Original Article

DOI: 10.7860/JCDR/2016/18096.7849

Radiology Section

# Normal Proximal Coronary Artery Diameters in Adults from India as Assessed by Computed Tomography Angiography

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## ABSTRACT

**Introduction:** The normative data of coronary artery size among Indians are sparse. It is often essential to know the coronary dimensions especially during interventions such as stenting to choose the appropriate size of the stent and to decide the very need for stenting. In current practice it is the luminal angiography which is most widely employed to assess the coronary artery size. However, luminal angiography is not very accurate in estimating the epicardial coronary artery size as it does not take into account the mural thickness of the arterial wall. Hence it is prudent to assess coronary artery size by other methods such as Computed Tomography (CT) coronary angiography, quantitative coronary angiogram, Magnetic Resonanace (MR) angiogram, etc. In this study we chose computed tomography as it demonstrates mural thickness along with lumen of the vessels and hence measures the diameter more accurately.

**Aim:** To establish normative data for diameters of the proximal coronary artery segments during life by using MDCT in a cohort of individuals without any structural heart disease.

**Materials and Methods:** Between October 2012 and April 2013, 168 consecutive patients who did not have any structural heart disease underwent CT coronary angiography for evaluation of Coronary Artery Disease (CAD) with atypical symptoms with low pretest probability. Patients who were found to have no coronary artery disease on CT-CAG were recruited in this study. The baseline clinical status and demographic data were obtained from the hospital records.

**Results:** In our study we found that the mean indexed diameter to BSA among females for LMCA 2.32±0.12mm, LAD 1.95±0.15mm, LCX 1.73±0.20mm and RCA 1.84±0.22mm. For males the values were LMCA 2.33±0.13mm, LAD 1.94±0.16mm, LCX 1.74±0.21mm, and RCA 1.79±0.20mm. These values are comparable to other studies.

**Conclusion:** We attempted to establish normative data for normal proximal coronary artery dimensions among South Indian population. Coronary artery dimensions in Indians (indexed to BSA) for proximal major epicardial coronary arteries are similar to that reported in the West.

**Keywords:** Cardiac CT, Coronary CT, CTA, CT angiogram, MDCT, Normal diameters

## INTRODUCTION

There have been a very few reports of estimates of normal (un-diseased) coronary artery dimensions during life in Indian population. It is often essential to know the coronary dimensions especially during interventions such as stenting to choose the appropriate size of the balloon, stent, need for stenting, etc. In current practice it is the luminal angiography which is most widely employed to assess the coronary artery size. However, luminal angiography is not very accurate in estimating the epicardial coronary artery size as it does not take into account the mural thickness of the arterial wall. So far the available evidence has been based on visual estimates or electronic caliper measurements from cine-angiographic films [1-4]. It is not clear whether the coronary artery dimensions among Indians are equivalent to that of western population. There is a general perception that Indians may be harboring smaller epicardial coronary arteries when compared to their western counterparts which is based on the estimates by evaluating the diseased coronary artery size in patients undergoing Coronary Artery Bypass Grafting (CABG) or in autopsy specimens [5]. So we tried to establish a normative data for normal epicardial coronary arteries in a sub population of Indians from Sourthern India without any structural heart disease using 64-slice quantitative Multi Detector Computed Tomography (MDCT) coronary angiography.

## MATERIALS AND METHODS

In this prospective study between Oct 2012 and April 2013, 168 consecutive patients who had normal CT coronary angiography and no structural heart disease were enrolled in the study at Sri Jayadeva Institute of Cardiovascular Sciences and research, Bengaluru, Karnataka, India. All the patients were evaluated by a cardiologist and underwent thorough clinical examination, routine blood chemistry, standard 12 lead ECG (Electro Cardiogram), 2D ECHO (2 dimensional echocardiogram) and CXR-PA (chest X-ray postero-anterior) view. Detailed history and a thorough clinical examination were used to find out any alternative diagnosis for the symptoms. A normal standard 12-lead ECG, a normal 2D ECHO, and a normal chest radiograph-PA view were mandatory for inclusion in the study. Patients with low pretest probability for Coronary Artery Disease (CAD) were referred for Computed Tomography Coronary Angiogram (CT-CAG), to evaluate for the presence of coronary artery disease. The common parameters for CT-CAG were symptoms of atypical chest pain, a positive exercise stress test result with low pretest probability or a borderline exercise test result. Patient characteristics were as depicted in [Table/Fig-1]. The inclusion criteria were patients aged above 18 years with a normal clinical examination, normal standard 12 lead ECG, normal echocardiogram, normal chest X ray (PA view) and a normal CT coronary angiogram. CT-CAG was done at the same centre under the supervision of radiologist using 64-row MDCT. One ml/kg of non-ionic, water-soluble Iohexol 755mg injection; equivalent to Iodine 350mg, was used. No adverse reactions to contrast were noted in any of the subjects. ECG gated MDCT was done at a resting heart rate of 60 to 70bpm as per the guidelines [6-9]. If the heart rate was >70bpm, it was pharmacologically controlled using 5 mg of I.V. metoprolol with a maximum dose of 15mg. In patients who had history of reactive airway disease or known sensitivity to metoprolol, 5-10mg of IV diltiazem was used to control the rate. Sublingual

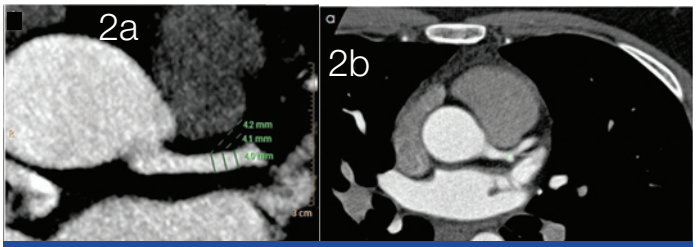
| Parameter | Females(n=77) | | | | Males (n=91) | | | | Both sexes (n=168) |
|---|---|---|---|---|---|---|---|---|---|
| | 18 – 40 years (n=12) | > 41years (n=65) | Total (n=77) | p-value | 18-40 years (n=27) | >41 years (n=64) | Total (n=91) | p-value | Age (48.26±9.79) |
| Height (mts) | 1.59±0.04 | 1.58±0.04 | 1.58±0.04 | 0.242 | 1.68±0.04 | 1.67±0.07 | 1.67±0.06 | 0.606 | 1.63±0.07 |
| Weight(kgs) | 65.00±8.26 | 63.46±7.31 | 63.7±7.44 | 0.514 | 72.96±6.39 | 70.71±8.37 | 72.77±8.47 | 0.888 | 68.61±9.18 |
| BMI(kg/m$^2$) | 25.67±2.99 | 25.52±2.37 | 25.55±2.45 | 0.855 | 26.01±2.26 | 26.08±2.54 | 26.05±2.45 | 0.905 | 25.82±2.46 |
| BSA(m$^2$) | 1.69±0.11 | 1.66±0.11 | 1.67±0.11 | 0.429 | 1.84±0.10 | 1.82±0.15 | 1.83±0.13 | 0.843 | 1.76±0.15 |
| LMCA(mm) | 3.87±0.14 | 3.85±0.18 | 3.85±0.17 | 0.726 | 4.28±0.18 | 4.26±0.24 | 4.27±0.22 | 0.789 | 4.08±0.29 |
| LAD(mm) | 3.33±0.21 | 3.22±0.23 | 3.24±0.23 | 0.117 | 3.60±0.19 | 3.48±0.24 | 3.51±0.23 | 0.020 | 3.39±0.27 |
| LCX(mm) | 2.94±0.27 | 2.87±0.33 | 2.88±0.32 | 0.499 | 3.25±0.37 | 3.16±0.34 | 3.19±0.35 | 0.252 | 3.05±0.37 |
| RCA(mm) | 3.07±0.21 | 3.05±0.34 | 3.05±0.32 | 0.887 | 3.28±0.35 | 3.27±0.32 | 3.27±0.33 | 0.866 | 3.17±0.34 |
| LMCA/m$^2$ | 2.29±0.11 | 2.32±0.13 | 2.32±0.12 | 0.429 | 2.33±0.11 | 2.34±0.14 | 2.34±0.13 | 0.894 | 2.33±0.13 |
| LAD/m$^2$ | 1.97±0.12 | 1.94±0.16 | 1.95±0.15 | 0.530 | 1.97±0.15 | 1.91±0.17 | 1.93±0.17 | 0.142 | 1.94±0.16 |
| LCX/m$^2$ | 1.74±0.16 | 1.73±0.21 | 1.73±0.20 | 0.909 | 1.78±0.23 | 1.74±0.22 | 1.75±0.22 | 0.421 | 1.74±0.21 |
| RCA/m$^2$ | 1.81±0.09 | 1.85±0.24 | 1.84±0.22 | 0.652 | 1.84±0.22 | 1.79±0.18 | 1.79±0.20 | 0.869 | 1.82±0.21 |

**[Table/Fig-1]:** Demographic characteristics, mean major epicardial coronary diameters and indexed coronary diameters to BSA among male and female patients.

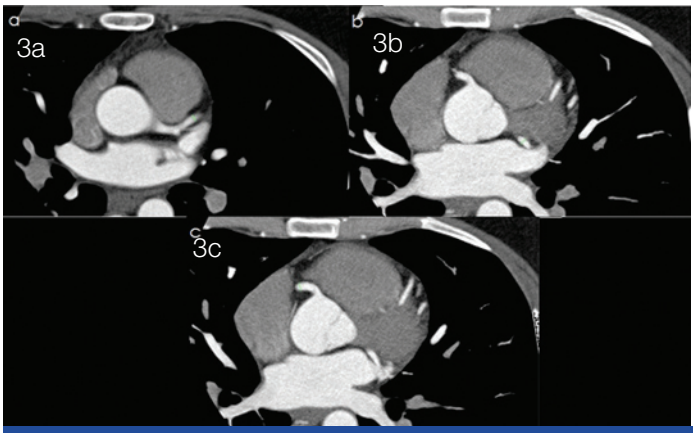
nitroglycerin was not used as it is known to cause coronary dilation and our objective being finding actual coronary diameters. The images were acquired as per the standard guidelines [6-9]. All the measurements for epicardial coronary arteries were taken at the end diastole with magnified source image or a curved thin multiplanar reformat image using standard DICOM viewer software provided with the machine.

The measurements were taken for Left Main Coronary Artery (LMCA) at 1cm from its origin from the left coronary sinus. The length of the LMCA was noted. If LMCA were to be >1cm in length [Table/Fig-2a], the same was documented and three measurements were taken and averaged. If the length was < 1cm [Table/Fig-2b] measurement was taken immediately proximal to bifurcation or trifurcation. Similarly for LAD (Left Anterior Descending) [Table/Fig-3a] and LCX (Left Circumflex) [Table/Fig-3b] the measurements were taken at 1cm from their origin from LMCA. The presence of ramus intermedius was noted. The measurements for the same were not taken as the size was highly variable and the values were not normally distributed to generate a normative data. For RCA (Right Coronary Artery), [Table/Fig-3c] measurements were taken at 1cm from its origin from right coronary sinus. The dominance of the coronary circulation was noted by the origin of PDA (Posterior Descending Artery), PLV (Posterior Left Ventricular) and the vessel crossing crux as documented in 3D reconstructed image [Table/Fig-4]. Any anomalies in origin, ectasia, spontaneous dissection were noted and such patients were excluded from the study. We did not make an attempt to measure the branches of major epicardial coronary arteries as their size, presence and anatomical distribution was highly variable.

Demographic characteristics of the patients and mean epicardial coronary artery diameters in different age groups among males and females and indexed values to body surface area are shown [Table/Fig-1].




**[Table/Fig-2a,b]:** Showing method of measurement of LMCA when it is more than 1cm in length and less than 1cm in length respectively.



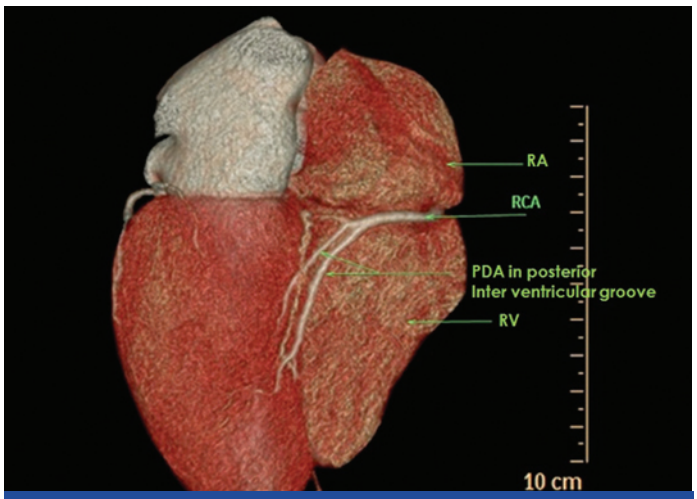

**[Table/Fig-3a-c]:** Depicting the method of measurement of LAD, LCX, RCA respectively.

## STATISTICAL ANALYSIS

Data were analysed. Results were expressed as mean±1SD. Descriptive statistics were used to describe demographic data. Correlations were estimated by Pearson correlation coefficient. Student's t-test was used for comparison of differences in coronary artery dimensions among males and females. One-way Anova was used to compare the descriptives between the two age groups. A two tailed p-value less than 0.05 was considered statistically significant.

## RESULTS

In our study we found (as depicted in [Tables/Fig-1,5,6] that the mean indexed diameter to BSA among females for LMCA 2.32±0.12mm, LAD 1.95±0.15mm, LCX 1.73±0.20mm and RCA 1.84±0.22mm. For males the values were LMCA 2.33±0.13mm, LAD 1.94±0.16mm, LCX 1.74±0.21mm, and RCA 1.79±0.20mm.




**[Table/Fig-4]:** Volume rendered (3 dimensional) image showing the RCA and PDA in posterior inter ventricular groove. (RA:Right Atrium; RV:Right Ventricle).

These values are comparable to other studies [10,11]. Among females 84.4% (n=65) had right dominant circulation, 9.1% (n=7) had left dominant circulation, while 6.5% (n=5) had co-dominant circulation. Among males 81.3% (n=74) had right dominant, 7.6% (n=7) left dominant and 10.9% (n=10) had co-dominant circulation. 85.7% (n=66) of females had an LMCA longer than 1cm, and 14.3 % (n=11) had an LMCA shorter than 1cm. Among males 90.1% (n=82) had an LMCA longer than 1cm and 9.9% (n=9) had an LMCA shorter than 1cm. As far as the ramus intermedius is concerned, 71.45% (n=55) of females did not have a ramus intermedius, while 28.6% (n=22) had a ramus intermedius. Among the males 78.1% (n=71) did not have a ramus, and 21.9% (n=20) had a ramus. In this study we did not find any significant correlation between the coronary artery dimensions with the age (p>0.489), sex (p>0.178), diabetic status (p>0.060), HTN (p>0.272) and dyslipidemia (p=>0.172). However, coronary artery diameters were positively correlated with height (p<0.001), weight (p<0.001), BMI (p<0.001) (which directly influence body surface area) and BSA (p<0.001). As there is reported change within dimensions with respect to age [12], both males and females in the study population were grouped into two different age groups, group one, those who were aged less than or equal to 40 years, group two, those who were aged more than 40 years and both the groups were analysed. Between the two age groups both in males as well as females, there was no significant difference in the indexed-diameters of coronary arteries (males, p=0.869, females, p=0.652).

## DISCUSSION

The dimensions of the coronary arteries are highly variable in the normal population [1,13,14]. Genetic factors, age, sex, body weight, body surface area, cardiac mass and ethnic or racial factors have all been correlated with the coronary artery anatomy in various studies [4,12,13,15-18]. Many of these studies were either injection studies in autopsy specimens or dissection studies. The inherent fallacy of these studies has been the various factors involved in the procurement, preservation, fixation & analysis of the epicardial coronary arteries. Therefore, the validity of these dimensions in estimating the true dimension of coronary arteries is questionable. Visual interpretation of coronary angiograms is inherently flawed & observer dependent [19,20]. Many studies have employed QCA (Quantitative Coronary Angiography) in various populations. Coronary angiogram is a luminogram and as coronary atherosclerosis begins as an abluminal process, many patients evaluated in these studies may have had early coronary atherosclerosis and be falsely labeled as normal. As CT-CAG can evaluate both the coronary wall and lumen, it appears to be a better tool to evaluate the coronary dimensions in truly normal coronary artery. Although there are many studies employing QCA to estimate coronary artery size in various populations, there are no published reports in current literature employing MDCT coronary angiogram to estimate coronary diameters among south Indian population. We attempted to derive normal coronary diameters among south Indians by employing 64-slice MDCT angiogram.

| Parameter | Females (n=77) | | Males (n=91) | |
|---|---|---|---|---|
| | Mean (mm) ±SD (n=77) | Range | Mean (mm) ±SD (n=91) | Range |
| Age(y) | 50.62±8.72 | 30-70 | 46.25±1.02 | 18-72 |
| Height (mt) | 1.58±0.04 | 1.47-1.67 | 1.67±0.06 | 1.55-1.83 |
| Weight(kg) | 63.7±7.44 | 50-86 | 72.77±8.47 | 55-96 |
| BMI(kg/m$^2$) | 25.55±2.45 | 21.5-32.5 | 26.05±2.45 | 20.7-34.4 |
| BSA(m$^2$) | 1.67±0.11 | 1.44-1.97 | 1.83±0.13 | 1.58-2.13 |
| LMCA(mm) | 3.85±0.17 | 3.3-4.2 | 4.27±0.22 | 3.6-4.9 |
| LAD(mm) | 3.24±0.23 | 2.7-3.7 | 3.51±0.23 | 2.9-3.9 |
| LCX(mm) | 2.88±0.32 | 2.2-4.1 | 3.19±0.35 | 2.2-4.1 |
| RCA(mm) | 3.05±0.32 | 1.5-3.5 | 3.27±0.33 | 2.2-4.1 |

**[Table/Fig-5]:** Demographic characteristics.

Coronary artery size in Indians has been reported to be significantly smaller when compared to that of the western population [18,19,21]. This has been attributed to body habitus, build and the body surface area. Lip reported that though the unadjusted angiographically estimated mean diameters of various coronary artery segments in the western population among Caucasians were higher than those of Indian Asians and there was no statistically significant difference when these were indexed to the body surface area leading them to conclude that the smaller size of the coronaries in Indian Asians is attributable to their relatively smaller body surface area. As expected, in our study we found that diameters are a little higher than what is reported in the literature for Indians by luminal angiography [Table/Fig-7]. This may be because of the fact that MDCT includes mural thickness of coronary arteries along with luminogram.

As earlier reports have suggested an age related change in coronary dimensions [12], we divided our patients into two groups (those less than or equal to 40years and >40years) and analysed. Both in males and females between the two age groups, there was no significant difference in coronary diameters. However, coronary artery diameters were positively correlated with height, weight, BMI and BSA. This is also reflected in previous reports where a positive correlation of the coronary dimensions with body surface area has been reported [18,21]. Generally the coronary artery size was greater in the male patients as compared to females in both left and right coronary systems. However, this difference vanished

| Parameter | | Females (n=77) | | | | Males (n=91) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 18-40y (n=12, 15.6%) | >40y (n=65, 84.4%) | Total (n=77) | p-value (2 sided) | 18-40y (n=27, 29.7%) | >40y (n=64, 70.3%) | Total (n=91) | p value (2 sided) |
| DM | Non-Diabetic | 11 | 58 | 69(89.6%) | 1.000 | 26 | 60 | 86(94.5%) | 1.00 |
| | Diabetic | 1 | 7 | 8(10.4%) | | 1 | 4 | 05(5.5%) | |
| HTN | Non-HTNve | 12 | 52 | 64(92.7%) | 0.201 | 26 | 50 | 76(83.5%) | 0.034 |
| | HTNve | 0 | 13 | 13(7.3%) | | 1 | 14 | 15(16.5%) | |
| Smoking | Non-Smokers | 12 | 65 | 77(100%) | ------ | 21 | 46 | 67(73.6%) | 0.613 |
| | Smokers | 0 | 0 | 00.00(0%) | | 06 | 18 | 24(26.4%) | |
| Dyslipidemia | Absent | 6 | 51 | 57.0(74%) | 0.680 | 10 | 7 | 79(86.8%) | 0.007 |
| | Present | 6 | 14 | 20.0(26%) | | 17 | 57 | 12(13.2%) | |
| TMT | Normal | 4 | 8 | 12(15.6%) | ------- | 7 | 12 | 19(20.9%) | ------ |
| | Abnormal | 8 | 57 | 65(84.4%) | | 20 | 52 | 72(79.1%) | |
| Ramus* | Absent | 9 | 46 | 55(71.4%) | 1.000 | 22 | 49 | 71(78%) | 0.783 |
| | Present | 3 | 19 | 22(28.6%) | | 5 | 15 | 20(21.9%) | |
| Dominance | Right | 11 | 54 | 65(84.4%) | ------ | 22 | 52 | 74(81.3%) | ----- |
| | Left | 1 | 6 | 07(09.1%) | | 1 | 6 | 07((7.6%) | |
| | Co-do | 0 | 5 | 05(06.5%) | | 4 | 6 | 10(10.9%) | |
| LMCA length | <1cm | 3 | 8 | 11(14.3%) | ------ | 2 | 7 | 9(9.9%) | ----- |
| | >1cm | 9 | 57 | 66(85.7%) | | 25 | 57 | 82(90.1%) | |

**[Table/Fig-6]:** Patient characteristics including LMCA length, prevalence of ramus and dominance of the epicardial coronary system.
*Only presence or absence was noted: dimensions not taken as it was highly variable.

| | 64 slice MDCT angio based | | | Conventional Luminal angiography based | | |
|---|---|---|---|---|---|---|
| | Current Study(Indians, n=168) | | | AIIMS data [7] (Indians, n=94, m:f=63:31) | Birmingham data [11] | |
| | Males (n=91) | Females (n=77) | Males and females | | Indian Asian (n=39, m:f=20:19) | Caucasians (n=77, m:f = 39:38 |
| LMCA/$m^2$ | 2.34±0.13 | 2.32±0.12 | 2.32±0.13 | 2.16±0.42 | 2.26±0.41 | 2.38±0.47 |
| pLAD/$m^2$ | 1.93±0.17 | 1.95±0.15 | 1.94±0.16 | 1.69±0.37 | 1.83±0.34 | 1.89±0.37 |
| pLCX/$m^2$ | 1.75±0.22 | 1.73±0.20 | 1.74±0.21 | 1.67±0.39 | 1.71±0.39 | 1.71±0.37 |
| pRCA/$m^2$ | 1.79±0.20 | 1.84±0.22 | 1.82±0.21 | 1.89±0.39 | 1.70±0.39 | 1.79±0.39 |

**[Table/Fig-7]:** Coronary artery diameter indexed to body surface area and compared with other series (mean diameter mm/$m^2$ BSA.

when diameters were indexed to BSA indicating that it is more BSA dependent than, sex.

Indians and South East Asians have been documented to have early and aggressive CAD [22]. The normal coronary artery dimensions can serve as a guide for selection of stent size especially in diffusely diseased coronaries. As under or oversized, under or over expanded stents are well documented risk factors for stent thrombosis, re-stenosis and procedure related complications, these normative data can serve to mitigate the same.

## LIMITATIONS

The study was done at a tertiary referral centre and may suffer from referral bias. In addition, we have studied normal CT coronary angiograms in patients who had reasons to undergo the investigation, such as typical or atypical chest pain and such patients may not truly represent a 'normal' population. Unlike other studies which have employed luminal angiography, MDCT measures total artery size including coronary artery mural thickness which may actually overestimate coronary artery lumen size [23,24].

## CONCLUSION

The study has attempted to establish normative data for normal proximal coronary artery dimensions among a sub population of Indians. Among Indians who do not have any structural heart disease the mean indexed diameter to BSA among females for LMCA 2.32±0.12mm, LAD 1.95±0.15mm, LCX 1.73±0.20mm and RCA 1.84±0.22mm. For males the values were LMCA 2.33±0.13mm, LAD 1.94±0.16mm, LCX 1.74±0.21mm, and RCA 1.79±0.20mm. Coronary artery dimensions (indexed to BSA) in Indians are similar to western population among Caucasians. Coronary artery dimensions measured on CT are slightly larger as compared to ones determined on luminogram of catheter angiogram. Effect of arteriosclerosis in reducing the vessel size is not significant. When diameters of right and left coronary systems are indexed to body surface area there is no significant difference among males and females.

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**FINANCIAL OR OTHER COMPETING INTERESTS:** None.

Date of Submission: **Dec 02, 2015**
Date of Peer Review: **Jan 09, 2016**
Date of Acceptance: **Mar 14, 2016**
Date of Publishing: **May 01, 2016**