Stent graft sizing for endovascular abdominal aneurysm repair using open source image processing software

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Stent Graft Sizing for Endovascular Abdominal Aneurysm Repair Using Open Source Image Processing Software

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Introduction: An important step to reach a favorable outcome of abdominal endovascular aneurysm repair (EVAR) is preoperative sizing of the stent graft using computed tomography angiography (CTA) images of the abdominal aorta. A variety of costly image processing software options is available to obtain the necessary aortic measurements. A package that can be used for EVAR sizing is OsiriX Lite®—an open source, freely downloadable image processing option. This study assesses the concurrent validity of OsiriX Lite® when compared with commercially available 3Mensio Vascular® and Siemens Syngo.via®.
Methods: CTA scans of 20 patients that underwent EVAR for abdominal aneurysm were selected, 10 elective and 10 ruptured. For each scan, 6 observers determined 20 parameters needed for proper stent graft sizing, 2 using Osirix Lite®, 3 using 3Mensio Vascular®, and 1 using Siemens Syngo.via®. For each parameter, an intraclass correlation coefficient (ICC) and a *P*-value were calculated. Interrater agreement was interpreted using the Koo and Li Guidelines. Time needed to perform EVAR planning was compared.
Results: Overall interrater agreement between the 3 sizing options was found to be either "good" or "moderate" for 16 out of 20 parameters (80%). Time needed to perform EVAR planning was not significantly different for Osirix Lite® (568 sec) when compared with 3Mensio Vascular® (603 sec) or Siemens Syngo.via® (659 sec) with a *P*-value of 0.88.
Conclusions: The authors conclude that Osirix Lite® is an accurate and time-effective image processing option for preoperative sizing of an EVAR stent graft when matched to 3Mensio Vascular® and Siemens Syngo.via®.

INTRODUCTION

In vascular medicine, an aortic abdominal aneurysm (AAA) is defined as a dilatation of the 3 vessel layers of the abdominal aorta with a diameter of 30 mm or more.[1] Elective surgery is usually performed based on an aneurysm diameter above 50 mm (women) or 55 mm (men). Ever since Parodi et al. reported on the transfemoral implantation of an intraluminal graft in 1991,[2] endovascular aneurysm repair (EVAR) has evolved to become the main surgical intervention for AAA, resulting in a shorter hospital stay and less perioperative blood loss when compared with traditional open repair.[3] The endovascular approach has also been proven to be effective and safe in ruptured abdominal aneurysm cases.[4]

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To reach a favorable outcome of EVAR, proper preoperative selection of stent graft type and size is of paramount importance, as incorrect sizing can lead to graft misalignment, graft thrombosis, and endoleaks.[5,6] This procedure of anatomical assessment and stent graft sizing is performed using preoperatively obtained radiological imaging. Computed tomography combined with angiography (CTA) is the first-choice modality for EVAR planning, both before elective repair and in case of ruptured abdominal aneurysms.[7–10]

A variety of image processing software packages is available to obtain accurate diameter and length measurements for stent graft sizing. For example, Siemens Syngo.via® (Siemens Healthineers, Germany) and 3Mensio Vascular® (Pie Medical Imaging, the Netherlands) are commercial, FDA cleared, and fully validated options.[11,12] These software packages can only be used on licensed computers and are often expensive.

Alongside these commercial options, other more accessible image processing software packages are available. The Osirix Lite® DICOM Viewer (Pixmeo SARL, Switzerland) is an open source software package that can be run on Apple Mac OS or mobile. It can be operated by medics on a personal device for a variety of image processing applications. For example, Osirix Lite® was found accurate in CT volumetry for predicting liver resection volume and future remnant liver function in patients undergoing partial hepatectomy[13] and in pretranscatheter aortic valve implantation aortic annulus sizing.[14] Fazzini et al. reported on ''Over-SIRIX'', an Osirix®-assisted method for sizing stent grafts in chimney procedures of the aortic arch, being effective in reducing the risk of type I endoleak.[15] The open source software, however, has not yet been examined or validated for EVAR stent graft sizing.

The aim of this study is to assess the variability between obtained measurements for stent graft sizing using the open source software package Osirix Lite® and validated image processing packages Siemens Syngo.via® and 3Mensio Vascular® and determine the concurrent validity[16] of Osirix Lite® when matched to these commercial options.

MATERIALS AND METHODS

CTA Data Selection

A group of 20 patients was selected retrospectively. Out of 20, 10 patients underwent elective EVAR for infrarenal abdominal aneurysm. The other 10 cases were treated with EVAR in an emergency setting for ruptured abdominal aneurysm. Cases were selected on being eligible for EVAR. Patients with an angulated neck not within the instructions for use for normal EVAR (>60° infrarenal neck) or otherwise hostile anatomy were excluded to reach a more valid comparison between software programs. All patients had been admitted to 2 medical centers between January 1st′ 2016 and December 1st′ 2018. Before EVAR, a preoperative CTA scan was obtained with a slice thickness of 1,0 mm. These CTA images were collected, anonymized, and coded.

Acquiring and Operating Osirix Lite®

Osirix Lite® for Apple Mac OS was downloaded from the manufacturers' official website https://www.osirix-viewer.com free of charge. The series of CTA images in Digital Imaging and Communications in Medicine (DICOM)-format was loaded into Osirix Lite® from an inserted USB-drive. The DICOM data were stored in Osirix Lite® PACS, either as standalone local series or as temporary files. Once loaded and stored, it is possible to group the CTA series in customizable folders. Images were assessed using the 3D-curved MPR viewer (Fig. 1).

EVAR Planning

For each patient, 5 vascular surgeons from 4 medical centers and one researcher after extensive sizing training performed EVAR planning on the preoperative CTA images. Four vascular surgeons used dedicated commercial image processing software for EVAR sizing as provided by their medical center of residence (three for 3Mensio Vascular ® and one for Siemens Syngo.via®). The Osirix Lite® DICOM viewer was operated by a researcher and a vascular surgeon. Per patient, a predefined set of 20 anatomical measurements was obtained by each observer (Fig. 2). Diameter measurements of the vessel were taken in two directions in each plane from outer wall to outer wall, with the average of the two defined as the final measurement. During the sizing process, a central lumen line (CLL) was defined automatically (3Mensio Vascular® and Siemens Syngo.via®) or manually (Osirix Lite®). Time needed to perform the EVAR planning was registered by the observers. During the sizing phase of this study, all observers were blinded to preoperative patient data and to the results of other observers.

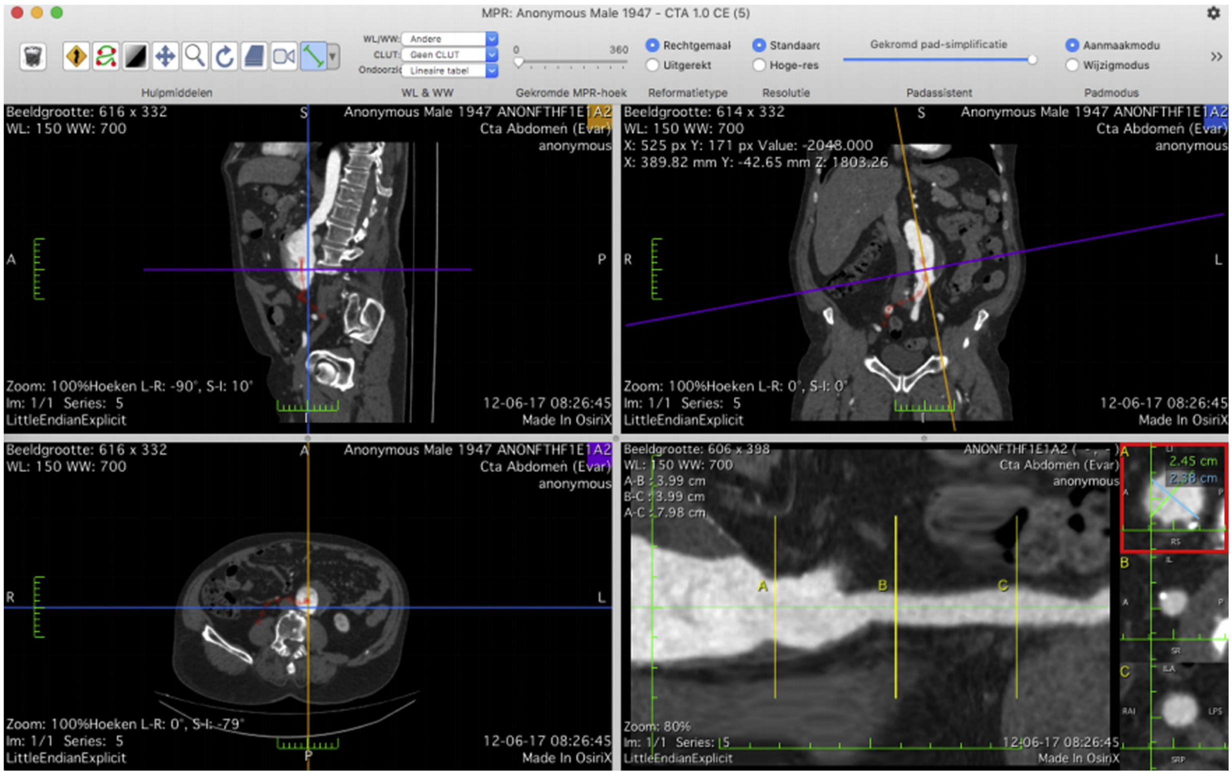

Fig. 1. The 3D curved MPR-viewer in Osirix Lite®. A construction of the central lumen line is shown bottom right.

Statistical Analysis

All calculations and statistical analyses were performed on IBM SPSS Statistics 25® (International Business Machines Corporation, United States) for Windows. For each of the 20 anatomical measurements, an intraclass correlation coefficient (ICC)[17] and a *P*-value were calculated using a mixed models approach. Software and anatomical position were labeled used as fixed effects. Found intercept and residual values determined intraclass correlation using the estimation formula as described by Stanish and Taylor.[18] ICCs were calculated pairwise and for the 3 different sizing packages overall. Interrater agreement was interpreted using the Koo and Li guidelines,[19] where an ICC below 0.50 is considered "poor", between 0.50 and 0.75 "moderate", between 0.75 and 0.90 "good", and above 0.90 "excellent". *P* values of >0.05 were considered a significant agreement.

The mean duration of EVAR planning was determined for all sizing procedures performed in Osirix Lite® and 3Mensio Vascular®. The mean time needed to perform planning was evaluated for elective and ruptured EVAR cases separately. Independent *t*-tests and one-way ANOVA tests were used to assess significance.

RESULTS

Anonymized CTA scans of 20 patients were assessed by 6 observers using Osirix Lite®, 3Mensio Vascular®, and Siemens Syngo.via®. For each CTA scan, 20 predefined parameters (Fig. 2) were assessed by each observer. Time needed obtain these measurements was determined.

Average measurements found by the observers were calculated for each software package separately, as shown in Figure 3. For each dimension, an intraclass correlation coefficient was calculated. Overall interrater agreement, as visualized as intraclass correlation coefficients in Table I, was determined to be either "good" or "moderate" for 16 out of 20 measurements (80%). For angle measurements (P1-P3) and the aortic bifurcation diameter (Dbif), poor agreement was found with ICCs below 0.50. Paired assessment of ICCs shows that when matching Siemens Syngo.via® with 3Mensio Vascular®, agreement on the value of Ddif came out just moderate. For every measurement a matching *P*-value was calculated (Table I). A significant difference was found for the additional values D1, IL1, and IL3.

Overall sizing duration per observer is shown in Figure 4, with an overall mean time of 610 sec or

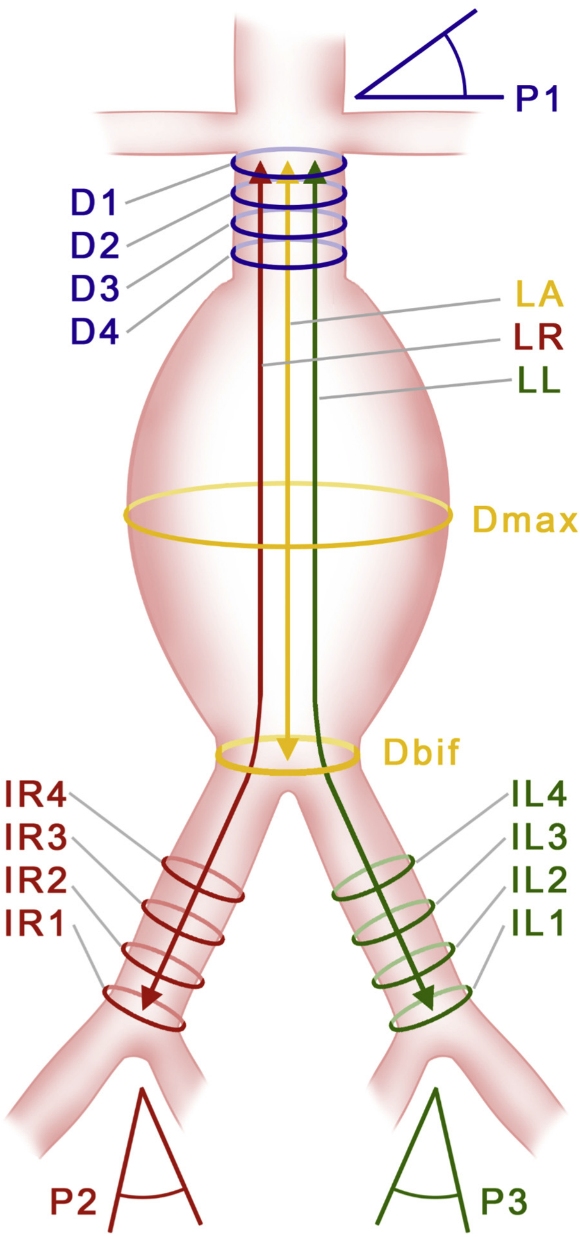

Fig. 2. Parameters to be obtained by observers for each scan. Neck measurements D1-D4 were defined as the diameter of the aorta distal to the renal artery (D1) and diameters on 5 mm (D2), 10 mm (D3), and 15 mm (D4) distal to D1. Dmax was defined at the maximum width of the aneurysm. Also, the diameter of the bifurcation was obtained (Dbif). Measurements of the right and left common iliac artery (IR1-4 and IL1-4 respectively) were defined as the diameter proximal to the internal iliac bifurcation (IR1/IL1) and diameters on 10 mm (IR2/IL2), 20 mm (IR3/IL3), and 30 mm (IR4/IL4) to IR1/IL1. A series of lengths were determined: LA (length of the aneurysm measuring from D1 to Dbif), LR (from D1 to IR1), and LL (from D1 to IL1). Finally, 3 angles were measured: P1 (position of the c-arm X-ray device in degrees of rotation needed to visualize the most distal renal artery), P2 (position of c-arm to visualize the right internal iliac artery), and P3 (position of c-arm to visualize the left internal iliac artery).

10 min and 10 sec. As shown in Table II, average sizing duration for Osirix Lite® (568 sec ± 60) was not significantly different compared with 3Mensio Vascular® (603 sec ± 221) and Siemens Syngo.via® (659 sec ± 121) with a *P*-value of 0.88. Additionally, average time needed to perform planning of scans of elective versus ruptured aneurysms was comparable for the 3 types of software ($P = 0.18$ and $P = 0.74$, respectively).

DISCUSSION

Currently, multiple commercial image viewers are available for EVAR planning and stent graft sizing. In this study, we aimed to assess the concurrent validity of the open source Osirix Lite® DICOM viewer® when compared with 2 validated software packages. It was found that measurements obtained using Osirix Lite® strongly correlated with those obtained using 3Mensio Vascular® and Siemens Syngo.via®, with only angle-based values (P1-P3) being of poor agreement for all three sizing packages. For P1, however, no significant difference was found between measurements taken with Osirix Lite® and 3Mensio Vascular®. Additionally, a slightly higher agreement was found between the commercial software options when assessing the diameter of the aortic bifurcation, neck diameter D1, and the diameters the left iliac artery IL1 and IL3.

Regarding time needed to perform EVAR planning, it was found that sizing duration was not significantly different. This is remarkable as 3Mensio Vascular® and Siemens Syngo.via® offer automated construction of the CLL and automated diameter measurements. This essential step in EVAR planning is drawn up by the software in seconds, leaving the user to simply making quick adjustments if necessary and thereby cutting a significant portion from the overall time needed to perform the sizing. However, (semi)automation of CLL construction is not always feasible. For example, in our study, a number of cases were ineligible for CLL automation because of an insufficient load of intraarterial contrast in CTA images. We observed that in these cases, time needed to perform EVAR planning heavily increased for 3Mensio Vascular® and Siemens Syngo.via® users, exceeding the duration for sizing in Osirix Lite®. One could therefore debate the implied time merit of CLL automation for individual cases.

Another advantage of ''drawing'' a CLL manually is that the user can predict the graft and delivery device position based on the curvature of the vessels,

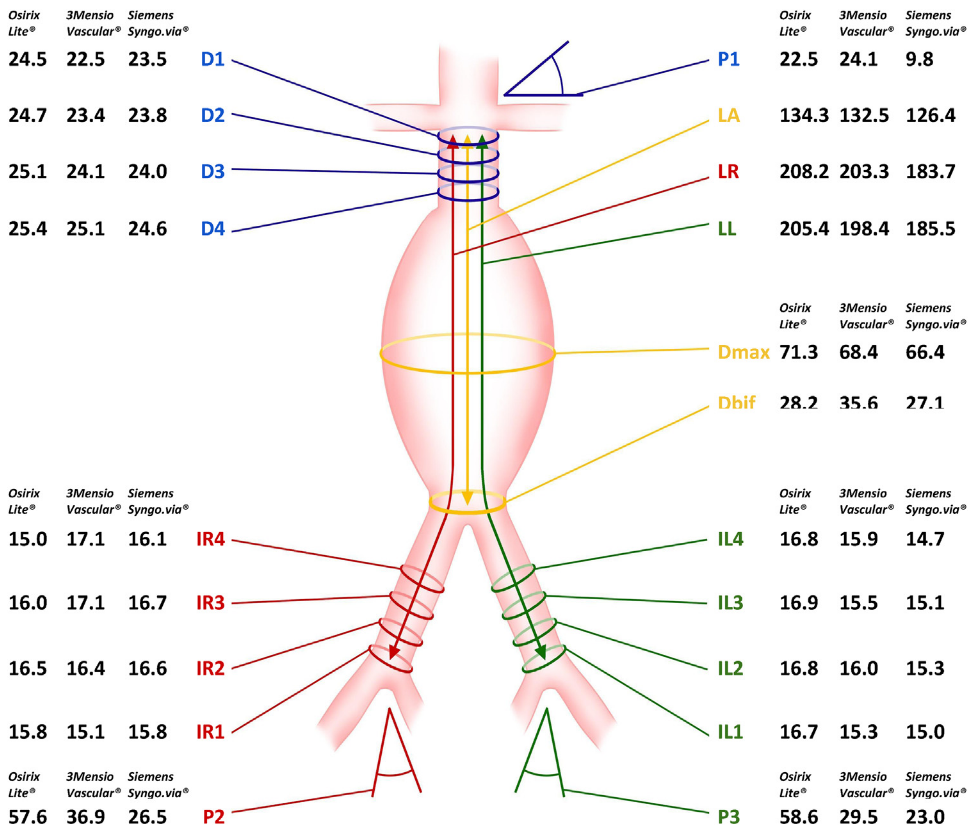

Fig. 3. Average measurements in mm (for diameters and lengths) or degrees (for angles), as found by the observers using Osirix Lite®, 3Mensio Vascular® and Siemens Syngo.via®.

which can result in more accurate length measurements. This could potentially cause differences in length measurements between Osirix Lite® and other software packages using automated CLL assessment. Also, contrary to Osirix Lite®, diameter measurements are automated in 3Mensio Vascular® and Siemens Syngo.via®. This could result in not measuring from outer to outer wall of the vessel which leads to underestimation of the vessel diameter.

Overall, moderate to good correlation was found assessing diameters and lengths in EVAR sizing between different software packages tested. However, for the assessment of angles and aortic bifurcation diameter, poor correlation was reported. Measuring angles and aortic bifurcation diameter is in our opinion extremely user dependent and cannot be done using a strict regime. Therefore, high measurement variability was found. Additionally, in this study, the observers did not use a maximum intensity projection (MIP) for measuring angles. This could explain the high variability among the observers, as an MIP provides a better three dimensional angiography-like view than a regular MPR viewer. For the aortic bifurcation, poor correlation might have been caused by different methods used by the observers to obtain the measurement (taking the diameter perpendicular to the CLL versus measuring in a 2D axial plane). Additionally, the preoperative measurement of angles can be of use for the execution of the EVAR procedure but is not essential to stent graft sizing. A faulty estimation can easily be corrected during the operation and therefore does not contribute to complication risk.

Sizing was performed on anonymized CTA images obtained before endovascular repair. As the conventional EVAR procedure does not offer a method of obtaining the actual diameters and lengths of the aortic aneurysm and adjacent vessels, it remains unknown whether preoperative measurements defined in image processing software are accurate to in vivo anatomy. Therefore, we were limited in assessing whether the measurements found in our study by users operating Osirix Lite® were accurate to reality. A comparison with patient anatomy as a golden standard could not be made, and therefore, we assessed the usability of Osirix Lite® for EVAR planning using concurrent

Table I. Interrater agreement calculated as intraclass correlation coefficients (ICCs) with corresponding *P*-value for each dimension found using Osirix Lite®, 3Mensio Vascular®, and Siemens Syngo.via®

	OsiriX versus 3Mensio		OsiriX versus Siemens		3Mensio versus Siemens		Overall	
Measurement	ICC	*P* value	ICC	*P* value	ICC	*P* value	ICC	*P* value
D1	0.70	0.01	0.74	0.17	0.63	0.38	**0.68**	**0.03**
D2	0.73	0.11	0.73	0.32	0.77	0.69	**0.74**	**0.26**
D3	0.70	0.30	0.81	0.27	0.73	0.95	**0.73**	**0.51**
D4	0.73	0.77	0.72	0.45	0.71	0.69	**0.72**	**0.82**
IR1	0.65	0.41	0.71	0.99	0.84	0.46	**0.69**	**0.65**
IR2	0.85	1.00	0.83	0.90	0.90	0.88	**0.87**	**0.99**
IR3	0.82	0.33	0.69	0.64	0.88	0.84	**0.82**	**0.67**
IR4	0.72	0.06	0.62	0.44	0.89	0.58	**0.76**	**0.22**
IL1	0.68	0.01	0.63	0.03	0.75	0.66	**0.69**	**0.02**
IL2	0.79	0.18	0.77	0.09	0.85	0.46	**0.80**	**0.20**
IL3	0.72	0.02	0.67	0.03	0.80	0.67	**0.73**	**0.04**
IL4	0.80	0.25	0.69	0.01	0.78	0.26	**0.76**	**0.12**
Dmax	0.82	0.30	0.77	0.20	0.85	0.55	**0.82**	**0.36**
Dbif	0.45	0.00	0.45	0.58	0.53	0.01	**0.42**	**0.00**
LA	0.83	0.61	0.73	0.25	0.70	0.31	**0.75**	**0.39**
LR	0.87	0.35	0.75	0.02	0.78	0.02	**0.80**	**0.20**
LL	0.90	0.33	0.72	0.07	0.79	0.24	**0.82**	**0.17**
P1	0.18	0.53	0.00	0.00	0.09	0.00	**0.12**	**0.00**
P2	0.15	0.00	0.33	0.00	0.26	0.14	**0.22**	**0.00**
P3	0.04	0.00	0.09	0.00	0.22	0.21	**0.06**	**0.00**

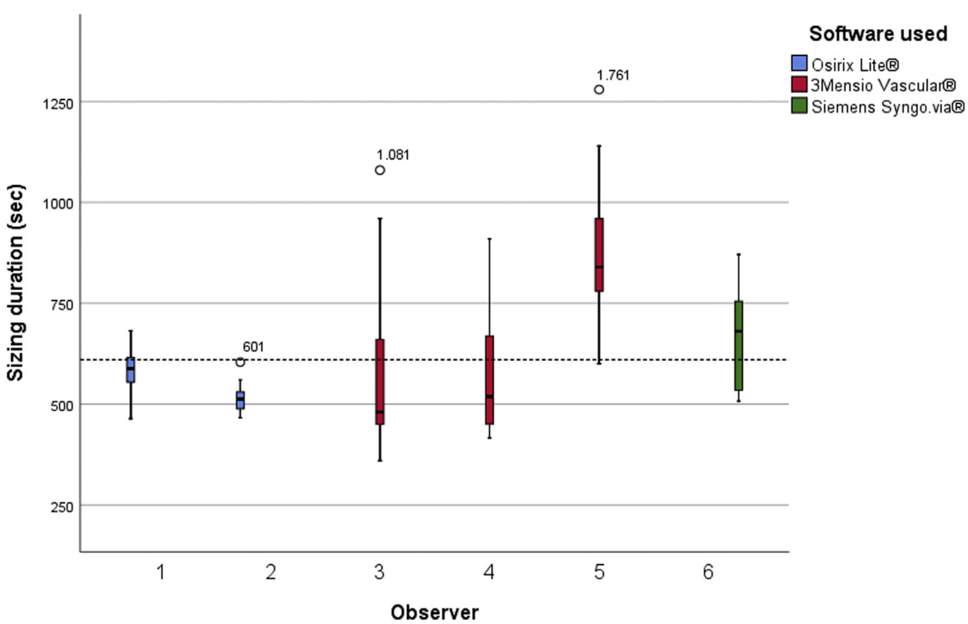

Fig. 4. Boxplot visualizing mean sizing duration in seconds for each observer using OsiriX Lite® (blue), 3Mensio Vascular® (red), and Siemens Syngo.via® (green). The horizontal dotted line represents the overall average planning time of 610 sec.

validity as our approach. Whether the measurements made in all 3 software options were agreeable to actual in vivo dimensions could not be examined with this study.

When assessing the concurrent validity of Osirix Lite® as matched by 3Mensio Vascular® and Siemens Syngo.via®, we were limited to examine interrater variability. Ideally, when faced with the

Table II. Mean planning duration in seconds using Osirix Lite® and 3Mensio Vascular® for elective (10x) and ruptured (10x) scans, standard deviation, and significance

Software	Mean (sec)	Standard deviation	*P* value
Elective			
Osirix Lite®	533	42	0.18
3Mensio Vascular®	733	133	
Siemens Syngo.via®	658	122	
Ruptured			
Osirix Lite	550	51	0.74
3Mensio Vascular	668	171	
Siemens Syngo.via	659	126	
Overall			
Osirix Lite	568	60	0.88
3Mensio Vascular	603	221	
Siemens Syngo.via	659	121	

lack of a golden standard, one would opt for a study design where both interrater and intrarater variability are assessed by having each observer operate all 3 image viewers. However, because of logistical difficulty and a possible recognition bias, we chose not to implement an intrarater variability assessment in our study design.

The Osirix Lite® software offers several practical advantages over 3Mensio Vascular® and Siemens Syngo.via®. Using Osirix Lite®, vascular surgeons can accurately assess preoperative CTA images in preparation for EVAR using their personal computer, laptop, tablet, or handheld. In addition, the Osirix Lite® system holds a number of features that further increase its user-friendliness. The open source software can be downloaded and operated within minutes. Also, the integrated PAC system allows for data to be stored and sorted automatically following the input of either a USB drive or a disc. After DICOM files are put in the registry, they can be readily processed without further need of the initial source. Data are stored on the operating device and are never transferred to a Pixmeo SARL server or a cloud, which guarantees patient data safety. As Osirix Lite® can be downloaded for free by any Mac OS-user, the software offers a way to perform stent graft sizing that is less expensive when compared with traditional commercial image viewers. This eliminates the need for costly commercial software licenses that are paid for per operable device. Next to Osirix Lite®, which is freely downloadable, Osirix MD® is also available as a certified for clinical use solution with complete integration with any PACS. There are, however, limitations to using Osirix Lite® for EVAR planning. As the appliance is iOS-based, non—Mac-users are unable to run and operate the software. In addition, the above mentioned absence of CLL and diameter automation could be considered a drawback. With Osirix Lite® being a general image viewer, it lacks dedicated vascular features that are optimized for EVAR sizing.

CONCLUSIONS

Based on our findings, it can be concluded that in EVAR planning, there is a low variability and a high agreement between the open source software package Osirix Lite® and validated image processing programs Siemens Syngo.via® and 3Mensio Vascular®. Obtained measurements of neck and common iliac diameters and aneurysm lengths for stent graft sizing were comparable in these sizing options. Combined with a user-friendly interface and high accessibility, Osirix Lite® could accurately be used for EVAR planning.

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