ขนาดหลอดเลือดแดงที่เป็นทางเลือกใหม่ในการผ่าตัดหลอดเลือดหัวใจอุดตันในผู้ป่วยโรคกล้ามเนื้อหัวใจขาดเลือด : การศึกษาในศพคนไทย

นางสาว นัชราภรณ์ ต๊กควรเฮง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาวิทยาศาสตร์การแพทย์

คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2544

ISBN 974-03-0281-5

EXTERNAL DIAMETER OF ALTERNATIVE ARTERIAL CONDUIT IN CORONARY ARTERY BYPASS GRAFT FOR MYOCARDIAL REVASCULARIZATION IN THAI ADULT CADAVERS

Miss Natcharaporn Tokkunheng

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science in Medical Science

Program of Medical Science

Faculty of Medicine

Chulalongkorn University

Academic Year 2001

ISBN 974-03-0281-5

Thesis Title	External Diameter of Alternative Arterial Conduit in Coronary Artery Bypass Graft for Myocardial Revascularization in Thai Adult Cadavers
By	Miss Natcharaporn Tokkunheng
Field of study	Medical Science
Thesis Advisor	Associate Professor Tanvaa Tansatit, M.D.
Thesis Co-advisor	Associate Professor Vichai Benjacholamas, M.D.

Accepted by the Faculty of Medicine, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master 's Degree

……………………………………………….. Dean of Faculty of Medicine

(Professor Pirom Kamolratanakul, M.D.)

THESIS COMMITTEE

……………………………………………….. Chairman

(Associate Professor Vilai Chentanez, M.D.)

……………………………………………….. Thesis Advisor

(Associate Professor Tanvaa Tansatit, M.D.)

……………………………………………….. Thesis Co-advisor

(Associate Professor Vichai Benjacholamas, M.D.)

……………………………………………….. Member

(Professor Meechai Srisai, M.D., Ph.D.)

……………………………………………….. Member

(Col. Assistant Professor Kosum Chinsethagij, Ph.D.)

นัชราภรณ์ ต๊กควรเฮง : ขนาดหลอดเลือดแดงที่เป็นทางเลือกใหม่ในการผ่าตัดหลอดเลือดหัวใจอุดตันในผู้ป่วยโรคกล้ามเนื้อหัวใจขาดเลือด : การศึกษาในศพคนไทย. (External Diameter of Alternative Arterial Conduit in Coronary Artery Bypass Graft for Myocardial Revascularization in Thai Adult Cadavers) อ. ที่ปรึกษา : รศ.นพ. ธันวา ตันสถิตย์, อ. ที่ปรึกษาร่วม : รศ.นพ. วิชัย เบญจชลมาศ ; 70 หน้า. ISBN 974-03-0281-5.

การศึกษาขนาดของหลอดเลือดแดง radial, ulnar, internal mammary (IMA), right gastroepiploic (RGEA), peroneal, posterior tibial และ mid left anterior descending (mid LAD) ที่ใช้เป็นทางเลือกใหม่ในการผ่าตัดหลอดเลือดหัวใจอุดตัน ในศพคนไทย จำนวน 37 ราย ที่มีช่วงอายุ 45 ถึง 91 ปีที่บริจาคร่างกาย ณ ภาควิชากายวิภาคศาสตร์ คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ขนาดเส้นผ่าศูนย์กลางภายนอกและความยาวของหลอดเลือดแดงวัดโดยใช้ Vernier caliper precision 0.02 มิลลิเมตรและ Tape line ตามลำดับ พบว่าขนาดเส้นผ่าศูนย์กลางภายนอกโดยเฉลี่ยของหลอดเลือดแดง radial, ulnar, IMA, RGEA, peroneal, posterior tibial และ mid LAD มีค่า 2.67±0.40, 2.22±0.17, 2.39±0.24, 2.65±0.12, 2.58±0.80, 4.57±0.61 และ 3.08±0.62 มิลลิเมตรตามลำดับ และความยาวเฉลี่ยของหลอดเลือดแดง radial, ulnar, IMA, RGEA, peroneal และ posterior tibial มีค่า 20.17±1.68, 21.98±1.68, 16.71±1.02, 16.28±1.71, 23.01±1.43 และ 23.27±1.67 เซนติเมตรตามลำดับ จากผลที่ได้พบว่าหลอดเลือดแดงทุกเส้นที่นำมาศึกษามีขนาดเส้นผ่าศูนย์กลางภายนอกมากกว่า 1.5 มิลลิเมตรซึ่งมีความเหมาะสมที่จะใช้เป็นทางเลือกใหม่ในการทำ coronary artery bypass graft (CABG) โดยเฉพาะอย่างยิ่ง posterior tibial artery เนื่องจากมีขนาดเส้นผ่าศูนย์กลางภายนอกและความยาวมากที่สุด

นอกจากนี้ได้ศึกษาถึงความสัมพันธ์ระหว่างขนาดเส้นผ่าศูนย์กลางภายนอก ความยาวของหลอดเลือดแดงกับความสูงและกับความยาวของกระดูกใกล้หลอดเลือดแดงบริเวณนั้น พบว่าขนาดเส้นผ่าศูนย์กลางภายนอกของหลอดเลือดแดงไม่มีความสัมพันธ์กับทั้งความสูงและความยาวของกระดูกใกล้หลอดเลือดแดงบริเวณนั้น($p>0.05$) แต่พบว่าความยาวของหลอดเลือดแดงมีความสัมพันธ์กับทั้งความสูงและความยาวกระดูกใกล้หลอดเลือดแดงบริเวณนั้น ($p<0.001$)

หลักสูตร วิทยาศาสตร์การแพทย์	ลายมือชื่อนิสิต…………………………………………..
สาขาวิชา วิทยาศาสตร์การแพทย์	ลายมือชื่ออาจารย์ที่ปรึกษา……………………………….
ปีการศึกษา 2544	ลายมืออาจารย์ที่ปรึกษาร่วม…………………..………

427 522 56 30 : MAJOR MEDICAL SCIENCE

KEY WORD: ARTERIAL CONDUIT /CORONARY ARTERY BYPASS GRAFT /MYOCARDIAL REVASCULARIZATION

NATCHARAPORN TOKKUNHENG : EXTERNAL DIAMETER OF ALTERNATIVE ARTERIAL CONDUIT IN CORONARY ARTERY BYPASS GRAFT FOR MYOCARDIAL REVASCULARIZATION IN THAI ADULT CADAVERS.(THESIS TITLE) THESIS ADVISOR : ASSOC.PROF. TANVAA TANSATIT, M.D., THESIS COADVISOR : ASSOC.PROF. VICHAI BENJACHOLAMAS, M.D., 70 pp. ISBN 974-03-0281-5.

The morphometric study of arteries are the radial, ulnar, internal mammary (IMA), right gastroepiploic (RGEA), peroneal, posterior tibial and mid left anterior descending (mid LAD) in 37 Thai adult cadavers whose ages ranged from 45 to 91 years on the Department of Anatomy, Faculty of Medicine, Chulalongkorn University. The external diameter and length of arteries were measured by means of the Vernier caliper precision 0.02 mm and the Tape line, respectively. The mean external diameters of the radial artery, ulnar artery, IMA, RGEA, peroneal artery, posterior tibial artery and mid LAD were 2.67 ± 0.4, 2.22 ± 0.17, 2.39 ± 0.24, 2.65 ± 0.12, 2.58 ± 0.8, 4.57 ± 0.61 and 3.08 ± 0.62 mm, respectively. The mean lengths of the radial artery, ulnar artery, IMA, RGEA, peroneal artery and posterior tibial artery were 20.17 ± 1.68, 21.98 ± 1.68, 16.71 ± 1.02, 16.28 ± 1.71, 23.01 ± 1.43 and 23.27 ± 1.67 cm, respectively. The result of this study indicates that all of the study arteries are larger than 1.5 mm in diameter. Therefore, these arteries are suitable for a new choice of arterial conduits in coronary artery bypass graft (CABG). Especially the posterior tibial artery, it is suitable for CABG due to the largest in external diameter and the longest in length.

In addition, this thesis has studied on the association between the external arterial diameter, arterial length and height and also body part representing by bony length. The result shows that the external arterial diameters were not correlated with both height and body part representing by bony length ($p>0.05$), but the arterial lengths were correlated with both height and body part representing by bony length ($p<0.001$).

Department -	Student's signature……………………………………
Field of study Medical Science	Advisor's signature…………………………………….
Academic year 2001	Co-advisor's signature…………………………………

ACKNOWLEDGEMENT

This thesis has been successful from the valuable advice, helpful guidance, suggestions and interests of my advisor, Associate Professor Tanvaa Tansatit and my co-advisor, Associate Professor Vichai Benjacholamas for their encouragement and valuable supervision and intellectual inspiration throughout the study. They are always kind and helpful.

I would like to express my special thanks to Associate Professor Vilai Chentanez, Professor Meechai Srisai and Col. Assistant Professor Kosum Chinsethagij, Ph.D, for their criticism and valuable suggestions and also for their serving thesis committee.

I would like to thank the Department of Anatomy, Faculty of Medicine, Chulalongkorn University and other members for assistance at various times in the course of this research.

Finally, I will not forget to express special thanks to my family for their cheerfulness through my graduate study.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CABG	Coronary artery bypass graft
CHD	Coronary heart disease
cm	centimeter
HDL	High-density lipoprotein
IHD	Ischemic heart disease
IMA	Internal mammary artery
LDL	Low-density lipoprotein
mid LAD	mid left anterior descending artery
mm	millimeter
PA	Peroneal artery
PT	Posterior tibial artery
RA	Radial artery
RGEA	Right gastroepiploic artery
UA	Ulnar artery

CHAPTER I

INTRODUCTION

1. Background and Rationale

At present time, ischemic heart disease (IHD) is the principal cause of death of Thai people in middle to late age. Ischemic heart disease refers to consequence of atherosclerosis of the coronary arteries and is also called the coronary heart disease.[1,2] The lesions of atherosclerosis occur principally within the innermost layer of the arterial wall, the intima. The form and content of the advanced lesions of atherosclerotic vessels demonstrate the results of three fundamental biological processes, the accumulation of intimal smooth muscle cells together with variable numbers of accumulated macrophages and T-lymphocytes, the formation by the proliferated smooth muscle cells of large amounts of connective tissue matrix, including collagen and elastic fibers, and accumulation of lipid is principally in the form of cholesterol esters and free cholesterol within the cells as well as in the surrounding connective tissues. The advanced lesions are clotting (thrombosis) and associated with the fibrous capsule leading to occlusion of the vessel.[3-6] The lesions of atherosclerosis take different forms depending upon their anatomic site and risk factors to which each individual has been exposed.[7-9] Among many risk factors for atherosclerosis that have been shown to be important are cigarette smoking, hypertension, diabetes mellitus, age, obesity and male gender.

Cigarette smoking provides the strongest and most consistent correlation with the increased incidence of atherosclerosis.[10] The smokers have increased levels of oxidation products including oxidized of low-density lipoprotein (LDL).[11,12] These effects are along with direct effects of carbon monoxide and nicotine and lead to process of endothelial damage. Apparently, cessation of cigarette smoking decreases the risk for development of the clinical sequelae of atherosclerosis.[13]

Hypertension has been an associated risk factor in the individual with elevated blood pressure showing acceleration of atherosclerosis. The potential mechanisms by which hypertension may cause coronary heart disease (CHD) include impaired endothelial function, increased endothelial permeability to lipoproteins, increased oxidative stress, and hemodynamic stress triggering acute plaque rupture.

Diabetes mellitus is an independent risk factor for CHD, increasing risk by two to three times for men and three to five times for women.[14] Coronary heart disease is the leading cause of death in diabetic patients and approximately 25 percent of myocardial infarction (MI) survivors have diabetes.[15]

Age might be considered one of the most potent cardiovascular risk factors.[16,17] CHD incidence rates in men are similar to those in women 10 years older.[18] Approximately 52 percent of women and 46 percent of men will eventually die of atherosclerotic disease.[19]

Obesity promotes insulin resistance, hypertension, low high-density lipoprotein (HDL) cholesterol.[20,21] The obesity was strongly and positively correlated with the risk of CHD in univariate analysis. In general, the greater degree of overweight has the higher risk of coronary mortality.[22]

Male gender is much more prone to atherosclerosis than female and it has been suggested that female has a decreased incidence because of a protective function exerted by estrogens. Estrogens have their effects on the smooth muscle cells and other elements of atherogenesis shows that estrogens can have an antiproliferative effect on the smooth muscle and can be protective to the endothelium in relation to stimulation by growth factors and other agents.[23]

The incidence and prevalence of coronary heart disease increase sharply with many factors when risk factors coexist, they multiply the risk of CHD severalfold.[24] The end of result is plaques that cause luminal narrowing of the coronary arterial tree and often total occlusion. When severity of ischemia is prolonged, it may lead to myocardial infarction finally.[25] Myocardial infarction most commonly involves the left ventricle and interventricular septum, approximately one-third to two-thirds of patients with inferior wall infarction have some involvement of the right ventricle.[26]

Currently, there are many methods of treatments for patients who have obstructive coronary artery disease and consequent ischemic heart disease. There are as follows [27]

- Drug therapy
- Coronary artery balloon angioplasty
- Surgical treatment

Coronary artery bypass graft (CABG) has been accepted as surgical method of treatment for patient who has obstructive coronary artery stenosis. The surgical goal of the coronary artery surgery is to relieve symptoms, alleviate ischemia, reduce the possibility of subsequent cardiac events, and lengthen life.[28] The concept of complete revascularization has been used to signify the restoration of an adequate coronary circulation to all regions of the ischemic myocardium through bypass grafting of obstructed coronary arteries. In general, all vessels 1.5 mm or greater in diameter are suitable for CABG if free of significant distal plaque.[29] Graft patency has been correlated with the size of the recipient coronary artery.[30] A significantly reduced patency rate occurs when vessels less than 1.5 mm in diameter are bypassed. Formerly, the saphenous vein graft was the standard conduit. Atherosclerotic deterioration of this graft and the disproportionately large size of the graft to coronary artery have relegated the vein graft to secondary roles. Veins may be damaged by rough preparation, which results in separation and desquamation of the vascular endothelium.[31] Vein graft atherosclerosis is generally diffuse and has been associated with elevated serum cholesterol, low HDL cholesterol, cigarette smoking[32] and this graft may progress faster than native vessel atherosclerosis.[33] The saphenous veins grafts have an accelerated failure rate because of graft atherosclerosis beyond the fifth year.[34] When complete revascularization cannot be obtained with the saphenous veins, thus another source of conduit must be considered. The arteries leading to expanded use for CABG are so-called alternative arterial conduits. The arterial conduits are the right gastroepiploic artery (RGEA), the inferior epigastric artery (IEA), and the radial artery (RA) for primarily as supplements to both internal mammary arteries (IMA).

The internal mammary artery (IMA) has been used as a conduit for almost as long as the saphenous vein. The advantages of the IMA graft have been accepted broadly, both for its durability and for better survival compared with vein graft. The 10-year actuarial survival was significantly better for patients with the IMA grafts and the diameter of the IMA graft usually is a closer match to that of the recipient coronary artery than the diameter of the saphenous vein.[35] This graft was extended in the form of bilateral thoracic artery grafts, free (aortocoronary) arterial grafts. It has been proved to be a valuable alternative for treating patients with coronary stenosis. The disadvantages of the IMA grafts are (1) its use has been limited to grating one or two arteries, usually the left anterior descending artery or its diagonal branch and the right coronary artery,[36,37] and(2) the IMA grafts are more demanding technique and operative time.[38,39]

The right gastroepiploic artery (RGEA) is a third arterial conduit with artery to artery anastomoses of comparable sizes. The advantages of the RGEA grafts are as follows (1) it can be harvested simultaneously with the IMA and the saphenous vein, (2) the proximal anastomosis (free grafts) is easy, (3) its use avoids bilateral IMA graft in patients at high risk for sternal infection, and(4) short-term studies of graft patency showed good results with patency rates in 90 to 100 percents. The disadvantages of the RGEA grafts are (1) the abdominal cavity must be exposed, (2) the graft is not available after a gastric operation, (3) there is the possibility of graft damage with future abdominal procedures, (4) the operating time is longer than the IMA, (5) at present, long-term patency rate is uncertain, and(6) this graft appears to be more prone to vasospasm than the IMA graft.[40,41]

The inferior epigastric artery (IEA) has been proposed as another alternative arterial conduit. The advantages of the IEA grafts are as follows (1) the harvesting technique can be with no special instrumentation, (2) it can be harvested simultaneously with the IMA and the saphenous vein if this is available, (3) short-term patency showed good results. The disadvantages of the IEA grafts are (1) the short length and variability in its size, and(2) its graft appears to be more prone to tendency for vasospasm.[42]

The radial artery has been advocated as an alternative to the saphenous vein for CABG because of its inherent advantages: (1) the large caliber and invariable in its size, (2) the quality of its wall (thick and resistant) offers very good technical conditions for coronary and aortic anatomosis, (3) it was good length, (4) it can be harvested concurrently with other arteries and vein grafts, and(5) the encouraging short-term results.[43,44] The disadvantages of this graft are (1) its greater tendency to vasospasm, (2)the harvesting this graft necessitates prior assessment of the Allen's test, and(3) the radial artery T-graft has complicated technique.[45,46]

2. Research Questions

Primary Question

: How much are the sizes of alternative arterial conduits (the radial artery, the ulnar artery, the internal mammary arteries (IMA), the peroneal artery and the posterior tibial artery) for a new choice of coronary artery bypass graft ?

Secondary Questions

1. How much are the sizes of the right gastroepiploic artery (RGEA) and the mid left anterior descending artery (mid LAD) ?
2. What is the relation between the external arterial diameter and height ?
3. What is the relation between the external arterial diameter and body part representing by bony length ?
4. What is the relation between the length of arteries and height?
5. What is the relation between the length of arteries and body part representing by bony length?

3. Limitation of the study

This thesis is the study on cadavers fixed with formalin, therefore the data may have few errors of measurement.

4. Objectives of the research

This thesis is aimed to investigate the external diameter and length of arteries in order to gain basic information for considering alternative arterial conduits in CABG. The investigations include :

4.1 To measure the external diameter and length of the radial artery, the ulnar artery, the internal mammary arteries (IMA), the peroneal artery and the posterior tibial artery.

4.2 To measure the external diameter and length of the right gastroepiploic artery (RGEA).

4.3 To measure the external diameter of mid left anterior descending artery (mid LAD).

4.4 To assess the relation between the external arterial diameter and height.

4.5 To assess the relation between the external arterial diameter and body part representing by bony length.

4.6 To assess the relation between the length of arteries and height.

4.7 To assess the relation between the length of arteries and body part representing by bony length.

5. Key words

Arterial conduit
Coronary artery bypass graft
Myocardial revascularization

6. Expected Benefit & Application

The result of this study may be beneficial in :-

1. Assisting in considering the alternative arterial conduit for a new choice of the coronary artery bypass graft.
2. Establishing the anatomical data for assessing the relation between:
   - 2.1 External arterial diameter and height and also body part representing by bony length.
   - 2.2 Arterial length and height and also body part representing by bony length.
3. The estimation of the arterial length applied to patients of different height and body part representing by bony length.

7. Research Methodology

- Subject collection

  The 37 Thai adult cadavers were collected with the ages ranged from 45 to 91 years.

- Process of study

Step 1. The cadavers were defined into 4 portions including the upper limb, the lower limb, the abdomen and the thorax.

Step 2. The arteries in each portion were harvested. The upper limb harvested arteries are the radial artery and the ulnar artery. The lower limb harvested arteries are the peroneal artery and the posterior tibial artery. The abdomen harvested artery of the stomach is the right gastroepiploic artery (RGEA). The thorax harvested arteries are the both internal mammary arteries (IMA). The heart harvested artery is the mid left anterior descending (mid LAD).

Step 3. The body part representing by bony length of each portion; the radial artery refers to the radius, the ulnar artery refers to the ulna, the peroneal artery refers to the fibula, the posterior tibial artery refers to the tibia and the IMA refers to the sternum.

Step 4. The external arterial diameter was measured by the Vernier caliper precision 0.02 mm in millimeters (mm).The lengths of arteries and body part representing by bony length were measured by Tape line in centimeters (cm).

Step 5. The average of external diameter and length of arteries and also body part representing by bony length were analyzed.

8. Administration and Time Schedule

phase	process	Time schedule							
		4	6	8	10	12	14	16	18
1	Preparation phase	→	→						
2	Subjects collection		→	→	→	→			
3	Data and statistic analysis				→	→	→		
4	Conclusion and writing the thesis						→	→	→

CHAPTER II

LITERATURE REVIEW

Many observations are studied on basic anatomy of the vessels. The review will present data only on the field of the arterial anatomy that is related to this study.

In 1993 Guerra et al. [47] described the noninvasive technique to assess the coronary artery anatomy in 100 asymptomatic atherosclerosis subjects (89 men and 11 women, mean age 40$\pm$6 years) by means of the ultrafast computed tomography (UFCT), with 3 mm thick ECG gated scans. The external diameter of the left main (LD) and the right (RD) coronary arteries were measured. The external diameter of total coronary artery (TD) refers to the summation of the LD and the RD (TD = LD+RD). The mean external diameter of the LD next to the left anterior descending artery (LAD) was 4.23$\pm$0.85 mm, and the mean of the RD diameter was 3.06$\pm$1.08 mm. The UFCT can be used for a noninvasive measurement of the coronary artery diameters and may be used to detect the early change of atherosclerosis individually and also in the population. After that in 1996 O' Connor et al.[48] reported the height, weight, sex, age, status at hospital discharge, and luminal diameter of the mid LAD in 1325 patients undergoing CABG. The small vessel size was associated with substantially increased risk of inhospital mortality. The vessel size was strongly related to both sex and body size. In multiple linear regression analysis, the vessel size was positively correlated with body surface ($p<0.01$), body mass index ($p=0.004$), height ($p=0.001$), and weight ($p=0.001$). The mean internal diameter of the mid LAD was 2.04 mm for men (n=963) and 1.81 mm for women (n=362). The median of the vessel size was 2.0 mm for both groups. However, in-patients with the same body size, the mean of the mid LAD diameter in men was significantly greater than that in women (mean difference ranged from 0.14 to 0.23 mm).

In 1986 Timmons[49]studied the vascular anatomy of the radial forearm flap by dissection of 56 cadavers with various techniques, including ink, latex and barium sulfate injections. The radial artery branches were divided into two main groups, one in the proximal half and the other in the distal half of the forearm.The proximal group can be considered as two subgroups. The most proximal branch arises either close to the origin of the radial artery itself or from the radial recurrent artery. Another major vessel is in the second proximal subgroup. In the distal half of the forearm, there are branches every 1 to 2 cm. Later on, Inoue et al.1996[50] studied the anatomic contribution to each tissue layer from the skin to bone derived from the brachial, radial, ulnar, anterior and posterior interosseous arteries between the elbow and the wrist. The radial and ulnar arteries give the main blood supply to the forearm. Proximally, the muscles receive branches from the brachial artery, the ulnar artery or the ulnar recurrent artery. Distally, they receive branches from the radial artery or the ulnar artery. The diameters of arterial branches were measured with the Vernier calipers precision 0.02 mm at their origins from the arterial source. The mean diameter of arterial branches, number of branches per arm and the position of branches of the brachial artery was 0.83 mm, 4 brs/arm and located between the biceps brachii and the triceps brachii muscles (58%). The mean diameter of the radial artery was 0.62 mm and had 12 brs/arm located between the brachioradialis and the flexor carpi radialis muscles (50%). The mean diameter of the ulnar artery was 0.69 mm and had 11.37/arm located between the flexor carpi ulnaris and the flexor digitorum superficialis muscles (38%). These data can be used to determine the position, the pattern of distribution of arterial branches in the forearm, the diameter and total number of vessels to the muscle of forearm. At the same time, Shima et al.[51] performed morphometric investigation of the forearm vessels for using in free forearm flap on 52 Japanese cadavers by the stereoscopic microscope (SMZ-10, Nikon) and the digital measuring system. The mean inner diameter of the radial and the ulnar arteries were 2.3$\pm$0.5 mm and 1.6$\pm$0.5 mm, respectively. The radial artery was measured at three points. Proximally, it was measured at 1 cm distal to the origin of the radial artery (2.3$\pm$0.5mm). Distally, it was measured on the Lister's tubercle (2.2$\pm$0.6mm). The third point was measured between the proximal and the distal points (2.2$\pm$0.6mm). There were significant differences between the inner diameters of the proximal and the distal points on the left radial artery. In individual subject, there was no significant difference between the inner diameter of the right and the left sides. The mean length of the radial artery was 18.1$\pm$1.7 cm.

In 1996 Takemura et al.[52] examined the physiologic properties of the internal thoracic artery (ITA) graft and assessed the relationship of the coronary artery stenosis to actual ITA flow at rest and during exercise by the Transthoracic color doppler echography. The internal thoracic artery diameter increased significantly from 2.2 mm to 2.4 mm after operation. In the next year Feng (1997)[53] investigated in terms of the external vessel diameter, vessel size discrepancy of the internal mammary and the thoracodorsal vessels. The internal mammary artery (IMA) diameter (2.36±0.55 mm, n=51) was significantly larger than the thoracodorsal artery diameter (1.79±0.34 mm, n=23; p<0.001). There was no significant difference between the diameters of the internal mammary vein (2.6±0.58 mm, n=52) and the thoracodorsal vein (2.51±0.5 mm, n=23; p=0.930). The right IMA (2.52±0.51 mm) was significantly larger external diameter than the left IMA (2.30±0.55 mm; p=0.046). The right internal mammary vein (2.89±0.56 mm) also was significantly larger external diameter than the left internal mammary vein (2.31±0.48 mm ; p=0.002).

In 1993 Strauch et al.[54] studied anatomy of the greater omentum and blood vessels. The gastroepiploic arterial arch that lies about a fingerbreadth from the greater curvature between its anterior two layers. From the gastroepiploic arterial arch, several short branches arise upward to the greater curvature of the stomach, and the three major omental arteries (right, middle, and left) course downward to the greater omentum. The middle omental artery at its terminal portion branches into the right and the left terminal segments that anastomose with the corresponding branches of the right and left omental arteries to form the arterial network of the greater omentum. On the right side, there is an accessory omental artery that branches from the right gastroepiploic artery and does not join the arterial network. The right gastroepiploic artery is the dominant vessel of the stomach. The mean external diameter of the right and the left gastroepiploic artery were 2.8±0.9 mm and 1.8 mm, respectively. At the same time, Nakao et al.[55] measured the postoperative graft diameter of the right gastroepiploic artery on the coronary artery revascularization in 55 cases. The patency ratio of the right gastroepiploic artery grafts was satisfactory, with an average diameter of 2.1mm (range from 1.2 to 3.5 mm).

In 1986 Wei et al.[56] studied anatomy of the cutaneous branches of the peroneal artery which supply the skin on the lateral aspect of the leg. The cutaneous branches of the peroneal artery, four to seven in number, are distributed segmentally at intervals of 2 to 6 cm from a distance of 4 to 27 cm below the fibula head. The diameter of these vessels at their origin ranges from 0.8 to 1.7 mm. In addition, the fibula matches the size of radius and ulna. Later on, in 1990 Yoshimura et al.[57] investigated the anatomy of the peroneal artery and vein and their branches was carried out on 80 adult cadaver legs. The mean number of the cutaneous branches was 4.8 ± 1.4 branches per leg. The mean length of the cutaneous branches was 5.4 ± 1.5 cm. The operating microscope was used to measure the external diameter of the cutaneous branches at the skin distribution site of the artery and vein. The mean of external diameter was 0.6 ± 0.2 mm for the arterial branches and 0.8 ± 0.3 mm for the vein branches and 1.6 ± 0.2 mm for the peroneal artery. Subsequently, Wu et al. 1993[58] studied the anatomic features of the skin and muscular branches of the posterior tibial vessels in 20 legs of 10 fresh cadavers. The mean external diameter of the posterior tibial artery was 10 ± 0.5 mm. The longest segment of the cutaneous branches was 6.7 ± 1.0 cm found between the direct muscular branches and the flexor digitorum longus muscle. This study is more practical approach when applied to patients of different height and leg length. Later on, Benjacholamas et al. 2000[59] reported a 64-year-old male having a restenosed coronary artery eight years after coronary bypass graft (CABG) due to needing a redo CABG. The usual graft conduits were not sufficient for his condition. Therefore, a posterior tibial artery was selected and used for graft conduit. This graft conduit had never previously been used. The operation was successful without any morbidity.

In this research, we choose to study the radial artery, the ulnar artery, the both IMA, the RGEA, the peroneal artery and the posterior tibial artery for new choices of alternative arterial conduit for coronary artery bypass graft.

CHAPTER III

MATERIALS AND METHODS

1. Materials

1.1 Population and Specimen

The study was carried on 37 Thai adult cadavers with the age between 45 to 91years old from the Department of Anatomy, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. The mean age and height are 73.66 $\pm$13.97 years and 165 $\pm$ 7.61 cm, respectively.

1.2 Method of Sampling Selection

The specimen selection is non-probability sampling by means of the convenient sampling for simplified descriptive items of the Thai adult cadavers.

The specimens were chose by the convenient selection from the cadavers and all specimens were studied due to the limitation a small numbers of specimens. Total numbers of specimen are 37 cases (male=19, female=18).

1.3 Instruments

The instrument of this study can be detailed as follows: -

1.3.1 The Vernier caliper precision 0.02 mm was used to measure of the external arterial diameters in millimeters (mm).

1.3.2 The cone shape tip-calibrating probe.

1.3.3 The Tape line was used to measure the length of arteries and also body part representing by bony length in centimeters (cm).

2. Methods

2.1 Research methods

1. The cadavers were separated into 4 portions including the upper limb, the lower limb, the abdomen and the thorax.

2. The arteries in each portion were harvested and each specimen was measured 3 times before calculating the average.
3. The upper limb harvested arteries are the radial artery and the ulnar artery. The radial artery was harvested from the bifurcation of the brachial artery to the styloid process of the radius. The external diameters of this artery were measured at 3 points by a caliper. The proximal end was measured where it bifurcated from the brachial artery. The distal end was measured at the styloid process of the radius. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from the point of origin of the radial recurrent artery to the styloid process of the radius by the Tape line.
4. The ulnar artery was harvested from the bifurcation of the brachial artery to the styloid process of the ulna.The external diameters of this artery were measured at 3 points by a caliper. The proximal end was measured where it bifurcated from the brachial artery. The distal end was measured at the styloid process of the ulna. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from the point of origin of the ulnar recurrent artery to the styloid process of the ulna by the Tape line.
5. The thorax harvested arteries are the both IMA. The IMA was harvested from the bifurcation of the subclavian artery to the xiphoid process of the sternum. The external diameters of this artery were measured at 3 points by a caliper.The proximal end was measured where it bifurcated from the subclavian artery. The distal end was measured at the xiphoid process of the sternum. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from the bifurcation of the subclavian artery to the xiphoid process of the sternum by the Tape line.
6. The heart harvested artery is the left coronary artery. This artery takes origin from the posterior aspect of the root of the ascending aorta and runs to the left behind the pulmonary trunk where its major branch arise, the anterior interventricular artery or the left anterior descending artery (LAD). This artery descends in the anterior interventricular groove toward the apex of the heart. The mid LAD was measured of

the external diameter by a caliper at the one-third of the distance from its proximal end.

7. The abdomen harvested artery of the stomach is the RGEA. The RGEA was harvested from the pyloric part of the stomach to the left gastorepiploic artery. The external diameters of this artery were measured at 3 points by a caliper. The proximal end was measured near the pyloric part of the stomach. The distal end was measured close to the left gastorepiploic artery. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from the pyloric part of the stomach to the left gastorepiploic artery by the Tape line.
8. The lower limb harvested arteries are the peroneal artery and the posterior tibial artery.The peroneal artery was harvested from the bifurcation of the posterior tibial artery to the tip of the lateral malleolus of fibula. The external diameters of this artery were measured at 3 points by a caliper. The proximal end was measured where it bifurcated from the posterior tibial artery. The distal end was measured at the tip of the lateral malleolus of fibula. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from the bifurcation of the posterior tibial artery to the tip of the lateral malleolus of fibula by the Tape line.
9. The posterior tibial artery was harvested from lower border of the popliteus muscle to the tip of the medial malleolus of tibia. The external diameters of this artery were measured at 3 points by a caliper. The proximal end was measured at lower border of the popliteus muscle. The distal end was measured at the tip of the medial malleolus of tibia. The middle point was measured at the mid point between the proximal and the distal ends. The length of this artery was measured from lower border of the popliteus muscle to the tip of the medial malleolus of tibia by the Tape line.
10. The body part representing by bony length of each portion was measured by the Tape line. The radial artery refers to the radius and the length of this bone is measured from the head of radius to the styloid process of the radius.

11. The ulnar artery refers to the ulna and the length of this bone is measured from the olecranon process of the ulna to the styloid process of the ulna.
12. The IMA refers to the sternum and the length of this bone is measured from the sternal notch to the xiphoid process of the sternum.
13. The peroneal artery refers to the fibula and the length of this bone is measured from the head of fibula to the tip of the lateral malleolus of fibula.
14. The posterior tibial artery refers to the tibia and the length of this bone is measured from the medial condyle of the tibia to the tip of the medial malleolus of tibia.
15. The mean of the external diameter and the length of arteries and also body part representing by bony length were analyzed.

2.2 Method of measurement

How to measure the external arterial diameter: the cone shape tip calibrating probe was inserted lightly into the lumen of the artery until it is fixed, then the external diameter was measured at that end by a caliper. The measurement sites were summarized in Table 1.

2.3 Statistic analysis

2.3.1 The analysis of difference between the external arterial diameter at each measurement site (proximal end, middle end, distal end) was determined by the Analysis of variance (Anova) with repeated measures (p value<0.05) from the Statistical Packages for the Social Science (SPSS) program.[60,61]

2.3.2 The analysis of difference between the external arterial diameter of the right and the left sides was determined by the Matched-pairs t-test (p value<0.05) from the SPSS program.[60,61]

2.3.3 The analysis of differences length between the arterial length and body part representing by bony length of the right and the left sides were determined by the Matched-pairs t-test (p value<0.05) from the SPSS program.[60,61]

2.3.4 The analysis of correlation was determined by the Simple linear regression from the SPSS program for finding the relationship as follows[60-63]

- To consider the associations between the external arterial diameter and height and also body part representing by bony length.
- To consider the associations between the arterial length and height and also body part representing by bony length.

2.3.5 The analysis of difference between the external arterial diameter of male and female was determined by the Unpairs t-test (p value<0.05) from the SPSS program.[62,63]

2.3.6 The analysis of differences length between the arterial length and body part representing by bony length of male and female were determined by the Unpairs t-test (p value<0.05) from the SPSS program.[62,63]

Table 1 Measurement sites of the external diameter, length of arteries and body part representing by bony length.

Artery	Measurement sites	
	Diameter (mm)	Length(cm)
RA	Proximal : bifurcation from brachial artery Distal : styloid process of radius Middle : between proximal and distal	Begin : near origin of radial recurrent artery End : styloid process of radius
Radius	-	Begin : head of radius End : styloid process of radius
UA	Proximal : bifurcation from brachial artery Distal : styloid process of ulna Middle : between proximal and distal	Begin : near origin of ulnar recurrent artery End : styloid process of ulna
Ulna	-	Begin : olecranon process of ulna End : styloid process of ulna
IMA	Proximal : bifurcation from subclavian artery Distal : xiphoid process of sternum Middle : between proximal and distal	Begin : bifurcation from subclavian artery End : xiphoid process of sternum
Sternum	-	Begin : sternal notch End : xiphoid process of sternum
RGEA	Proximal: near pyloric part of stomach Distal : near left gastroepiploic artery Middle : between proximal and distal	Begin : near pyloric part of stomach End : near left gastroepiploic artery
PA	Proximal : bifurcation from posterior tibial artery Distal : tip of lateral malleolus Middle : between proximal and distal	Begin : bifurcation from posterior tibial artery End : tip of lateral malleolus
Fibula	-	Begin : head of fibula End : tip of lateral malleolus
PT	Proximal : lower border of popliteus muscle Distal : tip of medial malleolus Middle : between proximal and distal	Begin : lower border of popliteus muscle End : tip of medial malleolus
Tibia	-	Begin : medial condyle of tibia End : tip of medial malleolus

RA: radial artery, UA: ulnar artery, IMA: internal mammary arteries, RGEA: right gastriepiploic artery, PA: peroneal artery, PT: posterior tibial artery, Proximal: the start site of measurement, Distal: the end site of measurement, Length : the lengths of arteries were measured from the beginning site to the end site.

CHAPTER IV

RESULTS AND DISCUSSIONS

Results

The result of this research can be presented into 8 parts as follows :-

1. Result of the external arterial diameter.
2. Result of the arterial length and body part representing by bony length.
3. Result of the comparison between the external arterial diameter at each measurement site.
4. Result of the comparison between the external arterial diameter of the right and left sides.
5. Result of the comparison between the arterial length and body part representing by bony length of the right and the left sides.
6. Result of the correlation was divided into:
   - 6.1 The correlation between the external arterial diameter and height.
   - 6.2 The correlation between the external arterial diameter and body part representing by bony length.
   - 6.3 The correlation between the arterial length and height.
   - 6.4 The correlation between the arterial length and body part representing by bony length.
7. Result of the comparison between the external arterial diameter of male and female.
8. Result of the comparison between the arterial length and body part representing by bony length of male and female.

The result of the external diameter and length of arteries were summarized in Table 2 for all subjects and were showed in detail with statistical analyses in Tables 3,4,5,6,9 and 10.

1. Result of the external arterial diameter

The average of the external arterial diameter was presented in mean± SD (Table 3). The mean external diameters of the radial artery, the ulnar artery, the IMA, the RGEA, the peroneal artery, the posterior tibial artery and the mid LAD were 2.67±0.4mm(n:68), 2.22±0.17mm(n:68), 2.39±0.24mm(n:62), 2.65±0.12mm(n:31), 2.58±0.8mm(n:48), 4.57±0.61mm (n:62) and 3.08±0.62mm(n:32), respectively.

2. Result of the arterial length and body part representing by bony length

2.1 The average of the arterial length

The result was showed in mean±SD (Table 3). The mean lengths of the radial artery, the ulnar artery, the IMA, the RGEA, the peroneal artery and the posterior tibial artery were 20.17±1.68cm(n:68), 21.98±1.68cm(n:68), 16.71±1.02cm(n:62), 16.28±1.71cm(n:32), 23.01±1.43cm(n:66) and 23.27±1.67cm(n:64), respectively.

2.2 The average of the body part representing by bony length

The result of body part representing by bony length was presented in mean±SD (Table 3). The mean lengths of the radius, the ulna, the sternum, the fibula and the tibia were 22.09±1.97 cm(n:68), 23.98±2.25cm(n:68), 14.88±1.13cm(n:31), 33.54±1.71cm(n:70), and 32.38±1.72cm(n:68), respectively.

3.Result of the comparison between the external arterial diameter at each measurement site

The result of differences between the external arterial diameter at each measurement site (the proximal end, the middle end and the distal end) was showed in mean±SD (Table 4). The external diameter at each measurement site of the radial artery, the ulnar artery, the IMA, the RGEA, the peroneal artery and the posterior tibial artery were determined by the Anova with repeated measures. The results of the comparison between the external arterial diameter showed significant difference of the proximal end, the middle end and the distal end at level of p value <0.001. Especially, the external diameter of the posterior tibial artery was highly different between the proximal end (6.53±0.80mm), the middle end (4.30±0.85mm) and the distal end (2.64±0.58mm). However, the external diameter of the RGEA showed significant difference between the proximal and the middle ends (p value<0.001), whereas the middle and the distal ends showed no significant differences (p value = 0.172).

4. Result of the comparison between the external arterial diameter of the right and the left sides

The result was presented in mean±SD (Table 5). Most of the studied arteries; the radial artery, the ulnar artery, the IMA, and the posterior tibial artery showed significant differences between the external diameters of the right and the left sides (p value<0.05). However, the peroneal artery showed no significant difference between the external diameter of the right and the left sides (p value = 0.643).

5. Result of the comparison between length of the artery and body part representing by bony length

The results of difference between the length of arteries and body part representing by bony length were presented in mean±SD (Table 6).

5.1 The comparison between the arterial length of the right and the left sides

Most of the studied arteries; the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery showed no significant differences between the arterial length of the right and the left sides (p value>0.05). However, the radial artery showed significant differences between the length of the right and the left sides (p value = 0.001).

5.2 The comparison between the body part representing by bony length of the right and the left sides

The mean difference between length of the body part representing by bony length of the radius and the ulna showed significant differences of the right and the left sides (p value <0.001). Nevertheless, the mean lengths of the fibula and the tibia showed no significant differences between the right and left sides (p value >0.05).

6. Result of the correlation

The results of all correlations were determined by the Simple linear regression[60-63] and presented in many factors are the coefficient of determination (R-square; %), the standard error of the estimate (SE), the constant (a), the regression coefficient (b) and p value at significant level 0.05. The results of the correlation were divided into 4 parts as follows:

6.1 The correlation between the external arterial diameter and height

Pairwise correlations between the external arterial diameter and height were presented in Table 7. The result of the correlation analysis of the mid LAD showed the maximum R-square value (29.6%). The minimum R-square value was 0.1% in the ulnar artery. The R-square values of the RGEA, the IMA, the radial artery, the posterior tibial artery and the peroneal artery were 12.7%, 10.4%, 6.6%, 1.2% and 0.3%, respectively. Most of the external arterial diameters; the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery were not correlated with height (p value >0.05). However, the external diameters of the RGEA (p value=0.049) and the mid LAD (p value=0.001) were weakly and strongly positive correlation with height, respectively (Figures 1 and 2).

6.2The correlation between the external arterial diameter and body part representing by bony length

Pairwise correlations between the external arterial diameter and body part representing by bony length were presented in Table 7. The results of all the correlations analysis showed the smallest R-square values (%) such as the peroneal artery was R-square value 0.10% and the posterior tibial artery was R-square value 0.00%, respectively. The scattergrams for these correlations with the great p value were showed in Figures 3 and 4. All of the studied external arterial diameters; the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery were not correlated with body part representing by bony length (p value >0.05).

6.3 The correlation between the arterial length and height

Pairwise correlations between the arterial length and height were showed in detail with statistic analyses in Table 8.The results of correlation analysis showed high tendency of the R-square value (%). The maximum R-square value was 75.4% in the peroneal artery. The minimum R-square value was 0.3% in the RGEA. The R-square values of the radial artery, the IMA, the posterior tibial artery and the ulnar artery were 73.6%, 66.9%, 50.1% and 40.9%, respectively. The scattergrams for these correlations gave the smallest p values. Most of the studied arterial lengths; the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery were strongly and positively correlated with height (p value <0.001) and inversely length of the RGEA was not correlated with height (p value=0.774) (see Figure 5). Figures 6, 7 and 8 shows the scattergram for those correlations with the smallest p values.

6.4 The correlation between the arterial length and body part representing by bony length

Pairwise correlations between the arterial length and body part representing by bony length were presented in detail with statistical analyses in Table 8.The results of all the correlations analysis showed the great tendency of R-square values (%). The maximum R-square value was 86.6% in the radius. The minimum R-square value was 58.2% in the tibia. The R-square values of the sternum, the fibula and the ulna were

76.5%, 72.4% and 65.4%, respectively. All of the studied arterial lengths; the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery were strongly and positively correlated with body part representing by bony length (p value <0.001). Figures 9 and 10 shows the scattergrams for those correlations with the smallest p values.

7. Result of the comparison between the external arterial diameter of male and female

The results of difference between the external arterial diameter of male and female were showed in mean±SD (Table 9). The average external diameters of the radial artery, the IMA, the RGEA, the peroneal artery and the posterior tibial artery showed no significant differences between the external arterial diameters of male and female (p value >0.05). However, the ulnar artery and the mid LAD showed significant differences between the external arterial diameters of male and female (p value <0.05).

8. Result of the comparison between the arterial length and body part representing by bony length of male and female

The results of difference between the length of arteries and body part representing by bony length of male and female were presented in mean±SD (Table 10).

8.1 The comparison between the arterial length of male and female

The average lengths of the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery showed significant differences between length of male and female (p value<0.05). However, the RGEA showed no significant difference between the length of male and female (p value =0.761).

8.2 The comparison between the body part representing by bony length of male and female

All of the average lengths the body part representing by bony length; the radius, the ulna, the sternum, the fibula and the tibia showed significant differences between male and female at level of p value <0.001.

Discussions

From our results, all of the studied external arterial diameters (the radial artery, the ulnar artery, the IMA, the RGEA, the peroneal artery, the posterior tibial artery and the mid LAD) were larger than the standard of vessel size (1.5 mm) for the coronary artery bypass graft (CABG). The largest average of the external diameter was 4.57±0.61mm in the posterior tibial artery and the smallest average of the external diameter was 2.2±0.17mm in the ulnar artery. The longest average length was 23.27±1.67cm in the posterior tibial artery and the shortest average length was 16.28±1.71cm in the RGEA. The longest average length of the body part representing by bony length was 33.54±1.71cm in the fibula and the shortest average length was 14.88±1.13 cm in the sternum (Table 3). The result of this study was different from other reports due to the method of measurement (the internal or external diameter), the specimens (the cadavers or patients) and the instruments (Table 11). Yoshimura et al.1990[57] measured external diameter of the peroneal artery on 40 Japanese adult cadavers by means of the operating microscope. The mean external diameter of the peroneal artery was 1.6±0.2 mm. In 1993 Strauch[54] described external diameter of the RGEA on adult cadavers by a caliper. The mean external diameter of the RGEA was 2.80±0.9 mm. Wu et al. 1993 [58] determined external diameter of the posterior tibial artery on 10 fresh cadavers with a microscope. The mean external diameter of the posterior tibial artery was 10±0.50 mm. Guerra et al. 1993 [47] described external diameter of the left coronary artery close to the mid LAD in 100 patients by using the ultrafast computed tomography (UFCT). The mean external diameter of this artery was 4.23±0.85 mm. In 1996 Shima et al.[51] measured internal diameter of the radial and the ulnar arteries on 52 Japanese cadavers by means of the stereoscopic microscope (SMZ). The mean external diameters of the radial and the ulnar arteries were 2.3±0.5 mm and 1.6±0.5 mm, respectively. O' Connor et al. 1996 [48] determined internal diameter of the mid LAD in 1325 patients undergoing CABG with a set of graduated probes. The mean internal diameter of the mid LAD was 2.04 mm for men and 1.81 mm for women. In 1997 Feng [53] measured external diameter of the IMA in 81 patients underwent breast free-flap reconstruction by a caliper.The mean external diameter of the IMA was 2.36$\pm$0.55 mm. The external arterial diameter in the present study tended to be slightly less than in other reports (Strauch 1993, Wu et al. 1993, Guerra et al. 1993). However, the external diameter of the peroneal artery in this study tended to be slightly more than that reported by Yoshimura et al. (1990). These results show that the mean of external arterial diameters were differences between the instruments (the caliper and the other instruments). The external diameter of the IMA in this study was similar to that reported by Feng (1997). This result presents that the mean of external arterial diameters were no differences between the specimens (the cadavers and the patients). In the present study, a tape line was used to measure the distance of arteries between the measurement points. This method is as well as accurate from other methods for measuring vessels (Shima 1996 used a silk thread to measure the vessels length). The average length of artery in the present study is suitable for a free graft in CABG.

In this study, the differences between the external arterial diameters at each measurement site showed significant differences of the proximal, the middle and the distal ends (p value <0.001), except for the RGEA diameter showed no significant differences between the middle and the distal ends (p value =0.172). These results show that the RGEA is invariable in its size (Table 4). Moreover, the external arterial diameter decreased from the proximal to distal portions. From our results, regarding the arterial width, if an artery of large diameter is needed for anastomosis, the proximal site is suitable for anastomosis.

The presented results of the mean external arterial diameters showed significant differences between the right and the left sides (p value<0.05). However, the peroneal artery diameter showed no significant difference between the right and the left sides (p value=0.643) (Table 5). The mean arterial lengths showed no significant differences between the right and the left sides (p value>0.05), except for the radial artery length showed significant difference between the right and the left sides (p value=0.001). This result presents the length of artery on both sides can be used as a conduit for CABG. The mean lengths of the radius and the ulna showed significant differences between the right and left sides (p value<0.001). However, the mean lengths of the fibula and the tibia showed no significant differences between the right and the left sides (p value>0.05) (Table 6).

Regarding to the correlation of the external arterial diameter and height and also body part representing by bony length, we found that all of the simple linear regressions of the external arterial diameter and height and also the body part representing by bony length show the smallest R-square values (less than 50%). The external diameters of the radial artery, the ulnar artery, the IMA, the peroneal artery and the posterior tibial artery were not correlated with both height and body part representing by bony length (p value>0.05). However, the external diameters of the RGEA (p value=0.049) and the mid LAD (p value=0.001) were weakly and strongly positive correlation with height, respectively (Table 7). These results showed that the height and the body part representing by bony length were no significant effect on the external arterial diameter in our study.

The correlation between the arterial length and height gave high tendency of R-square value that are the maximum R-square value in the peroneal artery (75.4%), the radial artery (73.6%) and the minimum R-square value in the RGEA (0.3%). Most of the correlations between the arterial length were strongly and positively correlated with height (p value<0.001). However, the RGEA length was not correlated with height (p value=0.774) (Table 8 and Figures 5, 6, 7 and 8). In addition to all of the correlations between the arterial length and body part representing by bony length showed good R-square values (more than 50%). All of the correlations between the arterial length were strongly and positively correlated with the body part representing by bony length (p value<0.001) (Table 8 and Figures 9 and 10). In the present study, the height and the body part representing by bony length were found to be the strongest independent predictor of the arterial length in Thai adult.

The comparison of the external arterial diameters in this study showed no significant differences between male and female (p value>0.05)(Table 9). Most of average arterial lengths showed significant differences between male and female (p value<0.05). Moreover, all of the average lengths of the body part representing by bony length showed significant difference between male and female (p value<0.001) (Table 10).

From our findings, the result shows that the posterior tibial artery was the largest average of external diameter (4.57$\pm$0.61mm), and the longest average length (23.27$\pm$1.67cm), variable in its size and less prone to vasospasm. The external diameter and length of the radial artery and the IMA are suitable for CABG, but their greater tendency to vasospasm.[64-66] The radial and the ulnar arteries were necessitates prior assessment of collateral circulation to the hand by the Allen test,[67,68] with visual assessment the skin of the palm and digits. The peroneal artery was good length, but variable in its size and complicated to harvest with the tibial nerve. The right gastroepiploic artery was a good length and caliber for CABG, but its greater tendency to vasospasm.[69,70] Currently, the radial artery and the right gastroepiploic artery are widely used for CABG. Some patients lack graft conduits for redo CABG, therefore another source of conduit must be considered. The posterior tibial artery has been widely used for vascular flaps in plastic and reconstruction surgery.[71] In recent year, the posterior tibial artery was used graft for a redo coronary artery bypass graft in Thai patient, who did not have diabetes mellitus and also did not have peripheral vascular disease and successful of the operation and without any morbidity.[59] Therefore, the posterior tibial artery is suitable for a new choice of arterial conduit in CABG. In the present study, the external diameter of this artery is larger than other arteries such as the radial artery, the ulnar artery and the IMA. The distal diameter of the posterior tibial artery was around 2.6 mm, the middle diameter was around 4.3 mm and the proximal diameter was about 6.5 mm. A proximal anastomosis at the ascending aorta is easier when compared to another artery.

Table 2 Descriptive statistic for the external diameter (mm) and the length of arteries (cm).

Artery	Length	External diameter	Difference diameter I &II & III	Difference length left & right side
mean ±SD(CV)	20.17± 1.68(8.33)	2.67± 0.4(14.98)		
RA median± IQR	20.11± 3.16	2.51± 0.74	significant	significant
range	4.76	1.22	(p <0.001)	(p=0.001)
N	68	68	68	60
mean ±SD(CV)	21.98± 1.68(7.64)	2.22± 0.17(7.66)		
UA median± IQR	21.91± 2.67	2.17± 0.17	significant	not significant
range	6.47	0.78	(p <0.001)	(p =0.235)
N	68	68	68	58
mean ±SD(CV)	16.71± 1.02(6.10)	2.39± 0.24(10.04)		
IMA median± IQR	16.52± 1.11	2.37± 0.26	significant	not significant
range	4.22	1.04	(p <0.001)	(p =0.505)
N	62	62	62	62
mean ±SD(CV)	16.28± 1.71(10.50)	2.65± 0.12(4.53)		
RGEAmedian± IQR	16.52± 2.60	2.66± 0.14	significant	-
range	7.67	0.50	(p<0.001, p=0.172)	
N	32	31	31	
mean ±SD(CV)	23.01± 1.43(6.21)	2.58± 0.80(31.00)		
PA median± IQR	23.22± 1.44	2.38± 0.67	significant	not significant
range	6.73	3.26	(p <0.001)	(p =0.958)
N	66	48	48	52
mean ±SD(CV)	23.27± 1.67(7.18)	4.57± 0.61(13.35)		
PT median± IQR	23.83± 1.88	4.50± 1.02	significant *	not significant
range	6.94	2.27	(p <0.001)	(p =0.396)
N	64	62	60	54
mid mean ±SD(CV)		3.08± 0.62(20.13)		
LAD median± IQR	-	2.85± 0.55	-	-
range		2.50		
N		32		

RA: radial artery, UA: ulnar artery, IMA: internal mammary arteries, RGEA: right gastroepiploic artery, PA: peroneal artery, PT: posterior tibial artery, mid LAD: mid left anterior descending artery, IQR: interquartile range, CV: coefficient of variation, I : the proximal site, II : the middle site, III: the distal site, N: number of subjects, PT* : The external diameter of the posterior tibial artery was highly different between the proximal site (6.53 ± 0.80 mm), the middle site (4.30±0.85 mm) and the distal site (2.64±0.58 mm).

Table 3 The mean of external diameter (mm) and the length of arteries (cm) and also body part representing by bony length (cm).

Artery		External diameter	Length of artery	Length of bone
	mean ±SD(CV)	2.67± 0.4(14.98)	20.17± 1.68(8.33)	22.09± 1.97(8.92)
RA	median± IQR	2.51± 0.74	20.11± 3.16	21.58± 3.62
	range	1.22	4.76	6.58
	N	68	68	68
	mean ±SD(CV)	2.22± 0.17(7.66)	21.98± 1.68(7.64)	23.98± 2.25(9.38)
UA	median± IQR	2.17± 0.17	21.91± 2.67	24.35± 3.98
	range	0.78	6.47	7.61
	N	68	68	68
	mean ±SD(CV)	2.39± 0.24(10.04)	16.71± 1.02(6.10)	14.88± 1.13(7.59)
IMA	median± IQR	2.37± 0.26	16.52± 1.11	14.57±1.54
	range	1.04	4.22	3.90
	N	62	62	31
	mean ±SD(CV)	2.65± 0.12(4.53)	16.28± 1.71(10.50)	
RGEA	median± IQR	2.66± 0.14	16.52± 2.60	-
	range	0.50	7.67	
	N	31	32	
	mean ±SD(CV)	2.58± 0.80(31.00)	23.01± 1.43(6.21)	33.54± 1.71(5.10)
PA	median± IQR	2.38± 0.67	23.22± 1.44	34.30± 12.80
	range	3.26	6.73	5.89
	N	48	66	70
	mean ±SD(CV)	4.57± 0.61(13.35)	23.27± 1.67(7.18)	32.38± 1.72(5.31)
PT	median± IQR	4.50± 1.02	23.83± 1.88	32.28± 3.61
	range	2.27	6.94	4.66
	N	62	64	68
mid	mean ±SD(CV)	3.08± 0.62(20.13)		
LAD	median± IQR	2.85± 0.55	-	-
	range	2.50		
	N	32		

RA: radial artery, UA: ulnar artery, IMA: internal mammary arteries, RGEA: right gastroepiploic artery, PA: peroneal artery, PT: posterior tibial artery, mid LAD: mid left anterior descending artery, IQR: interquartile range, CV: coefficient of variation, N: number of subjects.

Table 4 The comparison of the external arterial diameter at measurement site (mm).

Artery	Measurement site			P-value	N
	Proximal	Middle	Distal		
Radial artery	2.78±0.40	2.67±0.41	2.57±0.40	<.001	68
Ulnar artery	2.27±0.17	2.21±0.16	2.16±0.17	<.001	68
Internal mammary arteries	2.43±0.25	2.39±0.24	2.35±0.24	<.001	62
Right gastroepiploic artery	2.65±0.12	2.64±0.12	2.64±0.12	*	31
Peroneal artery	2.97±0.98	2.55±0.81	2.21±0.71	<.001	48
Posterior tibial artery	6.53±0.80	4.30±0.85	2.64±0.58	<.001	60

* Representing the external diameter of RGEA at each measurement site found that at the proximal end and the middle end were significant differences (p value < 0.001). However, the middle end and the distal end were no significant differences (p value=0.172), N : number of subjects, Mean ± SD (mm).

Table 5 The comparison between the external arterial diameter of the right and the left sides (mm).

Artery	Diameter		P-value	N
	Right side	Left side		
Radial artery	2.73±0.41	2.58±0.42	<.001	60
Ulnar artery	2.22±0.18	2.19±0.17	.035	60
Internal mammary arteries	2.45±0.25	2.33±0.24	<.001	62
Peroneal artery	2.36±0.43	2.38±0.51	.643	26
Posterior tibial artery	4.66±0.67	4.49±0.65	.031	42

N : number of subjects, Mean ± SD (mm).

Table 6 The comparison length between the arterial length and body part representing by bony length of the right and the left sides (cm).

Artery	Length		P-value	N
	Right side	Left side		
Radial artery	20.19±1.69	19.90±1.67	.001	60
Radius	22.27±2.01	21.95±1.94	<.001	64
Ulnar artery	21.97±1.66	21.80±1.75	.235	58
Ulna	24.15±2.19	23.81±2.24	<.001	64
Internal mammary arteries	16.70±1.09	16.73±0.97	.505	62
Peroneal artery	22.68±1.07	22.68±1.08	.958	52
Fibula	33.46±1.80	33.43±1.83	.826	64
Posterior tibial artery	23.16±1.58	23.01±1.64	.396	54
Tibia	32.38±1.78	32.25±1.79	.485	66

N : number of subjects, Mean ± SD (cm).

Table 7 The summary correlation of external diameter (mm) and height (cm) and also body part representing by bony length (cm).

External	Height						Bone length					
diameter	R^2	SE	a	b	P-value	N	R^2	SE	a	b	P-value	N
RA	6.6	0.395	0.411	1.37E-02	0.144	68	8.6	0.390	1.345	6.00E-02	0.092	68
UA	0.10	0.168	2.124	5.57E-04	0.887	68	0.50	0.168	2.342	-5.23E-03	0.690	68
IMA	10.4	0.232	0.781	9.76E-03	0.077	62	6.1	0.238	1.606	5.273E-02	0.179	31
RGEA	12.7	0.113	1.727	5.59E-03	0.049	31	-	-	-	-	-	-
PA	0.30	0.818	3.534	-5.75E-03	0.801	48	0.10	0.819	3.004	-1.26E-02	0.907	48
PT	1.20	0.612	3.121	8.82E-03	0.561	62	0.00	0.616	4.684	-3.41E-03	0.959	62
mid LAD	29.6	0.528	-3.96	4.27E-02	0.001	32	-	-	-	-	-	-

R^2 : coefficient of determination (%), SE : standard error of the estimate, a : constant, b : regression coefficient, N : number of subjects, RA : radial artery, UA : ulnar artery, IMA : internal mammary arteries, RGEA : right gastroepiploic artery, PA : peroneal artery, PT : posterior tibial artery, mid LAD : mid left anterior descending artery.

Table 8 The summary correlation of arterial length (cm) and height (cm) and also body part representing by bony length (cm).

Length of arteries	Height						Bone length					
	R^2	SE	a	b	P-value	N	R^2	SE	a	b	P-value	N
RA	73.6	0.878	-11.51	0.191	0.00	68	86.6	0.626	2.578	0.796	0.00	68
UA	40.9	1.310	-1.60	0.142	0.00	68	65.4	1.00	7.492	0.604	0.00	68
IMA	66.9	0.60	-0.62	0.105	0.00	62	76.5	0.504	4.960	0.790	0.00	31
RGEA	0.30	1.738	18.26	-1E-02	0.774	32	-	-	-	-	-	-
PA	75.4	0.721	-4.61	0.168	0.00	66	72.4	0.764	-0.98	0.718	0.00	66
PT	50.1	1.20	-2.76	0.158	0.00	64	58.2	1.10	-0.54	0.737	0.00	64

R^2 : coefficient of determination (%), SE : standard error of the estimate, a : constant, b : regression coefficient, N : number of subjects, RA : radial artery, UA : ulnar artery, IMA : internal mammary arteries, RGEA : right gastroepiploic artery, PA : peroneal artery, PT : posterior tibial artery.

Table 9 The comparison between the external arterial diameter (mm) of male and female.

Artery	Diameter		P-value	N
	Male	Female		
Radial artery	2.61±0.35	2.75±0.46	.317	38,30
Ulnar artery	2.17±0.11	2.28±0.20	.041	38,30
Internal mammary arteries	2.42±0.26	2.34±0.22	.350	28,34
Right gastriepiploic artery	2.68±0.11	2.62±0.13	.162	15,16
Peroneal artery	2.73±0.96	2.40±0.55	.325	26,22
Posterior tibial artery	4.73±0.69	4.43±0.49	.171	30,32
mid left anterior descending artery	3.34±0.75	2.81±0.28	.011	16,16

N : number of subjects between male and female respectively, Mean ±SD (mm).

Table 10 The comparison length between the arterial length and body part representing by bony length (cm) of male and female.

Artery	Length		P-value	N
	Male	Female		
Radial artery	21.15±1.48	18.93±0.97	<.001	38,30
Radius	23.12±1.83	20.80±1.26	<.001	38,30
Ulnar artery	22.64±1.85	21.15±0.95	.008	38,30
Ulna	25.04±2.26	22.63±1.36	.001	38,30
Internal mammary arteries	17.37±0.84	16.18±0.84	<.001	28,34
Sternum	15.76±0.79	14.15±0.81	<.001	28,34
Peroneal artery	24.02±1.11	22.16±1.08	<.001	30,36
Fibula	34.82±0.57	32.31±1.51	<.001	34,36
Posterior tibial artery	24.18±1.48	22.46±1.43	.002	30,34
Tibia	33.68±1.16	31.22±1.22	<.001	32,36
Right gastriepiploic artery	16.37±1.63	16.18±1.84	.761	16,16

N : number of subjects between male and female respectively, Mean±SD (cm).

Table 11 The comparison of the arterial data between this study and another study.

Another Study	Artery (mm)	Method	Specimens	Instrument	This study (mm)
Shima et al. (1996)	RA : 2.3± 0.5 UA :1.6 ± 0.5	Internal diameter	cadavers	SMZ	RA :2.67±0.40 UA : 2.22±0.17
Feng (1997)	IMA :2.36±0.55 RIMA : 2.52± 0.51 LIMA : 2.30± 0.55	External diameter	patients	caliper	IMA : 2.39± 0.24 RIMA : 2.45± 0.25 LIMA : 2.33± 0.24
Strauch (1993)	RGEA : 2.8± 0.9	External diameter	cadavers	caliper	RGEA : 2.65±0.12
Yoshimura et al. (1990)	PA : 1.6± 0.2	External diameter	cadavers	operating microscope	PA : 2.58±0.80
Wu et al. (1993)	PT : 10± 0.50	External diameter	cadavers	microscope	PT : 4.57±0.61
Guerra et al. (1993)	LD : 4.23± 0.85	External diameter	patients	UFCT	mid LAD: 3.08±0.62
O' Connor et al. (1996)	mid LAD : Men : 2.04 Women :1.81	Internal diameter	patients	graduated probes	mid LAD : Men : 3.34±0.75 Women :2.81±0.28

RA: radial artery, UA: ulnar artery, IMA: internal mammary arteries, RIMA: right internal mammary artery, LIMA: left internal mammary artery, RGEA: right gastroepiploic artery, PA: peroneal artery, PT: posterior tibial artery, LD: the left coronary artery close to the mid LAD, mid LAD: mid left anterior descending artery, SMZ: the stereoscopic microscope, UFCT: the ultrafast computed tomography, This study: the method of measurement was made in term of the external diameter, mean ± SD (mm).

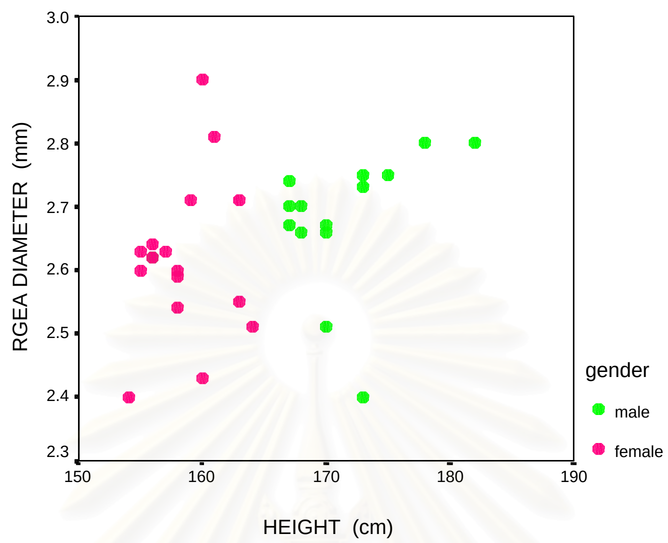

Fig 1 Scattergram of the RGEA diameter (mm) versus height (cm) :coefficient of determination was 12.7%, n: 31.

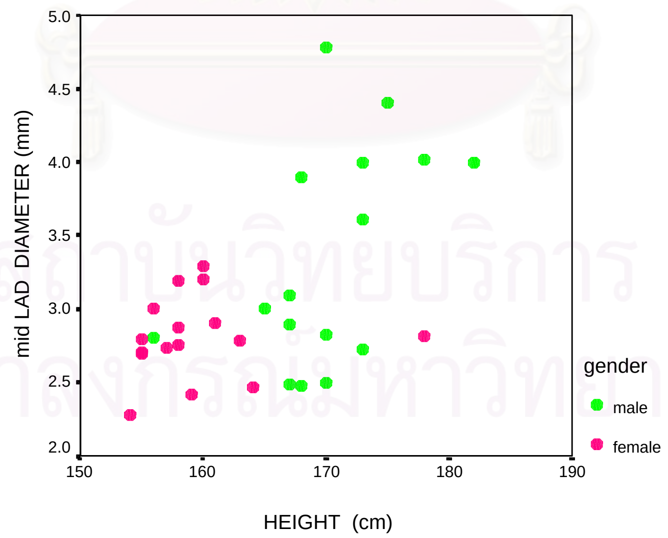

Fig 2 Scattergram of the mid LAD diameter (mm) versus height (cm) :coefficient of determination was 29.6%, n: 32.

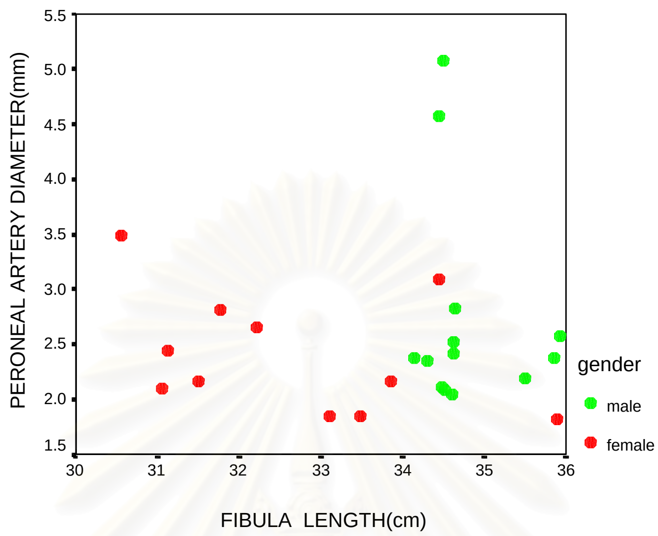

Fig 3 Scattergram of the peroneal artery diameter (mm) versus body part representing by bony length; fibula length (cm) :coefficient of determination was 0.10%, n: 48.

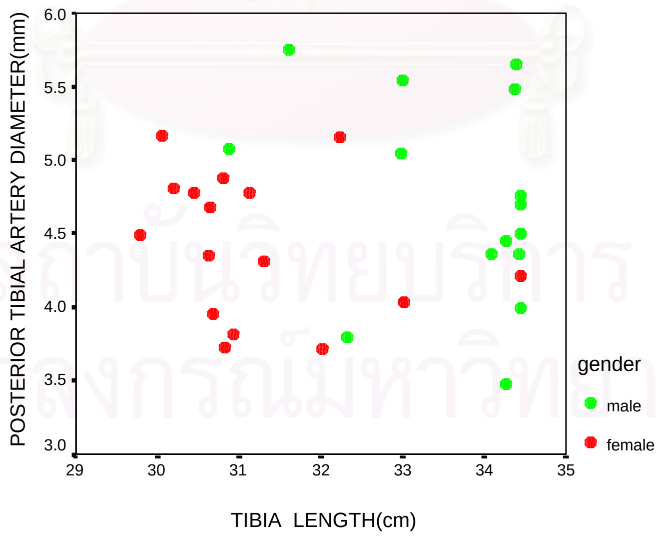

Fig 4 Scattergram of the posterior tibial artery diameter (mm) versus body part representing by bony length; tibia length (cm) :coefficient of determination was 0.00%,n: 62.

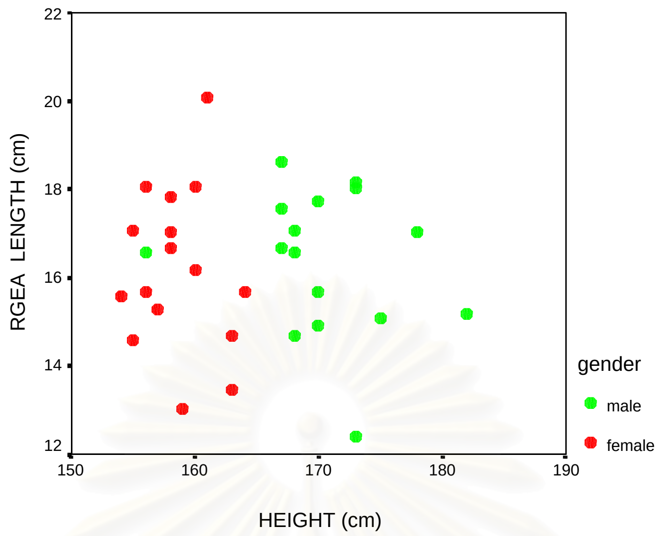

Fig 5 Scattergram of RGEA length (cm) versus height (cm) :coefficient of determination was 0.30%, n: 32.

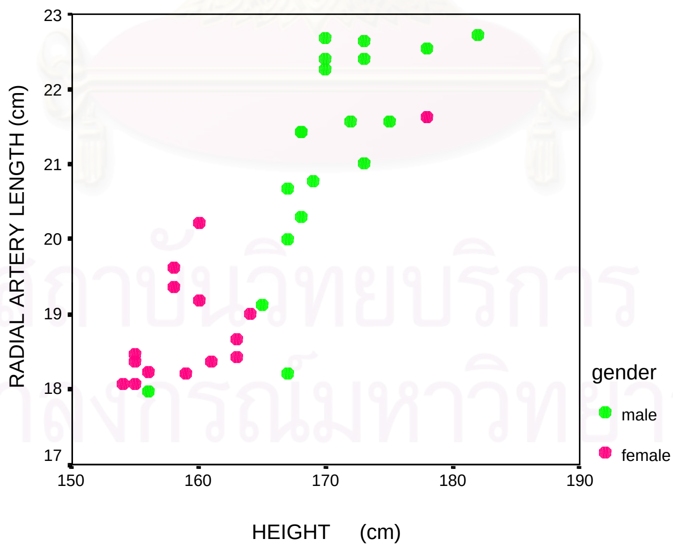

Fig 6 Scattergram of radial artery length (cm) versus height (cm): coefficient of determination was 73.6%, n: 68.

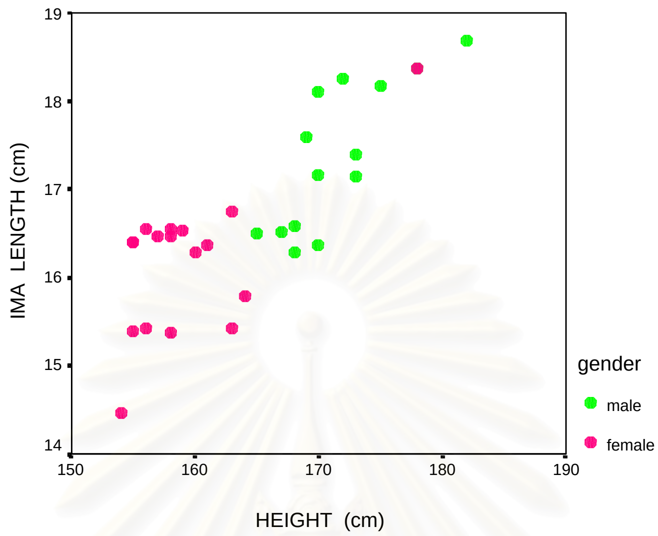

Fig 7 Scattergram of the IMA length (cm) versus height (cm) :coefficient of determination was 66.9%, n: 62.

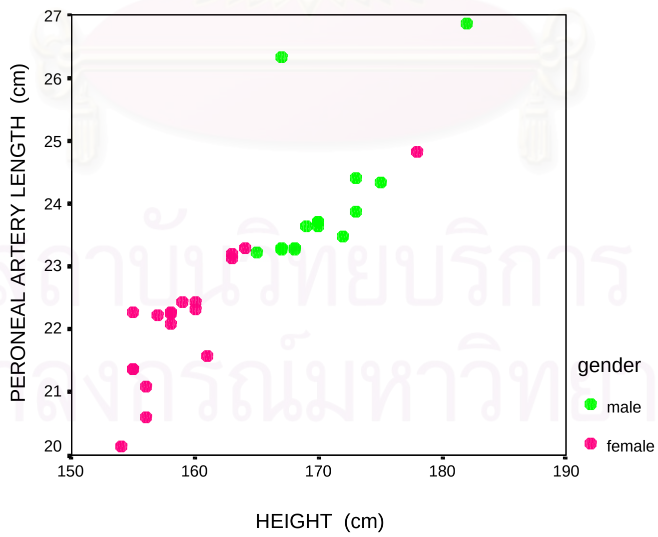

Fig 8 Scattergram of the peroneal artery length (cm) versus height (cm) :coefficient of determination was 75.4%, n: 66.

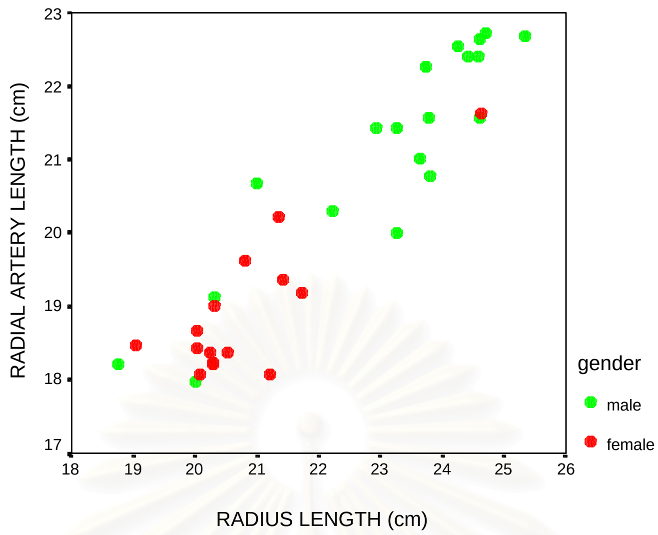

Fig 9 Scattergram of the radial artery length (cm) versus body part representing by bony length; radius length (cm) :coefficient of determination was 86.6%, n: 68.

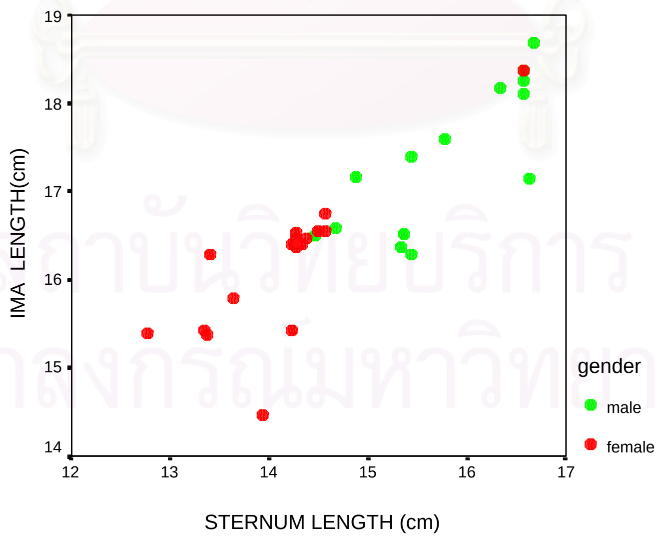

Fig 10 Scattergram of the IMA length (cm) versus body part representing by bony length; sternum length (cm) :coefficient of determination was 76.5%, n: 31.

CHAPTER V

CONCLUSION AND RECOMMENDATION

Ishemic heart disease is the common cause of death of Thai people in middle to late age. Atherosclerosis is believed to be the main cause of coronary artery stenosis. Coronary artery bypass graft (CABG) is now an accepted method of treatment for patients who have obstructive coronary stenosis. The vessel size greater than 1.5 mm in diameter is suitable for CABG. In this research, we choose to study the radial artery, the ulnar artery, the IMA, the RGEA, the peroneal artery and the posterior tibial artery for new choices of arterial conduit.

From our study, we found basis of anatomical data of arteries with regarding to select alternative arterial conduits for CABG. These findings suggest a new choice for CABG. The posterior tibial artery is suitable for CABG due to the appropriated size, length and less tendency to vasospasm. The correlation between the external diameter was not correlated with both height and body part representing by bony length (p value >0.05). Moreover, the correlation between arterial length was correlated with both height and body part representing by bony length (p value <0.001). Therefore, it is concluded that the external diameter of arteries cannot be predicted from height and body part representing by bony length. However, length of arteries can be predicted from height and body part representing by bony length in Thai adult whose ages ranged from 45 to 91 years.

In this study, we can predict the length of artery from two of the linear regression equations:

1. Length of artery (cm) = constant (a) + regression coefficient (b) Height (cm)

2. Length of artery (cm) = constant (a) + regression coefficient (b) Body part representing by bony length (cm)

1. Length of artery (cm) = constant(a) + regression coefficient(b) Height (cm)

Radial artery length	= (-11.51)+ (0.19) Height
Ulnar artery length	= (-1.60) + (0.14) Height
IMA length	= (-0.62) + (0.11) Height
Peroneal artery length	= (-4.61) + (0.17) Height
Posterior tibial artery length	= (-2.76) + (0.16) Height

2. Length of artery (cm) = constant (a) + regression coefficient (b) Body part representing by bony length (cm)

Radial artery length	= 2.58 + 0.80 Radius length
Ulnar artery length	= 7.49 + 0.60 Ulna length
IMA length	= 4.96 + 0.79 Sternum length
Peroneal artery length	= (-0.98)+0.72 Fibula length
Posterior tibial artery length	= (-0.54)+0.74 Tibia length

REFERENCES

1. Jennings RB, Steenbergen C Jr, Heackel DB. The heart. In : Rubin E, Farber JL, editors. Pathology. 2 nd ed. Philadelphia : Lippincott, 1994 : 521-33.
2. The heart. In : Kumar V, Cotran RS, Robbins SL, editors. Basic pathology. 5 th ed. Philadelphia : Saunders, 1992 : 307-10.
3. Ross R, Glomset JA. Atherosclersis and the arterial smooth muscle cell. Science 1973 ; 180 : 1332.
4. Ross R, Glomset JA. The pathorogenesis of atherosclersis. N Engl J Med 1976 ; 420 : 295-369.
5. Ross R, Haeker L. Hyperlipidemia and atherosclersis. Science 1976 ; 193 : 1094.
6. Fuster V, Badimon L, Badimon JJ, Chesebro JH. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Engl J Med 1992; 326 : 242-50.
7. Ross R. The pathogenesis of the atherosclersis : a perspective for the 1990s. Nature 1993 ; 362 :801-9.
8. Stary HC, Chandler AB, Glagov S, Guyton JR, Insull W Jr, Rosenfeld ME, et al. A definition of initial, fatty streak, and intermediate lesions of atherosclersis. Circulation 1994 ; 89 : 2462-78.
9. Wissler RW, Hiltscher L, Oinuma T, PDAY Research Group. The lesions of atherosclersis in the young : from fatty steaks to intermediate lesions. In : Fuster V, Ross R, Topol EJ, editors. Atherosclerosis and coronary artery disease. Philadelphia : Lippincott-Raven,1996 : 475-89.
10. Ross R. Factors influencing atherosclersis. In : Alexander RW, Schlant RC, Fuster V, O' Rourke RA, Roberts R, Sonnenblick EH, editors. Hurst' s the heart. Vol 1. 9 th ed. New York : McGraw-Hill, 1998 : 1139-59.
11. Maron DJ, Ridker PM, Pearson TA. Risk factors and the prevention of coronary heart disease. In : Alexander RW, Schlant RC, Fuster V, O' Rourke RA, Roberts R, Sonnenblick EH, editors. Hurst' s the heart. Vol 1. 9 th ed. New York : McGraw-Hill,1998 : 1175-95.
12. Frei B, Forte TM, Ames BN, Cross CE. Gas phase oxidants of cigarette smoke induce lipid peroxidation and changes in lipoprotein properties in human

blood plasma. Protective effects of ascorbic acid. <u>Biochem J</u> 1991;277:133-8.

13. Stafford RS, Becker CG, Cigarette smoking and atheroclerosis. In : Fuster V, Ross R, Topol EJ. <u>Atheroclerosis and coronary artery disease</u>. Philadelphia : Lippincott-Raven,1996 : 303-25.

14. Krolewski AS, Warram JH, Valsania P, Martin BC, Laffel LMB, Christlieb R. Evolving natural history of coronary artery disease in diabetes mellitus. <u>Am J Med</u> 1991 ; 90(suppl 2A) : 56S-61S.

15. Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult treatment panel II). <u>Circulation</u> 1994 ; 89 : 1329-1445.

16. Enos WF Jr, Beyer JC, Holmes RH. Pathogenesis of coronary disease in American soldiers killed in Korea. <u>JAMA</u> 1955 ; 58 : 912-4.

17. McNamara JJ, Molot MA, Stremple JF, Cutting RT. Coronary artery disease in combat casualties in Vietnam. <u>JAMA</u> 1971 ; 216 : 1185-7.

18. Castelli WP. Epidemiology of coronary artery heart disease: the Framingham study. <u>Am J Med</u> 1984 ; 276(2A) : 4-12.

19. Thom TJ. Cardiovascular disease mortality among United States women. In : Eaker ED, Packard B, Wenger NK, Clarkson TB, Tyroler HA, editors. <u>Coronary Heart Disease in Women</u>. New York : Haymarket Doyma ,1987.

20. Pi-Sunyer FX. Short- term medical benefit and adverse effects of weight loss. <u>Ann Intern Med</u> 1993 ; 119(7 pt 2) : 722-6.

21. MacMahon SW, Wilcken DEL, Macdonald GJ. The effect of weight reduction on left ventricular mass : a randomized controlled trial in young, overweight hypertensive patients. <u>N Engl J Med</u> 1986 ; 314 : 334-9.

22. Larsson B. Regional obesity as a health hazard in men : prospective studies. <u>Acta Med Scand Suppl</u> 1988 ; 723 :45-51.

23. Sullivan TR, Karas RH, Aronovitz M, Faller GT, Ziar JP, Smith JJ, et al. Estrogen inhibits the response-to-injury in a mouse carotid artery model. <u>J Clin Invest</u> 1995 ; 96 : 2482-8.

24. Wilson PWF. Established risk factors and coronary artery disease : the Framingham study. <u>Am J Hypertens</u> 1994 ; 7 : 7S-12S.

25. Pasternak RC, Braunwald E, Sobol BE. Acute myocardial infarction. In : Braunwald

E, editor. Heart disease : a textbook of cardiovascular medicine. Vol 2. 4 th ed. Philadelphia : Saunders, 1992 : 1201-9.

26. Haupt HM, Hutchins GM, Moore GW. Right ventricular infarction : role of the moderate band artery in determining infarct size. Circulation 1983 ; 67: 1268.
27. ประดิษฐ์ชัย ชัยเสรี. Management of ischemic heart disease ทางด้านศัลยกรรม. ใน : ถาวร สุทธิไชยากุล, บรรณธิการ. Cardiology. พิมพ์ครั้งที่ 1. กรุงเทพมหานคร : แซดอีเอ็น กราฟฟิคเพรศ, 2541 : 219-24.
28. Loop FD, Muehrcke DD. Surgical treatment of atherosclerotic coronary heart disease. In : Alexander RW, Schlant RC, Fuster V, O' Rourke RA, Roberts R, Sonnenblick EH, editors. Hurt's the heart. Vol 1. 9 th ed. New York : McGraw-Hill, 1998 :1473-85.
29. Livesay JJ, Cooley DA. Which vessels should be grafted ?. In : Wheatley DJ , editor. Surgery of coronary artery disease. 1 st ed. London : Chapmans, 1986 : 387-413.
30. Crosby IK, Wellons HA, Taylor GJ. Critical analysis of the preoperative and operative predictors of aortocoronary bypass patency. Ann Surg 1981 ; 193 : 743-51.
31. Braumann FG, Catinella FP, Cunningham JN Jr, Spencer FC. Vein contraction and smooth muscle cell extensions as causes of endothelial damage during graft preparation. Ann Surg 1981 ; 194 : 199-211.
32. Campeau L, Enjalbert M, Lesperance J, Bourassa MG, Kwiterovich P Jr, Wacholder S, et al. The relation of risk factors to the development of atherosclerosis in saphenous-vein bypass grafts and the progression of disease in the native circulation : a study 10 years after aortoconary bypass surgery. N Engl J med 1984 ; 311 : 1329-32.
33. Grondin CM. Graft disease in patient with coronary artery bypass grafting.J Thorac Cardiovas Surg 1986 ; 92 : 323.
34. Grondin CM, Campeau L, Lesperance J, Enjalbert M, Bourassa M. Comparison of late changes in internal mammary artery and saphenous vein grafts in two consecutive series of patients 10 years after operation. Circulation 1984 ; 70(Suppl 1) : 208-12.
35. Cmolik BL, Geha AS . Coronary artery operations and reoperations : techniques

and conduits. In : Baue AE, Geha AS, Hammond GL, Laks H, Naunheim KS, editors. Glenn's thorac cardiovasc surgery. Vol 2. 6 th ed . Stamford Connecticut : Appletons & Langes , 1996 : 2081-92.

36. Calafiore AM, Giammarco GD, Luciani N, Maddestra N, Nardo ED, Angelini R. Composite arterial conduits for a wider arterial myocardial revascularization. Ann Thorac Surg 1994 ; 58 : 185-90.
37. Sapsford RN. Artificial conduits. In : Wheatley DJ, editor. Surgery of coronary artery disease. 1st ed . London : Chapman, 1986 : 475-9.
38. Abramov D, Tamariz MG, Fremes SE, Guru V, Borger MA, Chistakis GT, et al. Trends in coronary artery bypass surgery results : a recent 9 year study. Ann Thorac Surg 2000 ; 70 : 84-90.
39. Dion R, Verhelst R, Rousseau M, Goenen M, Ponlot R, Chalant CH, et al. Sequential mammary grafting. J Thorac Cardiovasc Surg 1989 ; 98 : 80-9.
40. Sato T, Isomura T, Suma H, Horii T, Kikuchi N. Coronary artery bypass grafting with gastroepiploic artery composite graft. Ann Thorac Surg 2000 ; 69 : 65-9.
41. Pym J, Brown PM, Charrette EJP, Parker Jo, West RO. Gastroepiploic-coronary anastomosis : aviable alternative bypass graft. J Thorac Cardiovasc Surg 1987 ; 94 : 256-9
42. Vincent JG, Vanson JAM, Skotnicki SH. Inferior epigastric artery as a conduit in myocardial revascularization : the alternative free arterial graft . Ann Thorac Surg 1999 ; 49 : 323-5.
43. Bhan A, Gupta V, Choudhary SK, Sharma R, Singh B, Aggarwal R, et al. Radial artery in CABG : could the early results be comparable to internal mammary artery graft ?. Ann Thorac Surg 1999 ; 67 : 1631-6.
44. Acar C, Jebara VA, Portoghese M, Beyssen B, Pagny JY, Grare P, et al. Revivalof the radial artery for coronary artery bypass grafting. Ann Thorac Surg 1992 ; 54 : 652-60.
45. Chen AH, Nakao T, Brodman RF, Greenberg M, Charney R, et al. Early postoperative angiographic assessment of radial artery used for coronary artery bypass grafting. J Thorac Cardiovasc Surg 1996 ; 111 : 1208-12.

46. Dumanian GA, Segalman K, Mispireta LA, Walsh JA, Hendrickson MF, Wilgis EFS. Radial artery use in bypass grafting does not change digital blood flow or hand function. Ann Thorac Surg 1998 ; 65 : 1284-7.

47. Guerra OR, Janowitz WR, Agatston AS, Mantelle LL, Viamonte M. Coronary artery diameter and coronary risk factors: a study with ultrafast computed tomography. Am Heart J 1993 ; 126 : 600-6.

48. O' Connor NJ, Morton JR, Birkmeyer JD, Olmstead EM, O'Connor GT. Effect of coronary artery diameter in patients undergoing coronary bypass surgery. Circulation 1996 ; 93 : 652-5.

49. Timmons MJ. The vascular basis of the radial forearm flap. Plast Reconstr Surg 1986 ; 77 : 80-92.

50. Inoue Y, Taylor GI. The angiosomes of the forearm : anatomic study and clinical implications. Plast Reconstr Surg 1996 ; 98 : 195-210.

51. Shima H, Ohno K, Michi KI, Egawa K, Takiguchi R. An anatomical study on the forearm vascular system. J Cranio-Maxillo Surg 1996 ; 24 : 293-9.

52. Takemura H, Kawasuji M, Sakakibara N, Tedoriya T, Ushijima T, Watanabe Y. Internal thoracic artery graft function during exercise assessed by transthoracic doppler echography. Ann Thorac Surg 1996 ; 61 : 914-9.

53. Feng LJ. Recipient vessels in free-flap breast reconstruction : a study of the internal mammary and thoracodorsal vessels. Plast Reconstr Surg 1997 ; 99 : 405-16.

54. Greater omentum transfer. In : Strauch B, Yu HL, editors. Atlas of microvascular surgery :anatomy and operative approaches. 1 st ed. New York : Thiemes, 1993 : 462 -3.

55. Nakao T, Kawaue Y.Effect of coronary revascularization with the right gastroepiploic artery comparative examination of angiographic finding in the early postoperative period. J Thorac Cardiovas Surg 1993 ; 106 :149-53.

56. Wei FC, Chen HC, Chuang CC, Noodhoff SM. Fibular osteoseptocutaneous flap : anatomic study and clinical application. Plast Reconstr Surg 1986 ;78:191-208.

57. Yoshimura M, Shimada T, Hosokawa M. The vasculature of the peroneal tissue

transfer. Plast Reconstr Surg 1990 ; 85 : 915-21.

58. Wu WC, Chang YP, So YC, Yip SF, Lam YL. The anatomic basis and clinical applications of flaps based on the posterior tibial vessels. Br J Plast Surg 1993 ; 46 : 470-9.

59. Benjacholamas V, Jindarak S. Posterior tibial artery : a new alternative graft conduit for redo coronary artery bypass grafts. Chula Med J 2000 ; 44 : 277-81.

60. สมรัตน์ เลิศมหาฤทธิ์, ปิยลัมพร หะวานนท์. สถิติในการวิจัยและการพิจารณาขนาดตัวอย่าง. ใน : ภิรมย์ กมลรัตนกุล, มนต์ชัย ชาลาประวรรต์, ทวีสิน ตันประยูร, บรรณาธิการ. หลักการทำวิจัยให้สำเร็จ. พิมพ์ครั้งที่ 1. กรุงเทพมหานคร : เท็กซ์ แอนด์ เจอร์นัล พับลิเคชั่น,2542 : 99 -130.

61. เติมศรี ชำนิจารกิจ. สถิติประยุกต์ทางการแพทย์. พิมพ์ครั้งที่ 4. กรุงเทพมหานคร : โรงพิมพ์จุฬาลงกรณ์มหาวิทยาลัย, 2537.

62. ศิริชัย พงษ์วิชัย. การวิเคราะห์ข้อมูลทางสถิติด้วยคอมพิวเตอร์.พิมพ์ครั้งที่ 9.กรุงเทพมหานคร : สำนักพิมพ์แห่งจุฬาลงกรณ์มหาวิทยาลัย, 2540 : 281-300.

63. สุวิชาน มนแพวงศานนท์. วิเคราะห์ข้อมูลทางสถิติด้วย SPSS for Windows. พิมพ์ครั้งที่ 1. กรุงเทพมหานคร : ซีเอ็ดยูเคชั่น , 2543.

64. Taggart DP. Radial artery-gartroepiploic artery composite graft for redo CABG. Ann Thorac Surg 1997; 64 : 1473-5.

65. Van Son JAM. Use of radial artery as coronary artery bypass graft in myocardial revascularization. Ann Thorac Surg 1999; 67 :1825-30.

66. Taggart DP. The radial artery as a conduit for coronary artery bypass grafting. Heart 1999 ; 82 : 409-10.

67. Carpentier A, Guermonprez JL, Deloche A, Frechette C, Dubost C. The aorta-to-coronary radial artery bypass graft. Ann Thorac Surg 1973 ; 16 :111-21.

68. Barner HB. Arterial grafting : techniques and conduits. Ann Thorac Surg 1998 ; 66 :S2- 5.

69. Mills NL, Everson CT. Right gastroepiploic artery:a third arterial conduit for coronary artery bypass. Ann Thorac Surg 1989 ; 47 : 706-11.

70. Manapat AE, McCarthy PM, Lytle BW, Taylor PC, Loop FD, Stewart RW, et al. Gastroepiploic and inferior epigastric arteries for coronary artery bypass early results and evolving applications. Circulation 1994 ; 90 (5Pt 2) : II 144-47.

71. Chen HC, Tang YB, Noordhoff MS. Posterior tibial artery flap for reconstruction of the esophagus. Plast Reconstr Surg 1991 ; 88(6) : 980-6.

Results of statistical analysis

1. The statistic used for the analysis of the correlation in this study was the Simple linear regression. The correlation were separately analyze.

A : Scattergram of external arterial diameter and height

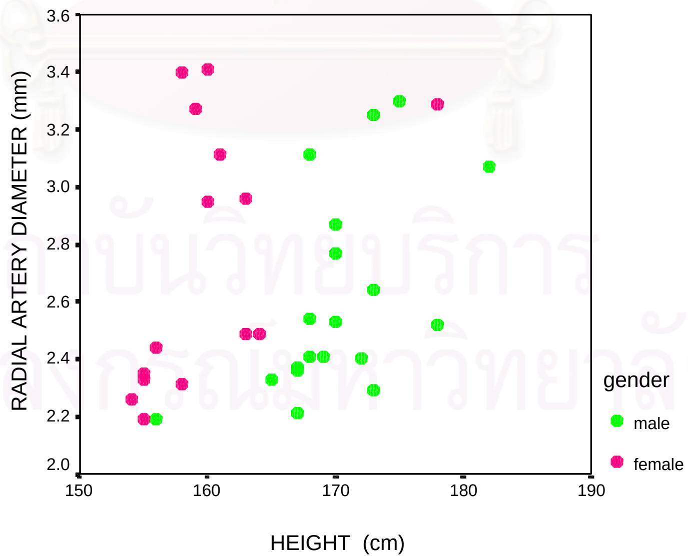

Figure 1 Scattergram of radial artery diameter (mm) versus height (cm): coefficient of determination was 6.6%, n: 68.

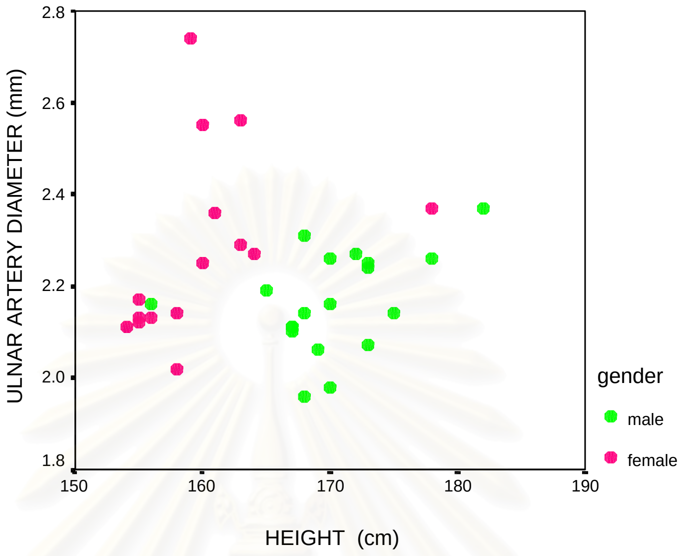

Figure 2 Scattergram of ulnar artery diameter (mm) versus height (cm): coefficient of determination was 0.10%, n: 68.

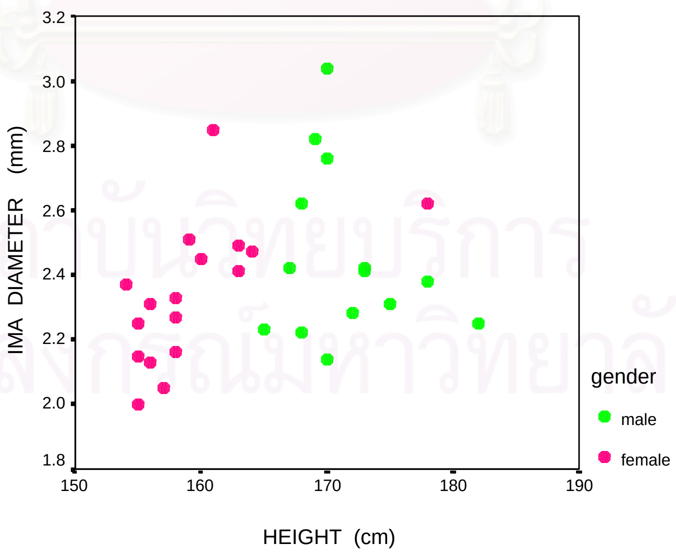

Figure 3 Scattergram of IMA diameter (mm) versus height (cm) : coefficient of determination was 10.40%, n: 62

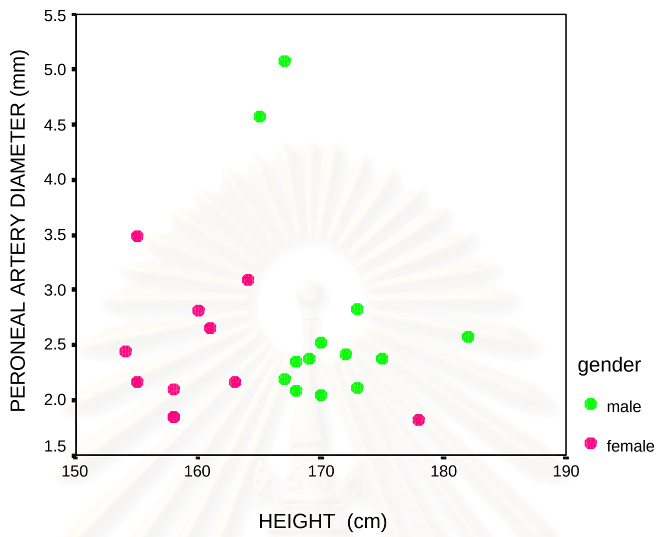

Figure 4 Scattergram of peroneal artery diameter (mm) versus height (cm): coefficient of determination was 0.30%, n: 48.

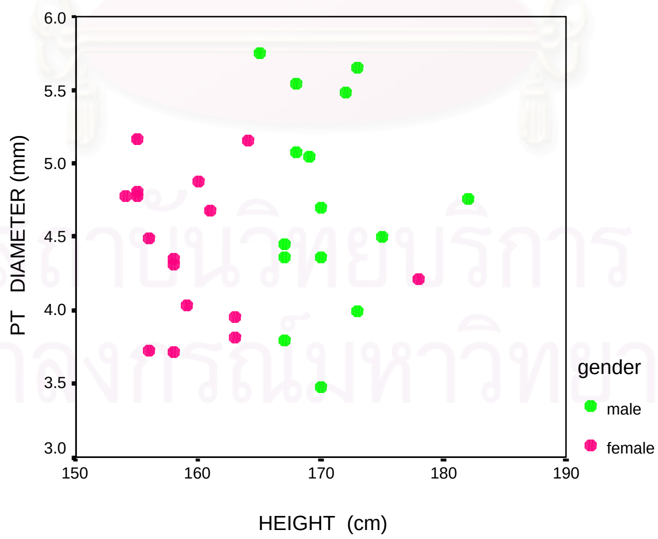

Figure 5 Scattergram of posterior tibial artery diameter (mm) versus height (cm): coefficient of determination was 1.20%, n: 62.

B : Scattergram of external arterial diameter and body part representing by bony length

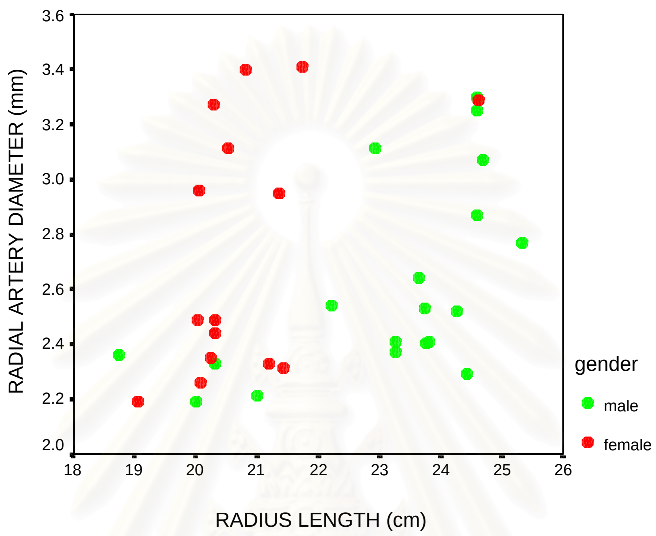

Figure 1 Scattergram of radial artery diameter (mm) versus body part representing by bony length ; radius length (cm): coefficient of determination was 8.6%, n: 68.

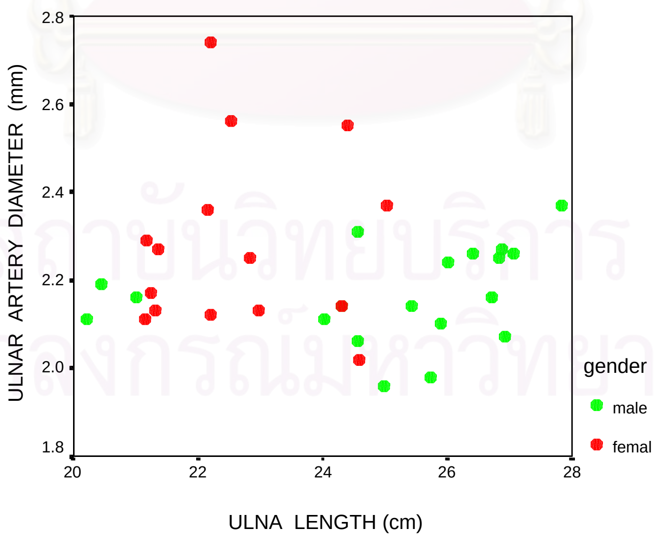

Figure 2 Scattergram of ulnar artery diameter (mm) versus body part representing by bony length ; ulna length (cm): coefficient of determination was 0.50%, n: 68.

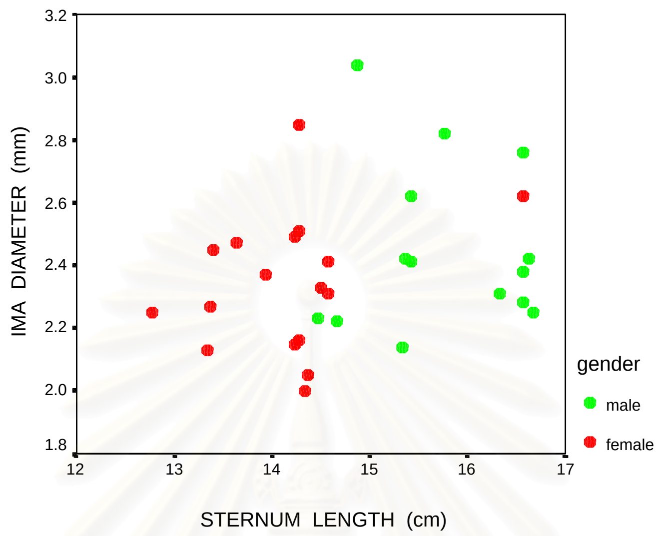

Figure 3 Scattergram of IMA diameter (mm) versus body part representing by bony length ; sternum length (cm): coefficient of determination was 6.10%, n: 31.

C : Scattergram of arterial length and height

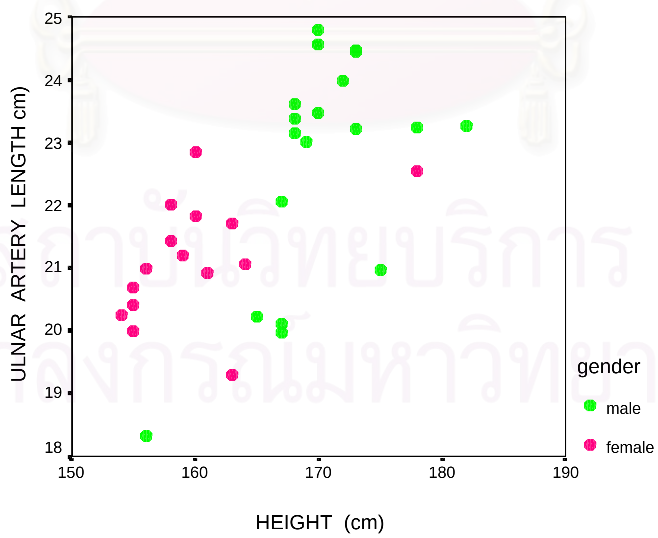

Figure 1 Scattergram of ulnar artery length (cm) versus height (cm) : coefficient of determination was 40.9%, n: 68.

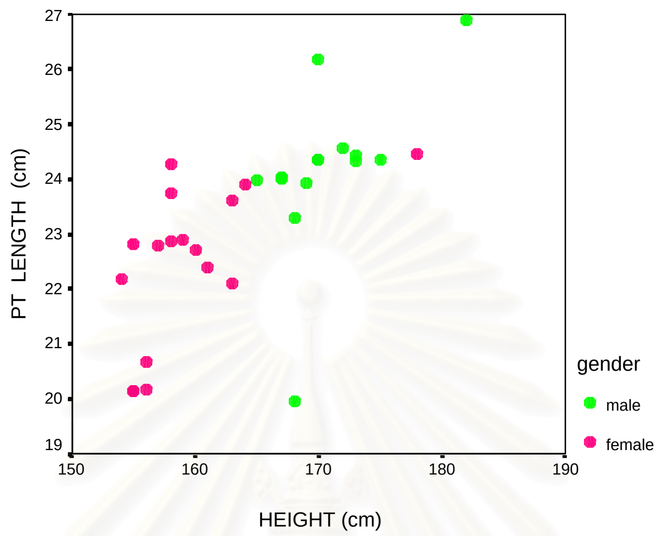

Figure 2 Scattergram of posterior tibial artery length (cm) versus height (cm): coefficient of determination was 50.1%, n: 64.

D : Scattergram of arterial length and body part representing by bony length

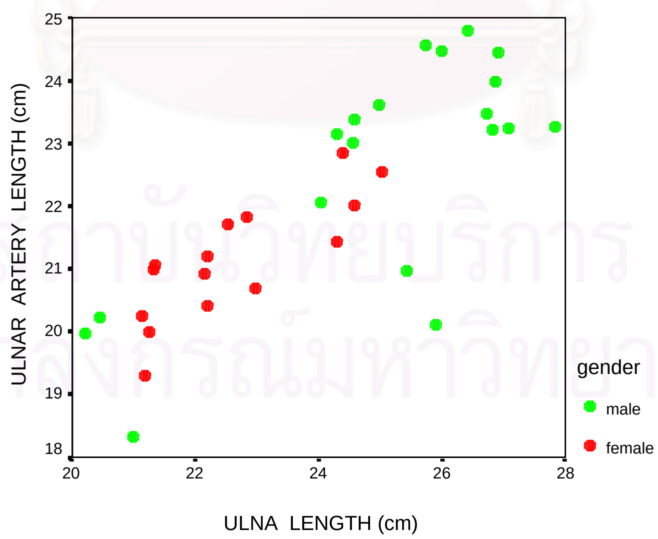

Figure 1 Scattergram of ulnar artery length (cm) versus body part representing by bony length ; ulna length (cm): coefficient of determination was 65.4%, n: 68.

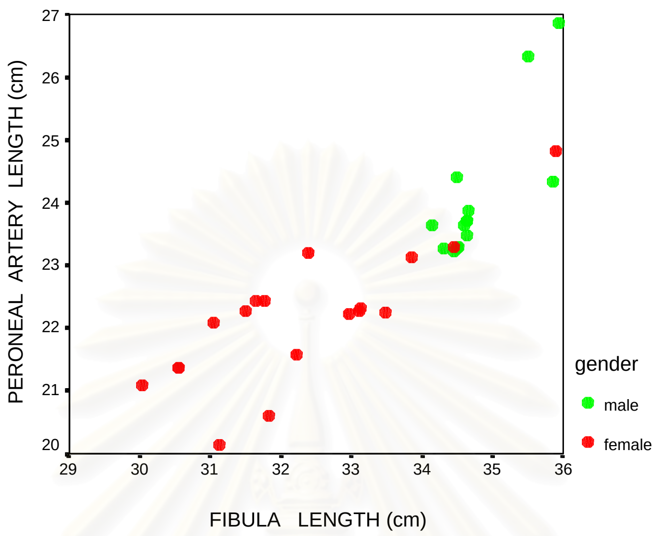

Figure 2 Scattergram of peroneal artery length (cm) versus body part representing by bony length ; fibula length (cm): coefficient of determination was 72.4%, n: 66.

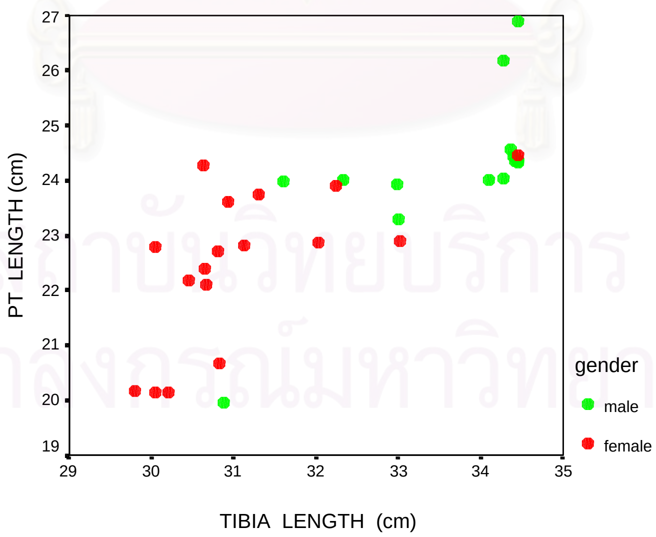

Figure 3 Scattergram of posterior tibial artery length (cm) versus body part representing by bony length ; tibia length (cm): coefficient of determination was 58.2%, n: 64.

2. The statistic used for the analysis of differences between the external arterial diameter of the right and the left sides were analyzed by Matched-pairs t-test.

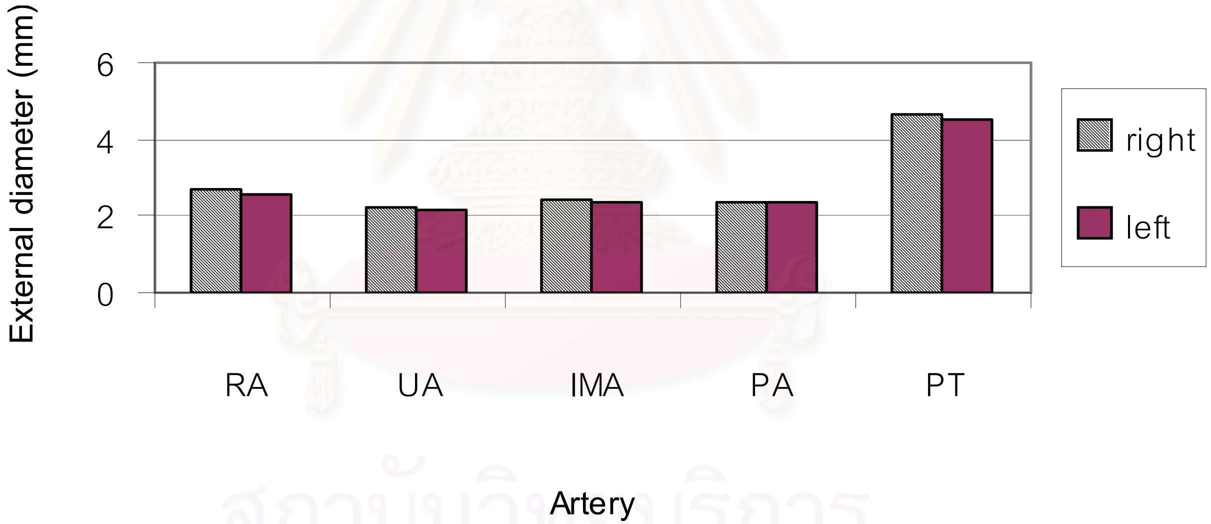

Figure 1 Comparison of the mean±SD between the external arterial diameter (mm) of the right and the left sides.

3. The statistic used for the analysis of differences between the arterial length and body part representing by bony length of the right and the left sides were analyzed by Matched-pairs t-test.

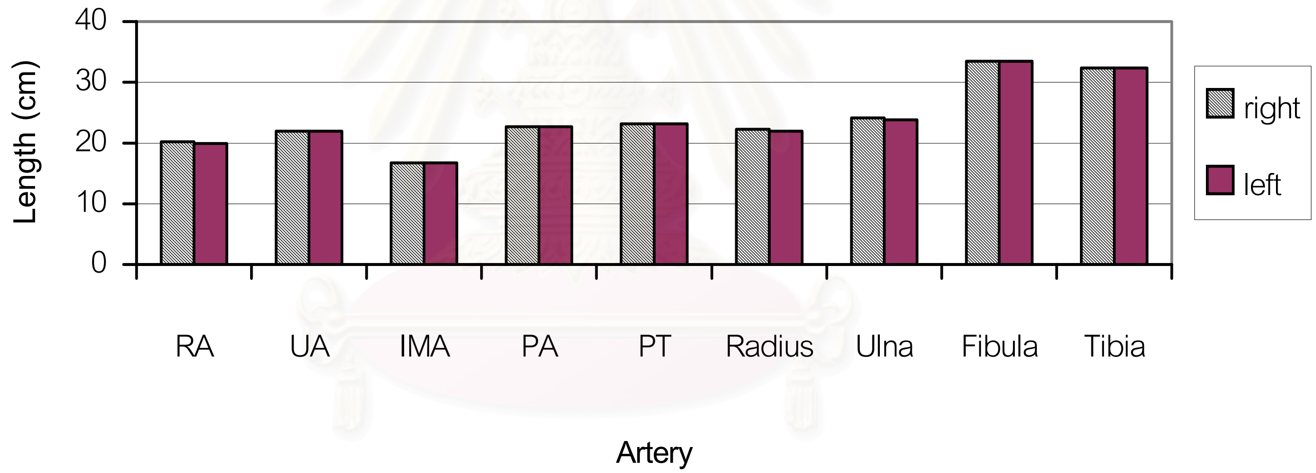

Figure 2 Comparison of the mean±SD between the arterial length (cm) and body part representing by bony length(cm) of the right and the left sides.

4. The statistic used for the analysis of differences between the external arterial diameter, the length of arteries and also the body part representing by bony length of male and female were analyzed by Unpaired t-test.

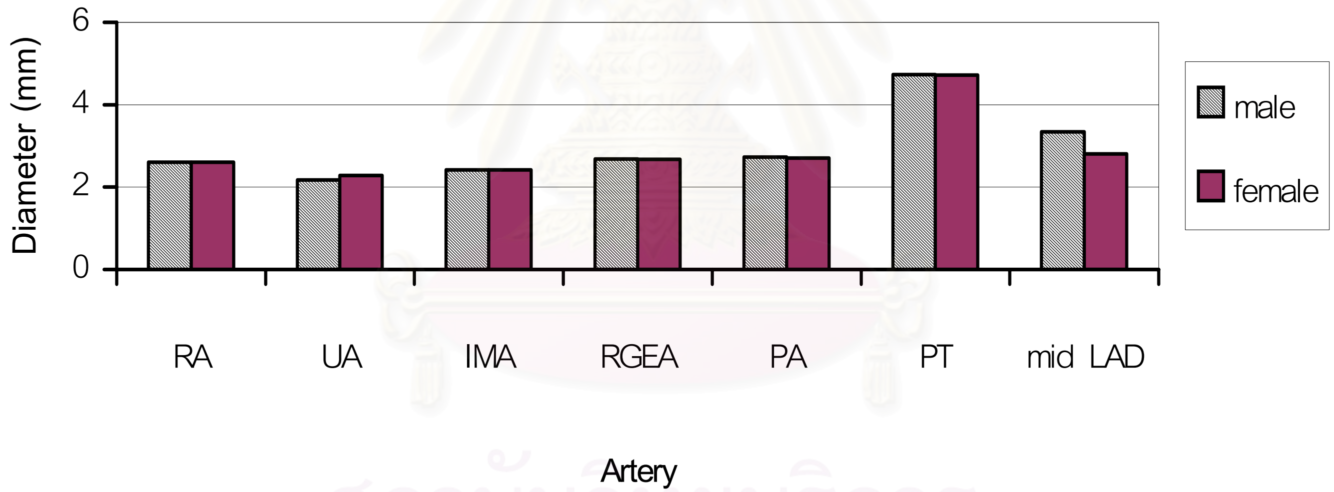

Figure 3 Comparison of the mean±SD between the external arterial diameter (mm) of male and female.

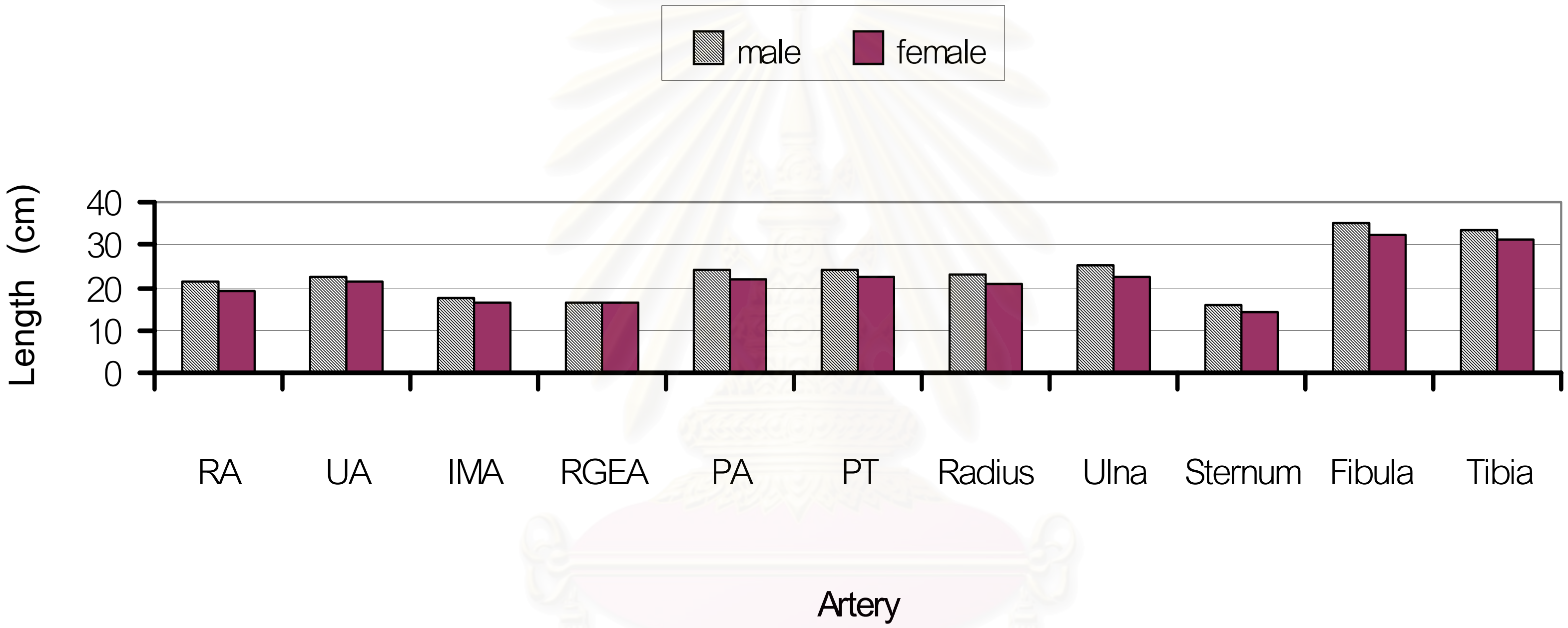

Figure 4 Comparison of the mean±SD between the arterial length (cm) and body part representing by bony length (cm) of male and female.

BIOGRAPHY

Miss Natcharaporn Tokkunheng was born on August 3, 1977 in Phitsanulok, Thailand. She received the degree of Bachelor of Radiological Technology in 1999 from faculty of Medical Technology, Mahidol University, Bangkok, Thailand. She has been enrolled at Chulalongkorn University in graduate program for the degree of Master of Science in Medical Science in 2001.