Editorial

3D printed coronary models offer new opportunities for developing optimal coronary CT angiography protocols in imaging coronary stents

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Three-dimensional (3D) printing is a rapidly evolving technology with applications in different medical fields. An increasing trend in research and publications have been observed recently in the journal of *Quantitative Imaging in Medicine and Surgery* (*QIMS*), especially in the 2019 January special issue with a focus on 3D printing in medicine. In that special issue, a number of publications (original studies, technical notes and review articles) were contributed by researchers from different countries with expertise in different fields highlighting the importance of 3D printing in medical applications (1-13). In addition to these applications, a recent paper in this issue of *QIMS* presents another new research direction of using personalized 3D printed coronary artery models for simulation of coronary stenting procedure (14).

Authors in this experimental study demonstrated the feasibility of placing a number of coronary stents with different diameters into three patient-specific 3D printed coronary models. They scanned the models with the latest third generation 192-slice dual-source computed tomography (CT) scanner with images reconstructed using different kernels (smooth and sharp kernel algorithms) to study the effect on visualization of stent lumen visibility. Both 2D and 3D images were generated from the original data for demonstration of stent position and patency as well as stent lumen within the coronary arteries (*Figure 1*). Of 6 stents placed in the 3D printed coronary models, 2 of them failed to obtain wall apposition due to insufficient balloon expansion during stenting procedure. The visibility of stent lumen was found to be overall good ranging from 54% to 97% with the lowest visibility seen in the stents which did not achieve full expansion. The sharp kernel algorithm significantly improved the visualization of stent lumen, and this is especially apparent in detecting stenting regions where there were stent wires overlapping or stents were placed in the tortuous coronary location (*Figures 2,3*). Further, authors produced 3D virtual intravascular endoscopy (VIE) intraluminal views of these stents with demonstration of stent location in relation to the coronary wall (*Figures 4-6*). VIE images provide further information to confirm patency of these stents and their position inside the coronary arteries. When images were reconstructed with a sharp kernel algorithm, visualization of stent structures is improved when compared to those with a smooth kernel algorithm (*Figures 4-6*).

It is well known that 3D printing in cardiovascular disease mainly focuses on pre-surgical planning and simulation of complex cardiovascular (primarily in congenital heart disease) procedures, and the current research in this area is dominated by case reports, case series and some original studies (15-17). With regard to usefulness of 3D printed coronary models, the current literature shows their applications in guiding or managing treatment of complex coronary anomalies (18-22), while there is little or no information available about the simulation of coronary stenting. There are only a few studies reporting the research of developing optimal CT scanning protocols based on 3D printed heart and pulmonary artery models (2,3,23,24). In this study we further extend 3D printing's application to simulating coronary stenting in the 3D printed

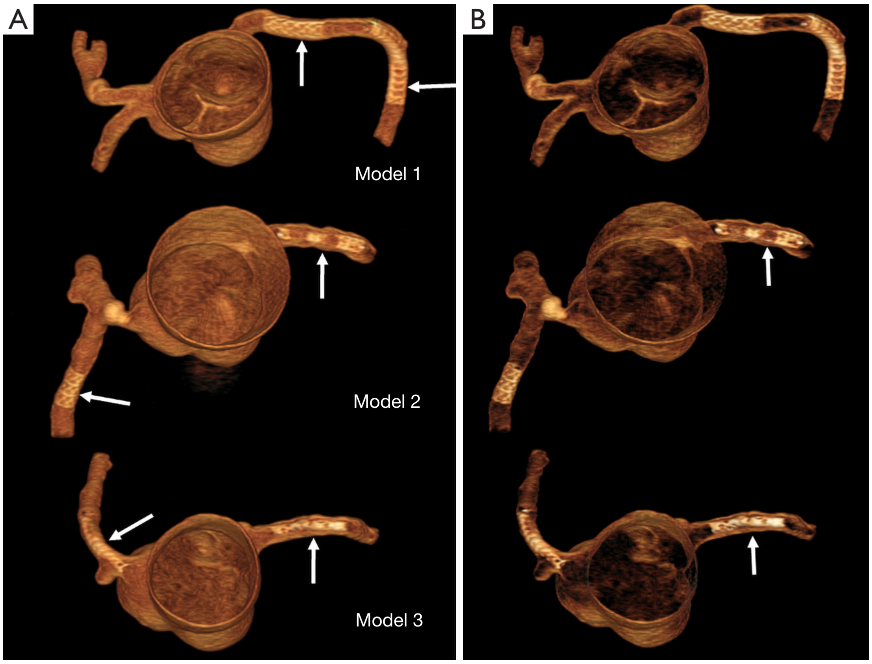

Figure 1 Three-dimensional (3D) volume rendering image visualization of coronary stents placed in the 3D printed coronary models. (A) Six coronary stents (arrows) were placed in these 3D printed coronary models with two stents in each model; (B) with windowing adjusted, 3D volume rendering images better demonstrate the stent metal components inside the coronary arteries, with two stents (arrows) in the right coronary artery in models 2 and 3 failing to achieve full expansion.

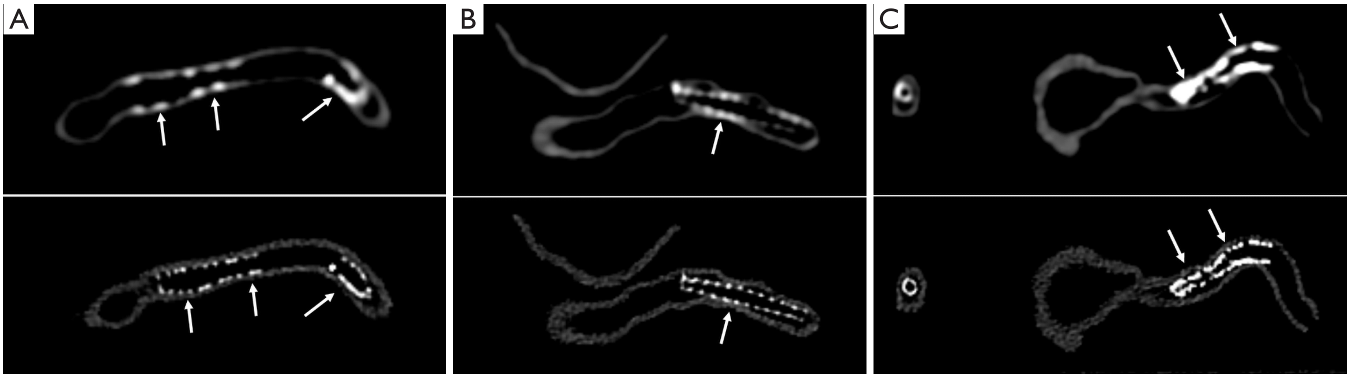

Figure 2 Comparison of stent lumen visibility between images reconstructed with soft smooth and sharp kernel algorithms. Visibility of the stent lumen is improved with use of a sharp kernel algorithm (bottom row images) and this is especially apparent in detecting stent wires in models 2 and 3 (B and C) when compared to images in model 1 (A). Arrows refer to the stent wires.

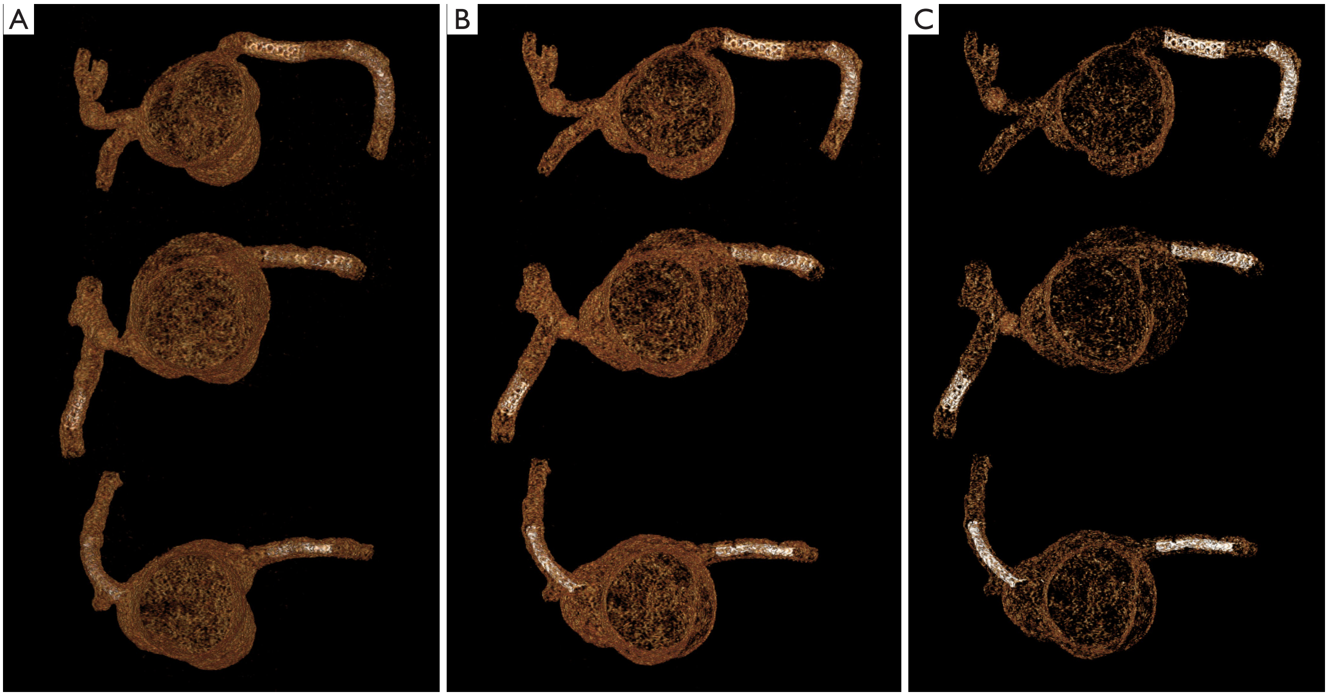

Figure 3 Three-dimensional (3D) volume rendering of coronary stents with images reconstructed with a sharp kernel algorithm. (A) Metal components of the coronary stents are clearly demonstrated, while soft tissue information is not well visualized; (B,C) with windowing adjusted, stent details are more clearly visualized inside the coronary arteries, with loss of soft tissue details.

realistic models, which is different from a previous study based on coronary stenting in a simple plastic tube (25). These 3D printed models were created from patient's cardiac CT images, thus replicating the actual diameters and dimensions of coronary anatomy, therefore, creating opportunities for testing different scanning parameters for identification of optimal coronary CT protocols in coronary stenting.

Despite novelty of utilizing 3D printed coronary models in coronary stenting, this preliminary report will need to be further improved by simulating a wide range of coronary stents with inclusion of different materials. To represent the realistic physiological condition, 3D printed models should be filled with contrast medium to simulate contrast-enhanced coronary CT angiography, thus, allowing more accurate assessment of stent lumen diameter. Furthermore, simulation of in-stent restenosis is another area that deserves to be investigated due to the importance of detecting the restenosis following coronary stenting procedure. These areas are well highlighted in the study limitations and further results are expected to arise from this exciting proof-of-concept research report.

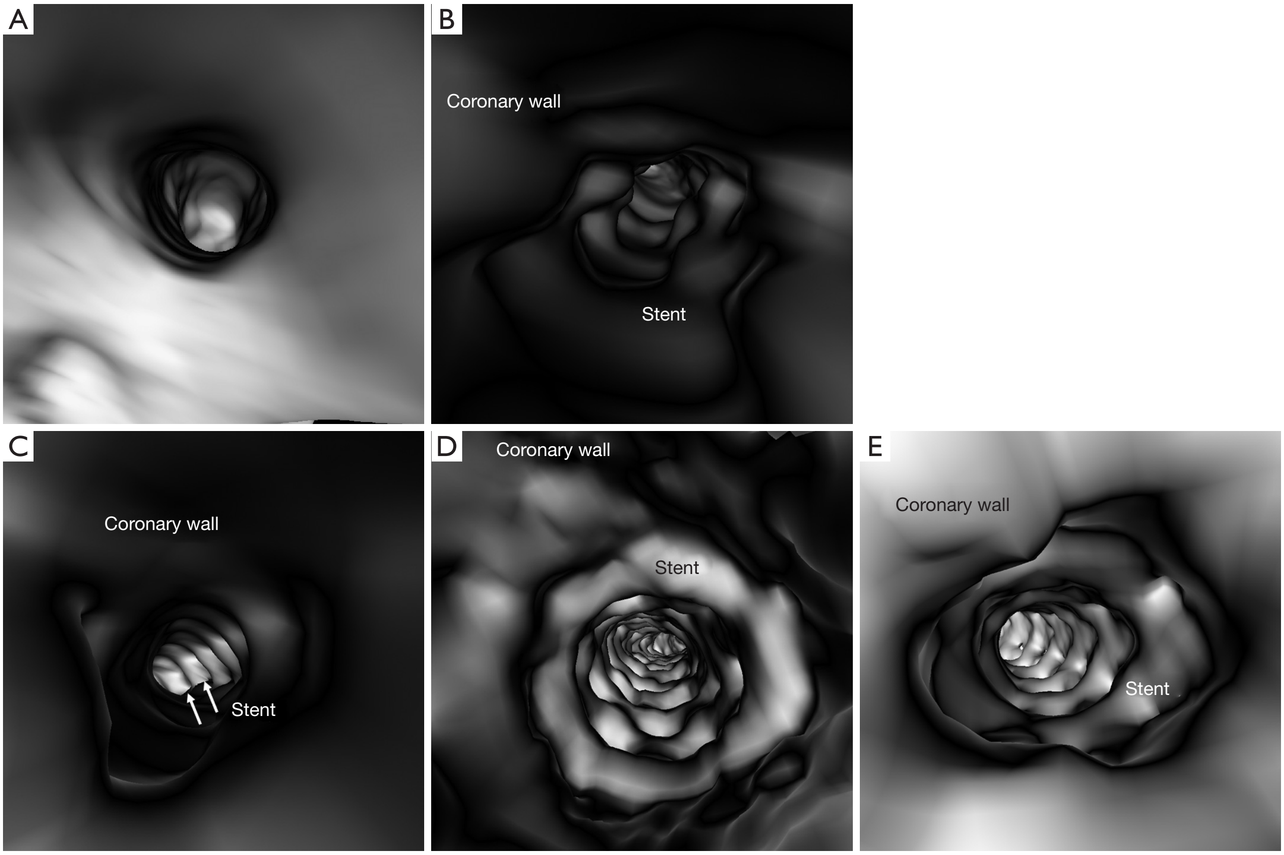

Figure 4 Three-dimensional (3D) virtual intravascular endoscopy (VIE) views of coronary stents and coronary wall in model 1. (A) VIE view of the right coronary ostium with smooth appearance; (B,C) VIE of the proximal and distal coronary stents in the right coronary artery with images reconstructed using a smooth kernel algorithm; (D,E) VIE view of these two stents with images reconstructed using a sharp kernel algorithm showing clearer visualization of the stent appearance when compared to (B) and (C).

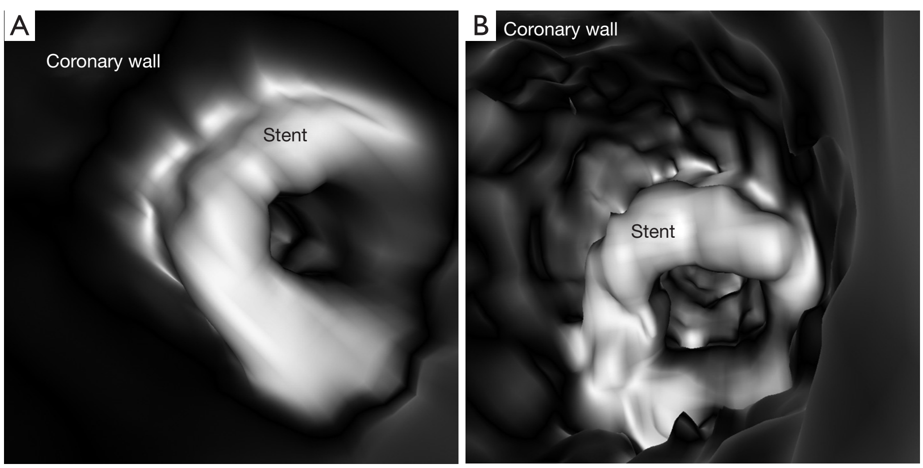

Figure 5 Three-dimensional (3D) virtual intravascular endoscopy (VIE) views of coronary stent and coronary wall in model 2. (A) VIE view of the right coronary stent with images reconstructed using a smooth kernel algorithm showing that the stent did not expand completely resulting in a lack of apposition between the stent and coronary wall; (B) VIE view of the right coronary stent with images reconstructed using a sharp kernel algorithm showing improved stent visualization, but compromising coronary wall visualization.

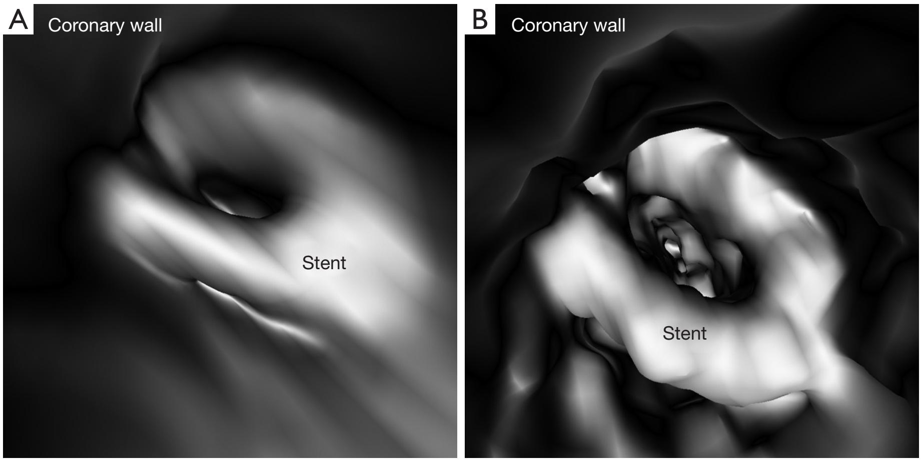

Figure 6 Three-dimensional (3D) virtual intravascular endoscopy (VIE) views of coronary stent and coronary wall in model 3. (A) VIE view of the right coronary stent with images reconstructed with a smooth kernel showing insufficient expansion of the stent; (B) the stent was more clearly visualized with images reconstructed with a sharp kernel with no apposition of the stent along the wall, but compromising visualization of coronary wall.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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