Fusion of morphological data obtained by coronary computed tomography angiography with quantitative echocardiographic data on regional myocardial function

Piotr Lipiec¹, Paulina Wejner-Mik², Katarzyna Wdowiak-Okrojek¹, Ewa Szymczyk², Adam Skurski³, Andrzej Napierski³, Marek Kamiński³, Konrad Szymczyk¹, Jarosław D. Kasprzak²

¹Department of Rapid Cardiac Diagnostics, Medical University of Lodz, Lodz, Poland
²Department of Cardiology, Medical University of Lodz, Lodz, Poland
³Department of Microelectronics and Computer Science, Lodz University of Technology, Lodz, Poland

Abstract

Background: Three-dimensional (3D) fusion of morphological data obtained by coronary computed tomography angiography (CCTA) with functional data from resting and stress echocardiography could potentially provide additional information compared to examination results analyzed separately and increase the diagnostic and prognostic value of non-invasive imaging in patients with suspected coronary artery disease (CAD). Using vendor-independent software developed in our institution, we aimed to assess the feasibility and reproducibility of 3D fusion of morphological CCTA data with echocardiographic data regarding regional myocardial function.

Methods: Thirty patients with suspected CAD underwent CCTA and resting transthoracic echocardiography. From CCTA we obtained 3D reconstructions of coronary arteries and left ventricle (LV). Offline speckle-tracking analysis of the echocardiographic images provided parametric maps depicting myocardial longitudinal strain in 17 segments of the LV. Using our software, 3 independent investigators fused echocardiographic maps with CCTA reconstructions in all patients. Based on the obtained fused models, each segment of the LV was assigned to one of the major coronary artery branches.

Results: Mean time necessary for data fusion was 65 ± 7 s. Complete agreement between independent investigators in assignment of LV segments to coronary branches was obtained in 94% of the segments. The average coefficient of agreement (kappa) between the investigators was 0.950 and the intra-class correlation coefficient was 0.9329 (95% CI 0.9227–0.9420).

Conclusions: Three-dimensional fusion of morphological CCTA data with quantitative echocardiographic data on regional myocardial function is feasible and allows highly reproducible assignment of myocardial segments to coronary artery branches. (Cardiol J 2016; 23, 3: 264–269)

Key words: coronary artery disease, hybrid imaging, myocardial function, echocardiography, coronary computed tomography angiography
**Introduction**

Coronary angiography remains the reference technique in the diagnostics of coronary artery disease (CAD). However, it is an invasive examination associated with risk of complications. The qualification of patients to coronary angiography is based on clinical presentation and results of non-invasive examinations. Coronary computed tomography angiography (CCTA) is one of such modalities, but its specificity (64–83%) in detecting significant coronary stenoses may be regarded as suboptimal, especially in patients with obesity, coronary calcifications, higher heart rates or irregular heart rhythms [1]. Other valuable non-invasive diagnostic tools include imaging techniques enabling assessment of resting and stress myocardial perfusion and function — stress echocardiography, single-photon emission computed tomography (SPECT) and positron emission tomography (PET) [1, 2].

Recently, the fusion of SPECT and CCTA (SPECT/CCTA), as well as PET and CCTA (PET/CCTA), has been intensively studied, as it allows combining the morphological data (coronary angiogram) with functional data (resting and stress perfusion or metabolism), thus increasing the diagnostic and prognostic value of non-invasive imaging [3–5]. However, these techniques are associated with increased exposure to radiation [6]. In contrast, echocardiography is a relatively inexpensive and widely available technique, free from such risks, therefore the possibility of using the data from resting and stress echocardiography instead of functional data from PET or SPECT seems a promising and safer alternative in patients with suspected or known CAD.

Using software developed in our institution, we aimed to assess the feasibility and reproducibility of three-dimensional (3D) fusion of morphological CCTA data with functional echocardiographic data regarding regional myocardial function in patients with suspected CAD.

**Methods**

Thirty patients (14 men; mean age 60 ± 7 years, range 46–74 years) with suspected CAD (mean Canadian Cardiovascular Society class 2.1 ± 0.7) referred for CCTA by their attending physicians were included in the study. Within 2 days of CCTA, they all underwent resting transthoracic echocardiography. The study protocol was approved by the Ethics Committee of our institution.
Our software, which can be deployed on any
PC station without any constrains of hardware and
software configuration, requires uploading three
files for each patient: two STL (StereoLithography)
files representing CCTA-based 3D reconstructions
of the LV and the coronary arteries and one JPG,
TIFF or PNG file containing echocardiographic
test’s-eye map. It should be noted that all these file
formats are standardized and supported by numer-
ous software packages and, therefore, our software
allows vendor-independent analysis.

Merging 2-dimensional (2D) bull’s-eye maps
with a 3D model requires accurate orientation,
which is achieved by mapping each point of a 2D
image onto sections of the 3D LV model. We use
a semi-automatic solution, in which the user is asked
to manually place 3 equivalent markers both on the
3D model of the LV and on the 2D map (1 marker
at apex of the LV and 2 markers at the base of the
LV: one on the border between anterior septum and
the anterior wall and the second one on the border
between inferor septum and the inferior wall). This
provides enough information for executing a
fully automated matching and texturing algo-
rithms. Custom texturing (UV mapping technique)
is used to merge the two different domain (3D and
2D) images into one interactive view. The last stage
(fully automatic) of the fusion procedure is adding
the 3D reconstruction of the coronary arteries.

The final result of data fusion is an interactive
3D model, which allows allocation of LV segments
to coronary arteries and is supposed to help in
recognizing whether possible coronary stenosis
observed on CCTA is associated with possible
abnormality in myocardial function (Fig. 1).

**Statistical analysis**

Continuous and categorical variables are ex-
pressed as mean ± standard deviation and as
percentages (%), respectively. The agreement be-
tween investigators in assignment of LV segments
to one of major coronary branches was assessed
using inter-rater agreement statistic (kappa) and
the the intra-class correlation coefficient.

**Results**

Three-dimensional data fusion was feasible in
all cases. The mean time necessary for data fusion
was 65 ± 7 s (range: 51–79 s). Complete agreement
between independent investigators in assignment
of LV segments to one of major coronary branches
was obtained in 481 (94%) segments (Table 1). The
average coefficient of agreement (kappa) between
the investigators was 0.950 and the intra-class correlation coefficient was 0.9329 (95% confidence interval 0.9227–0.9420).

Left ventricular segments most frequently assigned to different major coronary artery branches by independent investigators were: apical lateral (discrepancies in 7 cases), apical inferior (discrepancies in 6 cases), apical septal (discrepancies in 6 cases), mid inferolateral (discrepancies in 4 cases) and mid anterolateral (discrepancies in 2 cases).

**Discussion**

To the best of our knowledge, this is the first study documenting feasibility and reproducibility of vendor-independent 3D fusion of morphological CCTA data with functional echocardiographic data in patients with suspected CAD. In the literature, we found only 1 case report describing feasibility of vendor-specific fusion of data from 3D speckle tracking echocardiography with CCTA images [7].

We used echocardiographic bull’s-eye maps representing peak systolic longitudinal strain due to the fact that it is a well validated parameter of myocardial systolic function and it can be also used for quantitative analysis of a stress test, as demonstrated by our group and other investigators [8, 9]. However, it is also possible to fuse maps representing other echocardiographic parameters of regional function, such as strain rate.

Based on encouraging results available in the literature, showing incremental clinical value of hybrid PET/CCTA and SPECT/CCTA imaging in patients with suspected CAD, one can assume that fusion of morphological data obtained by CCTA with functional data from resting and stress echocardiography could potentially provide additional information compared to examination results analyzed separately, and could increase the diagnostic and prognostic value of non-invasive imaging in this patient population (Fig. 2). Nevertheless, this assumption and the choice of most suitable echocardiographic parameters to fuse with CCTA data require validation in further clinical studies.

In our study, we obtained functional data from 2D echocardiography. Functional maps can also be created from 3D echocardiographic datasets, although 3D echocardiography remains less widely available and inferior in temporal resolution to 2D techniques, which is an important limitation in functional analysis. Furthermore, functional parameters derived from quantitative analysis of 2D echocardiographic images are still more validated than those obtained by 3D echocardiography [10, 11].

**Limitations of the study**

This is a single-center study on a relatively small group of patients. However, such preliminary feasibility and reproducibility data are required before this technique can be evaluated in larger clinical studies. Another limitation of this study is the use of only 1 computed tomography scanner and 1 echocardiograph, instead of equipment provided by various vendors. Since our software allows using file formats, which are standardized and supported by numerous software packages (STL, JPG, TIFF or PNG), we believe that it can also be used for fusion of data acquired with other computed tomography scanners and echocardiographs. Nevertheless, this assumption requires validation.

It should also be underlined that our findings regarding feasibility and reproducibility of CCTA-echocardiography fusion are based on analysis of only resting echocardiographic images. However, we believe that these results can be extrapolated to fusion of CCTA data with stress echocardiography. Our software tool uses echocardiographic bull’s-eye maps, which can be obtained with various analysis packages (in our case EchoPac, GE Medical Systems) at low and high heart rates — the feasibility of obtaining strain data and bull’s-eye maps during stress echocardiography, as well as their diagnostic value, have been presented in numerous papers, including the one from our group [8, 9].

---

**Table 1. Agreement between investigators in assignment of 510 left ventricular segments to major coronary artery branches in 30 patients.**

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Complete agreement</th>
<th>Coefficient of agreement (kappa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 vs. 2</td>
<td>496 (97%) segments</td>
<td>0.965 (95% CI: 0.947–0.983)</td>
</tr>
<tr>
<td>1 vs. 3</td>
<td>490 (96%) segments</td>
<td>0.950 (95% CI: 0.928–0.971)</td>
</tr>
<tr>
<td>2 vs. 3</td>
<td>484 (95%) segments</td>
<td>0.935 (95% CI: 0.910–0.959)</td>
</tr>
</tbody>
</table>

CI — confidence interval
Conclusions

Three-dimensional fusion of morphological CCTA data with quantitative echocardiographic data on regional myocardial function is feasible, rapid and allows highly reproducible assignment of myocardial segments to coronary artery branches. Further studies in patients with suspected and known CAD seem warranted and are needed to provide data on the diagnostic and prognostic value of this technique.

Figure 2. Diagnostic evaluation of a 66-year-old female patient with symptoms of stable coronary artery disease. **Upper panel:** Coronary computed tomography angiography (CCTA) revealed lesions of proximal left anterior descending coronary artery and intermediate coronary artery, as well as suspected lesion in proximal large first diagonal branch; **Middle panel:** Invasive coronary angiography confirmed stenoses of these three coronary branches; **Lower panel:** Quantitative analysis of stress echocardiography images revealed lower longitudinal strain within anterior and lateral walls with the area of lowest strain within the middle segments of these walls. Three-dimensional fusion of CCTA with stress echocardiographic functional data indicated that this area can be allocated to the large first diagonal branch.
Conflict of interest: Piotr Lipiec and Jarosław D. Kasprzak have received speaker fees from GE Medical Systems Inc.

References


