Reviewer Assessment

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Artificial vascular models for endovascular training (3D printing)

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Reviewers’ Comments to Original Submission

Reviewer 1: Karolis Tijunaitis

Jun 05, 2018

Reviewer Recommendation Term: Accept with Minor Revision
Overall Reviewer Manuscript Rating: 95

Custom Review Questions
Is the subject area appropriate for you? 5 - High/Yes
Does the title clearly reflect the paper’s content? 5 - High/Yes
Does the abstract clearly reflect the paper’s content? 5 - High/Yes
Do the keywords clearly reflect the paper’s content? 5 - High/Yes
Does the introduction present the problem clearly? 5 - High/Yes
Are the results/conclusions justified? 5 - High/Yes
How comprehensive and up-to-date is the subject matter presented? 5 - High/Yes
How adequate is the data presentation? 5 - High/Yes
Are units and terminology used correctly? 5 - High/Yes
Is the number of cases adequate? 3
Are the experimental methods/clinical studies adequate? 5 - High/Yes
Is the length appropriate in relation to the content? 5 - High/Yes
Does the reader get new insights from the article? 5 - High/Yes
Please rate the practical significance. 5 - High/Yes
Please rate the accuracy of methods. 5 - High/Yes
Please rate the statistical evaluation and quality control. 5 - High/Yes
Please rate the appropriateness of the figures and tables. 5 - High/Yes
Please rate the appropriateness of the references. 5 - High/Yes
Please evaluate the writing style and use of language. 5 - High/Yes
Please judge the overall scientific quality of the manuscript. 5 - High/Yes
Are you willing to review the revision of this manuscript? Yes

Comments to Authors:
The manuscript ISSN-2018-0020 entitled “Artificial vascular models for endovascular training (3D Printing)” is a review article analysing 3D printing value for endovascular training.
In an effort to provide more transparency regarding the decision, five aspects of your paper were rated. Below are the scores received by your manuscript:

- Novelty = 4
- Clinical Impact = 5
- Scientific Impact = 4
- Definitive = 4
- Interesting to the Specialty = 5

(1 = Not at all, 3 = Average, 5 = Completely)

A. General Evaluation
Well written manuscript for the most part.

B. Specific Remarks
B1. It might be good to discuss briefly cost effectiveness of 3D printing in training process and case planning, because a wide application depends whether this method is gonna be approved as a cost effective.
B2. Paragraph “Introduction”: (www.shapeways.com e www.imaterialise.com) e change to comma.
B3. In the sentence “...insufficient transparency or resistance are the main problem.” Please change problem to problems.
B4. Paragraph 3D printing sentence “In addition, directly 3D-printing a hallow aneurysm is a one-step process; therefore, it is faster and more accurate” sounds a bit out of context. It might be better to change its place.
B4. Paragraph “Printed model post-processing” - citations are missing.
B5. In the sentence: “Although no 3D printing materials show ...” please write a comma after although.

P.S.
I suggest adding definitions for all figures

9–16% of complications are associated with access injuries. It is usually related to inexperience with closure device systems. Possibility to involve the whole procedure in 3D models simulation from groin puncture to closure with closure devices would have sufficiently reduced operative time and operative success.

Reviewer 2: anonymous

Jun 20, 2018

Reviewer Recommendation Term: Accept with Minor Revision
Overall Reviewer Manuscript Rating: N/A

Custom Review Questions

| Question                                                                 | Response |
|-------------------------------------------------------------------------|----------|
| Is the subject area appropriate for you?                                | 5 - High/Yes |
| Does the title clearly reflect the paper’s content?                     | 5 - High/Yes |
| Does the abstract clearly reflect the paper’s content?                  | 5 - High/Yes |
| Do the keywords clearly reflect the paper’s content?                    | 5 - High/Yes |
| Does the introduction present the problem clearly?                      | 5 - High/Yes |
| Are the results/conclusions justified?                                  | 5 - High/Yes |
| How comprehensive and up-to-date is the subject matter presented?       | 4        |
| How adequate is the data presentation?                                  | 4        |
| Are units and terminology used correctly?                               | 4        |
| Is the number of cases adequate?                                        | 5 - High/Yes |
| Are the experimental methods/clinical studies adequate?                 | 3        |
| Is the length appropriate in relation to the content?                   | 5 - High/Yes |
| Does the reader get new insights from the article?                      | 5 - High/Yes |
| Please rate the practical significance.                                 | 5 - High/Yes |
| Please rate the accuracy of methods.                                    | 4        |
| Please rate the statistical evaluation and quality control.             | 4        |
| Please rate the appropriateness of the figures and tables.              | 4        |
| Please rate the appropriateness of the references.                     | 4        |
| Please evaluate the writing style and use of language.                  | 4        |
| Please judge the overall scientific quality of the manuscript.          | 5 - High/Yes |
| Are you willing to review the revision of this manuscript?              | Yes     |
Authors’ Response to Reviewer Comments

Jul 02, 2018

Reviewer #1:
The manuscript ISS-2018-0020 entitled “Artificial vascular models for endovascular training (3D Printing)” is a review article analysing 3D printing value for endovascular training.

In an effort to provide more transparency regarding the decision, five aspects of paper were rated. Below are the scores received by your manuscript:

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Clinical Impact = 5
Scientific Impact = 4
Definitive = 4
Interesting to the Specialty = 5

(1 = Not at all, 3 = Average, 5 = Completely)

A. General Evaluation

Well written manuscript for the most part.

Thank you very much for your comments; they certainly helped to improve this article.

B. Specific Remarks

B1. It might be good to discuss briefly cost effectiveness of 3D printing in training process and case planning, because a wide application depends whether this method is goanna be approved as a cost effective.

This is certainly a very important issue, therefore this paragraph was added to the discussion:

A retrospective study at Stanford University Medical Center showed a 30% cost increase on EVAR, when the use of stent graft extensions was necessary, compared to cases where the standard number of pieces was used (mean device-related cost US$13,220 vs. US$17,107, p < 0.01); the authors concluded that appropriate preoperative planning and device selection can minimize the cost [41]. The improvement in surgical planning and surgical efficiency can make the use of simulators cost-effective. The cost to produce 3D printed models (Itagaki et al US$50.34 to US$232.03; Torres et al US$ 200.00 to US$1,200.00) seems reasonable comparing to the cost of the endovascular material [19,42], nevertheless a study designed to analyse cost reduction after simulations is necessary to confirm this conclusion.

B2. Paragraph “Introduction”: (www.shapeways.com e www.imaterialise.com) e change to comma.

It was changed.

B3. In the sentence “...insufficient transparency or resistance are the main problem.” Please change problem to problems.

It was changed.

B4. Paragraph 3D printing sentence “In addition, directly 3D-printing a hallow aneurysm is a one-step process; therefore, it is faster and more accurate” sounds a bit out of context. It might be better to change its place.

This sentence was moved to the beginning of the section 3D printing, a few more comments were added to put it in context.
It is possible to directly 3D print hollow flexible models, which is a one-step process; therefore, it is faster and more accurate than the commonly used lost wax technique.

B4. Paragraph “Printed model post-processing” - citations are missing.
The post-processing work description was based basically on the author experience. The detailed description was not found prior to our research. Due to limited number of words, the process was only shortly described in our published paper. Nevertheless, the citation was added: After 3D-printing, the object needs to be post-processed. Each material requires different work [19].

B5. In the sentence: “Although no 3D printing materials show ...” please write a comma after although.
A comma was added.

B6. Table 1 and Table 2 are shown twice
I am sorry, that was probably a mistake when the files were uploaded. Extra attention will be paid during the process.

P.S.
I suggest adding definitions for all figures
The figures have legends, as shown below, maybe the legends were lost with the problem of the tables. I am not sure if I understood your comment, I hope this is the correct answer.

**FIGURE LEGENDS**

Figure 1: Steps to produce a 3D-printed aneurysm. 1: Images from an angioCT; 2: Abdominal aorta after image post-processing; 3: 3D printing process; 4: Post-processed 3D-printed aneurysm

Image post-processing. (A) Reconstruction of the aorta based on the contrast inside the arterial lumen - DICOM file. (B) Aorta after conversion of DICOM to STL file. (C) Surface of the aorta smoothed. (D) Wall of the aorta digitally thickened to 1.5 mm

Figure 3: Examples of 3D printers available for the production of vascular models. A and B are industrial machines. C, D and E are desktop machines

Figure 4: Post-processing of the aneurysms in Material 1: A) 3D-printed aneurysm with the support material. B) 3D-printed aneurysm after removing the support material. C) Areas reinforced with silicone. D) 3D-printed aneurysm connected to the simulator

Figure 5: Pillars produced during the printing process of the Form 1 + 3D printer. Test with an opaque material and an aneurysm produced in two parts

9–16% of complications are associated with access injuries. It is usually related to inexperience with closure device systems. Possibility to involve the whole procedure in 3D models simulation from groin puncture to closure with closure devices would have sufficiently reduced operative time and operative success.

This is a very important point. Currently most of the endovascular simulators are part task simulators, where the access to femoral arteries and the use of closure devices is not practiced. There are low fidelity simulators build to train this specific steps alone. It would certainly be interesting to have both things combined. The 3D printed simulators are being developed and there is a lot to improve. This is a good information for further tests. Thank you very much.

**Reviewer #2:**
This is a comprehensive review of current application of 3D-printing in generating training models for endovascular surgery.
Thank you very much for your comments; they certainly helped to improve this article.

There are some minor remarks:
It appears that the process for literature search is not structured. It would improve the quality of the manuscript if the author can add a short passage in methods regarding the algorithm for search/retrieval/selection of references.
This comment is absolutely pertinent. To address this problem, a paragraph was added. I hope it helped to make the review process clear.

We performed electronic searches on PubMed to collect studies on 3D printing technology and its applications in endovascular surgery training. Several searches were performed using combination of different terms: 3d printing and/or endovascular training and/or surgical planning. The only limit defined was language: only reports in Portuguese or English were considered. Titles and abstracts were screened to exclude irrelevant or duplicate abstracts. Then, included articles underwent a full-text review. We initially found 409 results, which were narrowed down to 190 after abstracts analysis (the authors excluded duplicated articles and researches deemed irrelevant to surgical practice). This set of results was then reviewed to form a set of 58 full-text articles used for the final analysis. In addition, the 3D printers’ website was searched for technical information.
The same applies for the author’s selection of post-processing software. It is suggested that the author either states the software mentioned as a personal experience/choice or (better) provides a comprehensive list of currently available segmentation and postprocessing software (open source and commercially).

This is important information; therefore Table 1 was added to the article.

Table 1: Softwares available for image post-processing

| Softwares for DICOM file processing | References |
|------------------------------------|------------|
| Mimics® (Materialise NV, Leuven, Belgium) | Biglino et al. [51]; Wilasrusnee et al. [23]; Hakansson et al. [52]; Yuan et al. [53]; Mafeld et al. [18]; Dong et al. [54]; Koleilat et al. [29]; Taher et al. [27] |
| OsiriX (Pixmeo SARL, Bernex, Switzerland) | Marro et al. [12]; Tam et al. [20]; Takao et al. [55] |
| Vitrea 3D Station (Vital Images, Inc., Minnetonka, MN) | O’hara et al. [56]; Russ et al. [57] |
| iNtuition software (TeraRecon, Inc, Foster City, Calif) | Koleilat et al. [29] |
| Vascular Modeling Toolkit (VMTK, Orobix, Bergamo, Italy) | Meess et al. [30] |

Softwares for STL file processing

| Softwares | References |
|-----------|------------|
| 3-matic® (Materialise NV, Leuven, Belgium) | Biglino et al., Mafeld et al. [18]; Koleilat et al. [29] |
| MeshLab (Visual Computing Lab - the ISTI-CNR, Roma, Itália) | Marro et al. [12] |
| Blender (Blender Foundation, The Netherlands, v 2.67 for Windows) | Itagaki et al. [42] |
| Google SketchUp (Trimble Inc., CA, USA) | Govsa et al. [58] |
| Magics (Materialise NV, Leuven, Belgium) | Yuan et al. [53] |
| Meshmixer software (Meshmixer, Autodesk, San Rafael, CA, USA) | O’hara et al. [56]; Takao et al. [55]; Russ et al. [57]; Meess et al. [30] |

Besides, the information of the author’s choice was added on the text:

For DICOM post-processing, the author’s choice were iNtuition Unlimited software (Aquarius, TeraRecon, San Matteo, CA, USA), OsiriX software (Pixmeo, Geneva, Switzerland) or Horos software (The Horos Project, sponsored by Nimble Co LLC d/b/a Purview, Annapolis, MD, USA). Thereafter, the authors have chosen Mesh Mixer (Mesh Mixer 2.8, Autodesk, Inc.) or Magics Software (Magics, 3-matic®, Materialise®) for STL processing.

In the manuscript, pricing for 3D printers and production costs is given. Here, the conditions/assumptions of production need to be clarified in order to enable comparison.

The companies Stratasys, Formlabs and Makerbot informed the cost of the 3D printers through invoices. The cost of the materials was calculated by two different 3D printing companies (3Dux and Anacon), based on the mean quantity of the material necessary for one aneurysm.

This information was added to the manuscript

Figure 3: source and copyright of figures needs to be stated.

This information was added to Figure 3:

Figures were collected from the companies’ website (www.stratsys.com; www.3dsystems.com; www.formlabs.com; www.xyzprinting.com). The companies agreed with the use of the Figures.

Figures 4 and 6 are redundant

Figure 6 was excluded.