ventricular wall thickness (LV).

When overall 224 cases were considered, mean heart weights for myocardial bridging group and non-myocardial bridging group were 326.57 and 290.63 grams, respectively (table 3). Analysis by paired Student t-test revealed that heart weights in myocardial bridging group were significantly heavier than non-myocardial bridging group ($p < 0.01$). When statistical analysis was performed in each sex, it was found that mean heart weights for myocardial bridging group and non-myocardial bridging group in female group were 326.57 and 290.63 grams, respectively and there was statistically significant between this two groups ($p < 0.05$). In contrast, mean heart weights for myocardial bridging group and non-myocardial bridging group in male group were 329.00 and 309.18 grams, respectively and there was almost statistically significant between this two groups ($p = 0.053$).

| Gender and Myocardial bridging | | N (sample) | Mean (grams) | SD | p-value |
|---|---|---|---|---|---|
| Female | No myocardial bridging | 67 | 256.87 | 47.712 | |
| | Myocardial bridging | 5 | 312.00 | 103.537 | **p = 0.027** |
| | Total | 72 | 260.69 | 54.030 | |
| Male | No myocardial bridging | 122 | 309.18 | 50.167 | |
| | Myocardial bridging | 30 | 329.00 | 49.085 | p = 0.053 |
| | Total | 152 | 313.09 | 50.419 | |
| Total | No myocardial bridging | 189 | 290.63 | 55.214 | |
| | Myocardial bridging | 35 | 326.57 | 57.902 | **p = 0.001** |
| | Total | 224 | 296.25 | 57.028 | |

Table 3 Relationship between heart weight and the existence of myocardial bridging

When left ventricular wall thickness (LV) values were statistically analyzed, mean LV values in myocardial bridging group and non-myocardial bridging group were 1.446 and 1.202 cm, respectively (table 4). It was demonstrated by paired Student t-test that LV in myocardial bridging group was significantly thicker than non-myocardial bridging group ($p < 0.001$). Mean LV values in myocardial bridging group and non-myocardial bridging group in female group were 1.340 and 1.085 cm, respectively and there was statistically significant between this two groups ($p < 0.001$). Similarly, mean LV values in myocardial bridging group and non-myocardial bridging group in male group were 1.463 and 1.266 cm, respectively and there was statistically significant between this two groups ($p < 0.001$).

| Gender and Myocardial bridging | | N (sample) | Mean LV (cm) | SD | p-value |
|---|---|---|---|---|---|
| Female | No myocardial bridging | 67 | 1.085 | 0.1406 | |
| | Myocardial bridging | 5 | 1.340 | 0.2510 | **p < 0.001** |
| | Total | 72 | 1.103 | 0.1618 | |
| Male | No myocardial bridging | 122 | 1.266 | 0.1775 | |
| | Myocardial bridging | 30 | 1.463 | 0.2008 | **p < 0.001** |
| | Total | 152 | 1.305 | 0.1979 | |
| Total | No myocardial bridging | 189 | 1.202 | 0.1865 | |
| | Myocardial bridging | 35 | 1.446 | 0.2091 | **p < 0.001** |
| | Total | 224 | 1.240 | 0.2094 | |

Table 4 Relationship between left ventricular wall thickness (LV) and the existence of myocardial bridging

To evaluate myocardial bridging parameters which affect the hemodynamic change, 35 cases of myocardial bridging which had no significant coronary stenosis and no abnormal cardiomegaly were chosen to statistical analysis. Mean heart weights for the length of myocardial bridging ≥1.5 cm group and the length of myocardial bridging < 1.5 cm group were 340.53 and 310.00 grams, respectively and there was no statistically significant between this two groups ($p > 0.05$) (table 5). On the contrary, mean LV values in the former group and the latter group were 1.521 and 1.356 cm, respectively and there was statistically significant between this two groups ($p < 0.05$).

| Length of myocardial bridging | | N (sample) | Mean values | SD | p-value |
|---|---|---|---|---|---|
| Heart weight (grams) | Myocardial bridging < 1.5 cm | 16 | 310.00 | 54.894 | |
| | Myocardial bridging ≥ 1.5 cm | 19 | 340.53 | 58.068 | p = 0.122 |
| LV (cm) | Myocardial bridging < 1.5 cm | 16 | 1.356 | 0.2128 | |
| | Myocardial bridging ≥ 1.5 cm | 19 | 1.521 | 0.1782 | **p = 0.018** |

Table 5 Effect of the length of myocardial bridging on heart weight and left ventricular wall thickness (LV)

When the depth of myocardial bridging was taken into account, mean heart weights for the depth of myocardial bridging ≥ 0.3 cm group and the length of myocardial bridging < 0.3 cm group were 332.22 and 320.59 grams, respectively and there was no statistically significant between this two groups ($p > 0.05$) (table 6). On the other hand, mean LV values in the former group and the latter

group were 1.522 and 1.365 cm, respectively and there was statistically significant between this two groups ($p < 0.05$).

| Depth of myocardial bridging | | N (sample) | Mean values | SD | p-value |
|---|---|---|---|---|---|
| Heart weight (grams) | Myocardial bridging < 0.3 cm | 17 | 320.59 | 58.145 | |
| | Myocardial bridging ≥ 0.3 cm | 18 | 332.22 | 58.767 | p = 0.560 |
| LV (cm) | Myocardial bridging < 0.3 cm | 17 | 1.365 | 0.2206 | |
| | Myocardial bridging ≥ 0.3 cm | 18 | 1.522 | 0.1700 | **p = 0.024** |

Table 6 Effect of the depth of myocardial bridging on heart weight and left ventricular wall thickness (LV)

## Discussion

The prevalence of myocardial bridging in Thai population in this study was 17.0% and exclusively involved the segment of LAD. The figures in this study were consistent with the prevalence ranging from 5 to 86% and predominant LAD branch in previous autopsy studies (Table 7). However, myocardial bridging was not found in other branches of coronary arteries in this study. This might be due to the very low prevalence of myocardial bridging in other branches of coronary arteries in Thai population. Moreover, this study demonstrated that LAD myocardial bridging in Thai population was found more predominantly in male than in female population about 3 times. Gender difference in myocardial bridging was not found in previous studies[24-25]. Thus, LAD coronary bridging which was predominant in Thai male population was thought to be the characteristics of Thai population. The location of LAD myocardial bridging in this study was existed at the mid-segment of LAD which was corresponding with previous studies[26]. This is shown that the common location of myocardial bridging was not dependent on gender, age group or ethnicity.

This study revealed that the heart weight and left ventricular wall thickness in myocardial bridging group were generally greater than that in non-myocardial bridging group. However, heart weight in myocardial bridging group in female population was significantly heavier than that in non-myocardial bridging group whereas heart weight in myocardial bridging group in male population was not statistically evident. In contrast, left ventricular wall thickness in myocardial bridging group in both genders was significantly thicker than that in non-myocardial bridging group. These findings supported the fact that myocardial bridging had the hemodynamic influence on cardiac structure because some literatures had reported myocardial ischemia in some myocardial bridging cases[53-68]. This phenomenon resulted from bridging segment which was relatively narrow during systolic myocardial

contraction and this caused relative myocardial ischemia in systolic phase. This reduction of myocardial perfusion leaded to cardiac remodeling and affected heart size and left ventricular wall thickness and this theory was consistent with data in this study.

| Author (Reference No.) | Sample Size (n) | Bridging (%) | Comment |
|---|---|---|---|
| **Autopsy** | | | |
| Geiringer[27] | 100 | 23 | LAD |
| Edwards et al[28] | 276 | 5 | All coronaries, 87% in the LAD |
| Polacek[29] | 70 | 86 | Including RCA loops, LAD: 60% |
| Giampalmo et al[30] | 560 | 7 | All coronaries, 95% LAD only |
| Lee and Wu[31] | 108 | 58 | LAD |
| Penther et al[32] | 187 | 18 | LAD |
| Risse and Weiler[33] | 1056 | 26 | All coronaries, 88% in the LAD |
| Ferreira et al[34] | 90 | 56 | All coronaries |
| Baptista and DiDio[35] | 82 | 54 | All coronaries, 35% in the LAD |
| Ortale et al[36] | 37 | 56 | LAD (7% coronary veins with bridges) |
| Kosinski and Grzybiak[37] | 100 | 41 | All coronaries |
| **Present study** | **318** | **17.0** | **LAD** |
| **Angiography** | | | |
| Noble et al[38] | 5250 | 0.5 | All patients |
| Binet et al[39] | 700 | 0.7 | Unspecified series of patients |
| Ishimori et al[40] | 313 | 1.6 | All patients, systolic compression 50% |
| Greenspan et al[41] | 1600 | 0.9 | All patients, exclusion of associated diseases |
| Rossi et al[42] | 1146 | 4.5 | All patients |
| Voß et al[43] | 848 | 2.5 | All patients |
| Kramer et al[44] | 658 | 12 | Patients with normal angiograms |
| Angelini et al[45] | 1100 | 4.5 | All patients |
| Garcia et al[46] | 936 | 4.9 | All patients |
| Wymore et al[47] | 64 | 33 | Heart transplantation patients |
| Somanath et al[48] | 1500 | 1.1 | All patients |
| Gallet et al[49] | 1920 | 1.0 | LAD only |
| Diefenbach et al[50] | 1780 | 3.5 | All patients |
| Juilliere et al[51] | 7467 | 0.8 | All patients |
| Harikrishnan et al[52] | 3200 | 0.6 | All patients |

Table 7 Prevalence of myocardial bridging in previous studies demonstrated by autopsy and angiography comparing with the present study

Regarding to the length and depth of myocardial bridging, various previous studies demonstrated that long myocardial bridging (15-20 mm or more) and deep myocardial bridging (2-5 mm or more) were more likely to have the significant effect on the heart including cardiac symptoms and even sudden death69-70. This study showed that the length of myocardial bridging ≥ 1.5 cm (15

mm) and the depth of myocardial bridging ≥ 0.3 cm (3 mm) had more significant effects on left ventricular wall thickness than heart weight. These values of the length and depth of myocardial bridging were corresponding with previous literatures[69-70]. Furthermore, findings in this study indicated that left ventricular wall thickness was affected by myocardial bridging before the change of heart size. This implied that left ventricular wall thickness was the sensitive parameter to evaluate the effect of myocardial bridging because this value changed prior to total heart weight. This finding helped forensic physicians in the investigation of sudden cardiac death in cases who had myocardial bridging and had no other abnormalities. As a result, forensic physicians should measure the length and depth of myocardial bridging accompanying with left ventricular wall thickness and heart size to assist in the evaluation of the diagnosis of sudden cardiac death.

## Conclusions

The overall prevalence of myocardial bridging in Thai population was 17.0% and was found more predominantly in male than in female about 3 times.

The existence of myocardial bridging had the effect on both heart weights and left ventricular wall thickness parameters indicating hemodynamic influence on the heart and this effect was evidently found more in female group than in male group.

The length of myocardial bridging ≥ 1.5 cm (15 mm) and the depth of myocardial bridging ≥ 0.3 cm (3 mm) were the well-predicted parameters forhemodynamic changes of hearts and left ventricular wall thickness was the sensitive cardiac parameter which was influenced by myocardial bridging prior to heart weight.

## References


1. Reyman HC. Diss. de vasis cordis propriis. Bibl Anat 1737;2:359–379.
2. Portmann WC, Iwig J. Die intramural koronarieim angiogramm. Fortschr Rontgenstr 1960;92:129–132.
3. 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.
4. Channer KS, Bukis E, Hartnell G, Rees JR. Myocardial bridging of the coronary arteries. Clin Radiol 1989;40:355–359.
5. Irvin RG. The angiographic prevalence of myocardial bridging in man. Chest 1982;81:198–202.
6. Mohlenkamp S, Hort W, Ge J, Erbel R. Update on myocardial bridging. Circulation. 2002;106:2616 –2622.
7. Angelini P, Trivellato M, Donis J, Leachman RD. Myocardial bridges: a review. Prog Cardiovasc Dis. 1983;26:75– 88. 11.
8. Ortale JR, Gabriel EA, Iost C, Marquez CQ. The anatomy of the coronary sinus and its tributaries. Surg Radiol Anat. 2001;23:15–21.
9. Ishimori T. Myocardial bridges: a new horizon in the evaluation of ischemic heart disease. Cathet Cardiovasc Diagn. 1980;6:355–357.

10. Rossi L, Dander B, Nidasio GP, Arbustini E, Paris B, Vassanelli C, Buonanno C, Poppi A. Myocardial bridges and ischemic heart disease. Eur Heart J. 1980;1:239 –245.
11. Voss H, Kupper W, Hanrath P, Mathey D, Montz R, Bucking J. Clinical correlations, lactate extraction, coronary venous blood flow and thallium-201 myocardial imaging in patients with isolated left anterior descending muscle bridges: normal variant or obstruction. Z Kardiol. 1980;69:347–352.
12. Somanath HS, Reddy KN, Gupta SK, Murthy JS, Rao AS, Abraham KA. Myocardial bridge (MB): an angiographic curiosity. Indian Heart J. 1989;41:296 –300.
13. Soran O, Pamir G, Erol C, Kocakavak C, Sabah I. The incidence and significance of myocardial bridge in a prospectively defined population of patients undergoing coronary angiography for chest pain. Tokai J Exp Clin Med. 2000;25:57– 60.
14. Geiringer E. The mural coronary. Am Heart J. 1951;41:359 –368.
15. Lee SS, Wu TL. The role of the mural coronary artery in prevention of coronary atherosclerosis. Arch Pathol. 1972;93:32–35.
16. Penther P, Blanc JJ, Boschat J, Granatelli D. Intramural anterior interventricular artery: anatomical study. Arch Mal Coeur Vaiss. 1977;70: 1075–1079.
17. Ferreira AG Jr, Trotter SE, Konig B Jr, Decourt LV, Fox K, Olsen EG. Myocardial bridges: morphological and functional aspects. Br Heart J. 1991;66:364 –367.
18. Baptista CA, DiDio LJ. The relationship between the directions of myocardial bridges and of the branches of the coronary arteries in the human heart. Surg Radiol Anat. 1992;14:137–140.
19. Sakuma M, Kamishirado H, Inoue T, Ichihara M, Takayanagi K, Hayashi Tet al. Acute myocardial infarction associated with myocardial bridge and coronary artery vasospasm. Int J Clin Pract 2002;56:721–722.
20. Nayar PG, Nyamu P, Venkitachalam L, Ajit SM. Myocardial infarction due to myocardial bridging. Indian Heart J 2002;54:711–712.
21. Berry JF, von Mering GO, Schmalfuss C, Hill JA, Kerensky RA. Systolic compression of the left anterior descending coronary artery: a case series, review of the literature, and therapeutic options including stenting. Catheter Cardiovasc Interv 2002;56:58–63.
22. Feld H, Guadanino V, Hollander G, Greengart A, Lichstein E, Shani J. Exercise-induced ventricular tachycardia in association with a myocardial bridge. Chest 1991;99:1295–1296.
23. Chee TP, Jensen DP, Padnick MB, Cornell WP, Desser KB. Myocardial bridging of the left anterior descending coronary artery resulting in subendocardial infarction. Arch Intern Med 1981;141:1703–1704.
24. Ferreira AG Jr, Trotter SE, Konig B Jr, Decourt LV, Fox K, Olsen EG. Myocardial bridges: morphological and functional aspects. Br Heart J 1991;66:364–367.
25. Noble J, Bourassa MG, Petitclerc R, Dyrda I. Myocardial bridging and milking effect of the left anterior descending artery: normal variant or obstruction? Am J Cardiol 1976;37:993–999
26. Polacek P, Kralove H. Relation of myocardial bridges and loops on the coronary arteries to coronary occlusions. Am Heart J 1961; 61:44–52.
27. Geiringer E. The mural coronary. Am Heart J. 1951;41:359–368.
28. Edwards JC, Burnsides C, Swarm RL, et al. Arteriosclerosis in the intramural and extramural portions of coronary arteries in the human heart. Circulation. 1956;13:235–241.
29. Pola´cˇek P, Kralove H. Relation of myocardial bridges and loops on the coronary arteries to coronary occlusions. Am Heart J. 1961;61:44–52.
30. Giampalmo A, Bronzini E, Bandini T. Sulla minor compromissioneaterosclerotica delle arteriecoronariequandosiano (per varianteanatomica) in situazioneintramiocardica. GiornaleItal Arterioscl. 1964;2:1–14.
31. Lee SS, Wu TL. The role of the mural coronary artery in prevention of coronary atherosclerosis. Arch Pathol. 1972;93:32–35.
32. Penther P, Blanc JJ, Boschat J, et al. L'artèreinterventriculaireantérieureintramurale: étudeanatomique. Arch Mal Coeur. 1977;70:1075–1079.

33. Risse M, Weiler G. Die koronareMuskelbrücke und ihreBeziehungzulokalerKoronarsklerose, regionalerMyokardischämie und Koronarspasmus.EinemorphometrischeStudie. Z Kardiol. 1985;74:700–705.
34. Ferreira AG Jr, Trotter SE, König B, et al. Myocardial bridges: morphologicaland functional aspects. Br Heart J. 1991;66:364–367.
35. Baptisda CAC, DiDio LJA. The relationship between the directions ofmyocardial bridges and the branches of the coronary arteries in the humanheart. Surg Radiol Anat. 1992;14:137–140.
36. Ortale JR, Gabriel EA, Lost C, et al. The anatomy of the coronary sinusand its tributaries. Surg Radiol Anat. 2001;23:15–21.
37. Kosinski A, Grzybiak M. Myocardial bridges in the human heart: morphological aspects. Folia Morphologica. 2001;60:65–68.
38. Noble J, Bourassa MG, Petitclerc R, et al. Myocardial bridging andmilking effect of the left anterior descending coronary artery: normalvariant or obstruction? Am J Cardiol. 1976;37:993–999.
39. Binet JP, Guiraudon G, Langlois J, et al. Angine de poitrine et pontsmusculairesurl'artèreinterventriculaireanterieure: a propos troiscasopérés. Arch Mal Coeur. 1978;71:251–258.
40. Ishimori T. Myocardial bridges: a new horizon in the evaluation ofischemic heart disease. CathCardiovascDiagn. 1980;6:355–357.
41. Greenspan M, Iskandrian AS, Catherwood E, et al. Myocardial bridgingof the LAD: evaluation using exercise thallium-201 myocardial scintigraphy.Cathet Cardiovasc Diagn. 1980;6:173–180.
42. Rossi L, Dander B, Nidasio GP, et al. Myocardial bridges and ischemicheart disease. Eur Heart J. 1980;1:239–245.
43. Voss H, Kupper W, Hanrath P, et al. Klinik, Laktatmetabolismus, Koronarvenenflussund biphasisches 201-Thallium-Myokardscintigramm beiMyokardbrücken des Ramus Descendens Anterior: VerlaufsvarianteoderObstruktion? Z Kardiol. 1980;69:347–352.
44. Kramer JR, Kitazume H, Proudfit WL, et al. Clinical significance ofisolated coronary bridges: benign and frequent condition involving theleft anterior descending artery. Am Heart J. 1982;103:283–288.
45. Angelini P, Tivellato M, Donis J, et al. Myocardial bridges: a review. Prog Cardiovasc Dis. 1983;26:75–88.
46. Garcia JF, VillalonAM, Chavero EP. Significadoclinico de lasbandasmuscularesen lasarterias coronaries. Arch InstCardiolMéx. 1983;53:413–420.
47. Wymore P, Yedlicka JW, Garcia-Medina V, et al. The incidence ofmyocardial bridges in heart transplants. CardiovascInterventRadiol.1989;12:202–206.
48. Somanath HS, Reddy KN, Gupta SK, et al. Myocardial bridge: an angiographic curiosity? Indian Heart J. 1989;41:296–300.
49. Gallet B, Adams C, Saudemont JP, et al. Pont myocardique de l'artèreinterventriculaireanterieureetinfarctus du myocarde. Le spasmecoronarie a-t-ilunrôle? Arch Mal Coeur. 1991;84:517–523.
50. Diefenbach C, Erbel R, Treese N, et al. Häufigkeit von Myokardbrückennachadrenerger Stimulation und NachlastsenkungbeiPatientenmit Angina Pectoris,aberunauffälligenKoronararterien. Z Kardiol. 1994;83:809–815.
51. Juillière Y, Berder V, Suty-Selton C, et al. Isolated myocardial bridgeswith angiographic milking of left anterior descending coronary artery: along-term follow-up study. Am Heart J. 1995;129:663–665.
52. Harikrishnan S, Sunder KR, Tharakan J, et al. Clinical and angiographicprofile and follow-up of myocardial bridges: a study of 21 cases. IndianHeart J. 1999;51:503–507.
53. Kneale BJ, Stewart AJ, Coltart DJ. A case of myocardial bridging: evaluation using intracoronary ultrasound, Doppler flow measurement, and quantitative coronary angiography. Heart 1996;76:374–376.
54. Tauth J, Sullebarger T. Myocardial infarction associated with myocardial bridging: case history and review of the literature. Cathet Cardiovasc Diagn 1997;40:364–367.
55. 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.
56. Amitani K, Yamaguchi T, Takahashi N, Uchida T, Kushikata Y, Munakata K et al. Two cases of myocardial bridge associated with myocardial ischemia [Japanese]. J Nippon Med Sch 2000; 67:206–209.
57. Schar B. Myocardial bridging: symptoms of coronary disease that sometimes is not [German]. Schweiz Rundsch Med Prax 2001; 90:1923–1928.

58. Akdemir R, Gunduz H, Emiroglu Y, Uyan C. Myocardial bridging as a cause of acute myocardial infarction: a case report. BMC Cardiovasc Disord 2002;2:15.
59. Yetman AT, McCrindle BW, MacDonald C, Freedom RM, Gow R. Myocardial bridging in children with hypertrophic cardiomyopathy— a risk factor for sudden death. N Engl J Med 2004; 339:1201–1209.
60. Yamaguchi M, Tangkawattana P, Hamlin RL. Myocardial bridging as a factor in heart disorders: critical review and hypothesis. Acta Anat (Basel) 1996;157:248–260.
61. Iversen S, Hake U, Mayer E, Erbel R, Diefenbach C, Oelert H. Surgical treatment of myocardial bridging causing coronary artery obstruction. Scand J Thorac Cardiovasc Surg 1992;26:107–111.
62. Noble J, Bourassa MG, Dyrda I, Petitclerc R. Hemodynamic significance of myocardial bridging and milking effect of the anterior interventricular artery: a mild variant or source of angina? [French] Schweiz Med Wochenschr 1976;106:1561–1563.
63. Gowda RM, Khan IA, Ansari AW, Cohen RA. Acute ST segment elevation myocardial infarction from myocardial bridging of left anterior descending coronary artery. Int J Cardiol 2003;90:117–118.
64. Bauters C, Chmait A, Tricot O, Lamblin N, Van Belle E, Lablanche JM. Images in cardiovascular medicine: coronary thrombosis and myocardial bridging. Circulation 2002;105:130.
65. ArnauVives MA, Martinez Dolz LV, AlmenarBonet L, Lalaguna LA, Ten Morro F, Palencia Perez M. Myocardial bridging as a cause of acute ischemia: description of a case and review of the literature [Spanish]. Rev Esp Cardiol 1999;52:441.
66. Laurent G, Cottin Y, Andre F, Pichon E, Piszker G, Gerard C et al. Symptomatic myocardial bridges. Apropos of 6 cases [French]. Arch Mal Coeur Vaiss 1996;89:883–887.
67. Baldassarre S, Unger P, Renard M. Acute myocardial infarction and myocardial bridging: a case report. Acta Cardiol 1996;51:461–465.
68. Mazzu A, Di Tano G, Cogode R, Lo Presti G. Myocardial bridging involving more than one site of the left anterior descending coronary artery: an uncommon cause of acute ischemic syndrome. Cathet Cardiovasc Diagn 1995;34:329–332.
69. Michael Tsokos, Michael J. P. Biggs, Benjamin Swift, and Mary N. Sheppard.: Myocardial Bridging: Is it Really a Cause of Sudden Cardiac Death? Forensic Pathology Reviews 2008;5:115-125.
70. Fabre A, Sheppard MN (2006) Sudden adult death syndrome and other non-ischaemic causes of sudden cardiac death. Heart 92:316–320.