Research Brief

Left main coronary artery diameter − A correlation between intravascular ultrasound and quantitative coronary angiography

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ABSTRACT

Coronary angiography mostly underestimates coronary artery size. Indian data is scarce on correlating quantitative angiographic coronary diameter (D_{QCA}) to intravascular ultrasound derived coronary diameter (D_{IVUS}). We retrospectively analyzed 10-year data (2008−2017) of patients undergoing IVUS guided left main percutaneous coronary intervention (LM-PCI). LM, ostio-proximal LAD (op-LAD), and ostio-proximal LCX (op-LCX) were analyzed in 186, 177 and 44 patients, respectively. A linear correlation was noted between D IVUS and D QCA with derived equations for LM $D_{IVUS} = 1.68 + 0.69 \times D_{QCA}$, op-LAD $D_{IVUS} = 1.91 + 0.53 \times D_{QCA}$, op- LCX $D_{IVUS} = 1.93 + 0.49 \times D_{QCA}$. We conclude that our equations could be used for an approximate estimation of true vessel size in the absence of IVUS assessment.

1. Introduction

Coronary angiography (CAG) has traditionally been the gold standard for invasive assessment of coronary artery disease (CAD).[1] However, CAG is essentially a luminogram which provides only a two-dimensional image of the vessel with significant interand intra-observer variability depending upon the angulation of the frame frozen for analysis. In contrast to CAG, intravascular imaging produces cross-sectional images of the coronary arteries with far greater spatial resolution and images closer to reality. It is capable of determining vessel size and plaque morphology more accurately eliminating some of the inherent disadvantages of angiography such as contrast streaming, foreshortening, vessel overlap, and angle dependency in addition.[1−3]

Assessment of true coronary artery size is all-the-more essential for optimal stent sizing during left main percutaneous coronary intervention (LM-PCI).[2,3] We, therefore, aimed to study left main(LM), ostio-proximal left anterior descending(op-LAD), and ostio-proximal left circumflex(op-LCX) coronary artery diameters in atheroma free segments by IVUS and QCA in Indian patients and derive a correlation between the artery diameters as obtained by these two methods.

2. Methodology

Data from consecutive patients who underwent IVUS guided PCI of the left main coronary artery in our institution from January 2008 to December 2017 were included in the study.

2.1. Selection criteria for target vessels

Angiographic measurements were done using standard quantitative coronary angiography (QCA) software employing electronic calipers. Contrast filled segments of coronary arteries, free of tortuosity, were assessed in segments without foreshortening. Catheter size was used as the calibrator for the QCA system by employing an automated and operator-independent edge detection technique. Measurements were taken uniformly in diastole, in disease-free segments, and widest dimension of each segment was then taken for analysis. The analyzed segments included the LM body, op-LAD before the origin of the first septal branch, and op-LCX before the first obtuse marginal (OM). Measurements were made in right anterior oblique (RAO) view or antero-posterior (AP) caudal viewor the left anterior oblique (LAO) caudal view whichever demarcated the left main bifurcation the best (Fig. 1, panel a−c).

IVUS was performed with 40 MHz catheter (Atlantis™/ Atlantis™ Pro ilab, Boston Scientificcorp, MA, USA). Auto-pullback was performed @0.5 mm/s from disease-free segment distal to the stenotic lesion and up to the proximal-most disease-free segment. All IVUS measurements were done offline with

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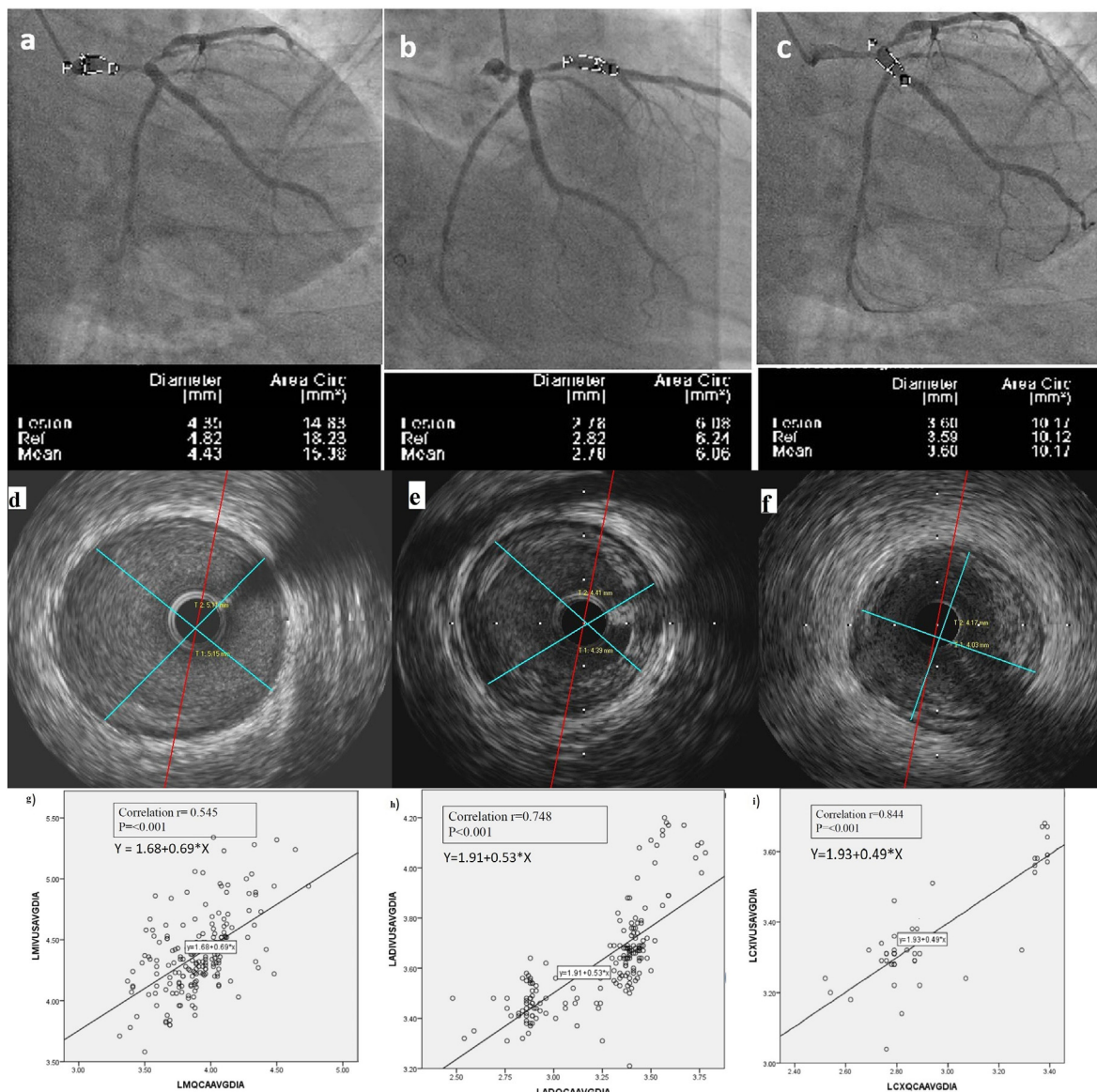
Fig. 1. Upper row shows QCA measurement of LM in AP caudal view**(panel a)**, LAD in RAO caudal view**(panel b)**, LCX in AP caudal view**(panel c)**. Middle row shows corresponding IVUS measurement of maximum and minimum vessel diameter in the disease-free segment of LM**(panel d)**, LAD**(panel e)**, LCX**(panel f)**. Bottom row shows scatter plot with linear correlation between IVUS and QCA derived diameters of LM**(panel g)**, ostio-proximal LAD**(panel h)** and ostio-proximal LCX**(panel i)**. AbbreviationsQCA = Quantitative Coronary Angiography, IVUS=Intravascular Ultrasound, LM = left main, AP = antero-posterior, RAO = right anterior oblique, LAD = Left anterior descending artery, LCX = left circumflex artery.

QIvus®iMapsoftware (Medis medical imaging systems BV, Leiden, Netherlands). For IVUS based vessel sizing, in disease-free segment of each vessel (LM/op-LAD/op-LCX) the shortest and longest cross-sectional diameters through the center point of lumen were measured till the external elastic membrane (EEM), and the mean of measurements was taken as IVUS size (Fig. 1, panel d–f).

2.2. Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, version 23, for Windows (SPSS™, IBM Corp, Chicago, IL, USA). Correlation was derived using Pearson's and Spearman's coefficients for continuous variables.

3. Results

During the 10-year study period (2008–2017), a total of 220 IVUS guided LM-PCI were done, of which 34 cases were excluded due to suboptimal IVUS imaging or QCA assessment. A flow chart showing study case flow is appended in Fig. 2. The study group included 86.6% males with a mean age of 57.5 ± 9.8 years. The mean BMI was 24.2 ± 3.1 kg/m^2, with a mean body surface area of 1.69 ± 0.12 m^2. 64 (34%) patients were diabetic and 98 (52.7%) had hypertension. 131 (70.4%) patients presented with stable coronary artery disease.

QCA derived mean diameters for LM, op-LAD and op-LCX were 3.89 ± 0.25 mm, 3.36 ± 0.28 mm and 2.85 ± 0.27 mm respectively. Mean diameters of the same segments assessed by IVUS were
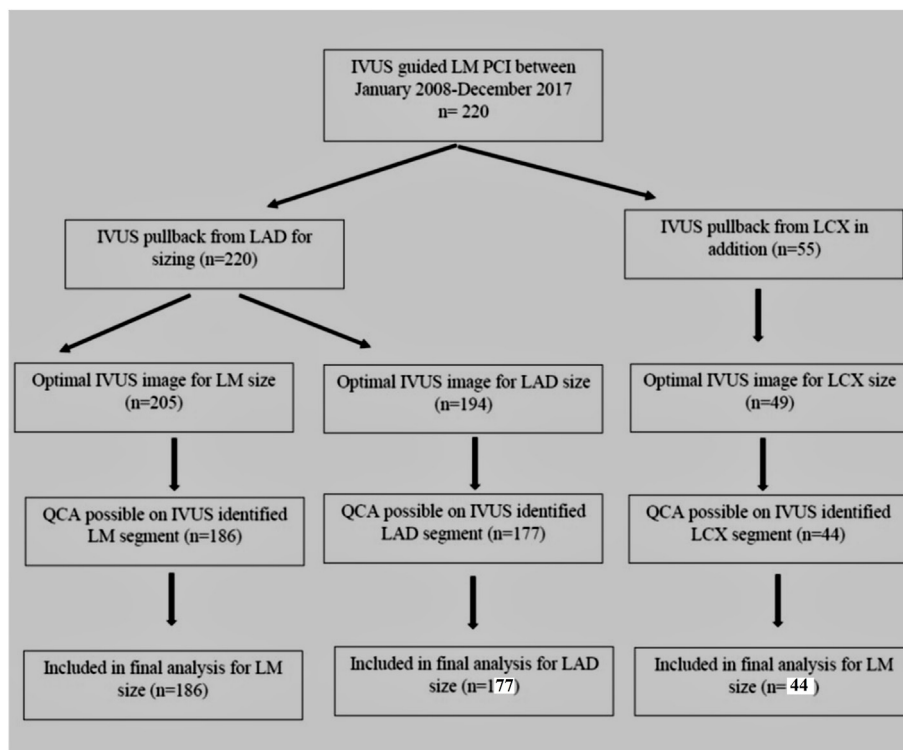
Fig. 2. A flow chart showing study case flow.; Abbreviations: QCA = Quantitative Coronary Angiography, IVUS=Intravascular Ultrasound, LM = left main, PCI = percutaneous coronary intervention, LAD = Left anterior descending artery, LCX = left circumflex artery.

4.33 ± 0.32 mm, 3.61 ± 0.21 mm and 3.31 ± 0.16 mm, respectively. IVUS derived diameters for all vessels were significantly larger as compared to QCA (Table 1). On subgroup analysis, we did not find any difference in the IVUS derived sizes with respect to hypertension, diabetes, sex and smoking (refer to supplementary data).

3.1. Correlation between QCA and IVUS measurements

There was a linear correlation between QCA and IVUS derived measurements (Fig. 1, panel g–i) with coefficient of correlation (r) being 0.545 ($p \leq 0.001$) for LM, 0.748 ($p \leq 0.001$) for op-LAD and 0.844 ($p \leq 0.001$) for op-LCX. Scatter plot diagram of the correlation between the two techniques for coronary artery measurements for LM, op-LAD and op-LCX showed a linear association; the equations being $D_{IVUS} = 1.68 + 0.69 \times D_{QCA}$, $D_{IVUS} = 1.91 + 0.53 \times D_{QCA}$ and $D_{IVUS} = 1.93 + 0.49 \times D_{QCA}$, respectively where D_{IVUS} was the IVUS derived diameter and D_{QCA} was the QCA derived diameter.

4. Discussion

Our study shows that coronary artery diameters when assessed by IVUS were significantly larger than the QCA derived diameter. A linear correlation was deduced between IVUS and QCA derived

Table 1
Intravascular Ultrasound and Quantitative coronary Angiography derived coronary artery diameters.

Mean Coronary artery diameter (mm)	IVUS	QCA	*p*-value
Left Main ($n = 186$)	4.33 ± 0.32	3.89 ± 0.25	0.003
Ostio-proximal LAD ($n = 177$)	3.61 ± 0.21	3.36 ± 0.28	0.002
Ostio-proximal LCX ($n = 44$)	3.31 ± 0.16	2.85 ± 0.27	0.002

Abbreviations: IVUS=Intravascular Ultrasound; QCA = Quantitative Coronary Analysis; LAD = Left anterior descending; LCX = Left Circumflex.

measurements with a derived straight–line equation. Coronary angiography has limitations in vessel sizing, especially in LMCA, because of aortic cusp opacification, streaming of contrast agent, short vessel length, and lack of a normal reference segment.[4] IVUS may be more relevant for LM intervention with much bigger true vessel size which is often under-estimated on QCA.[5] Despite some previous studies[6] showing IVUS to be effective in estimating and correlating with QCA for coronary measurements in the atheromatous segments, we specifically tried to assess the disease free segments within the complex of LM, op-LAD and op-LCX so as to exclude the effect of remodeling on the vessel sizes measured by IVUS. Reddy et al[7] published a contemporary data regarding IVUS and QCA derived diameters where IVUS measurements were found to be larger than QCA ones with age and body surface area (BSA) as the independent predictors of coronary diameters. Even after adjusting minimum luminal diameter (MLD) for BSA, Reddy et al[7] found that IVUS measurements of left main, proximal LAD and proximal RCA were significantly larger than QCA which is similar to our findings. Several studies show that IVUS guided PCI leads to better event free survival as compared to angiography-guided PCI.[8,9] ULTIMATE trial demonstrated that IVUS-guided DES implantation resulted in a lower incidence of target vessel failure at 12 months, particularly for patients who had an IVUS-defined procedural optimization compared to angiographic guidance only.[8] The underestimation of the vessel size by QCA lead to smaller diameter stents, which might have led to more under-expanded or undersized stents leading to suboptimal post PCI results.

In a study by Park et al[5] the average stent diameter at LM in IVUS guided stenting was significantly larger when compared with angiography guided group (3.6 ± 0.5 mm vs 3.4 ± 0.4 mm; $p = 0.0002$) resulting in the impact of IVUS on long-term mortality in stenting of unprotected LM disease. 2018 ESC/EACTS guidelines for myocardial revascularization give class II a recommendation to

IVUS for optimizing treatment of unprotected left main lesions.[10] However, in a real-world scenario, IVUS use in LM PCI is quite low. Sheridan et al in an international registry showed the use of IVUS was only 14%.[11] Unlike western countries, here in India we do not have a consolidated registry data to estimate the exact usage of coronary imaging in PCI. However, published national interventional council (CSI-NIC) data of 5 years (2013—2018) suggests a small but constantly increasing share of coronary imaging modalities (IVUS/OCT) being employed in coronary interventions viz. from 0.32% in 2013 and 1.16% in 2017 the proportion has gone rapidly up to 4.22% in 2018.[12] The low use of IVUS may be due to limited availability, added cost, and increased procedure time. Therefore, alternatively the straight—line equation derived by us between IVUS and QCA could help predict the IVUS diameter or the so-called true vessel size from QCA measurement in the absence of IVUS performance.

5. Limitations

Our study has some limitations. This was a single centre, cross-sectional, retrospective study with a smaller sample size. No follow-up IVUS data was available for analysis and monitoring of plaque progression. One of the major limitations of the study is that the analysis of QCA and IVUS data was largely done by the same operator. But to cover for this we made measurement from at least 2-3 adjacent frames per site specifically on an average of the same was used as the final measurement at that point. Our study population had only 13% females, thereby limiting the generalizability of the results. The measurements were not validated from an external core laboratory which could have allowed some intra-observer bias. Also, further research would be required to validate the derived equations for predictive accuracy and applicability in a broader subset of patients at a large scale.

6. Conclusion

We conclude that coronary artery measurements are under-estimated by angiography. Actual vessel size (IVUS size) could be predicted using the QCA measurement by a straight—line equation derived from our study. This equation may have great relevance to the optimal performance of LM interventional procedures especially in resource-constraint setting with limited access to intra-vascular imaging with respect to stent sizing.

Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and also all authors are in agreement with the manuscript. All authors declare there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ihj.2021.09.009.

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