European Review for Medical and Pharmacological Sciences 2018; 22: 516-522

The potential role of quantitative digital subtraction angiography in evaluating type B chronic aortic dissection during TEVAR: preliminary results

G. TINELLI[1], F. MINELLI[1], F. DE NIGRIS[1], C. VINCENZONI[1], M. FILIPPONI[1]
P. BRUNO[2], M. MASSETTI[2], A. FLEX[3], R. IEZZI[4]

[1]Department of Cardiovascular Sciences, Vascular Unit, Gemelli Foundation, Catholic University of the Sacred Heart, School of Medicine, Rome, Italy
[2]Department of Cardiovascular Sciences, Cardiac Surgery, Gemelli Foundation, Catholic University, of the Sacred Heart, School of Medicine, Rome, Italy
[3]Department of Internal Medicine, Gemelli Foundation, Catholic University, of the Sacred Heart, School of Medicine, Rome, Italy
[4]Department of Radiology, Gemelli Foundation, Catholic University, of the Sacred Heart, School of Medicine, Rome, Italy

Abstract. – OBJECTIVE: To evaluate the role of quantitative digital subtraction angiography (Q-DSA) with parametric color coding (PCC) in assessing patients with type B chronic thoracic aortic dissection (TBCAD) during thoracic endovascular aortic repair (TEVAR) procedures.

PATIENTS AND METHODS: A total of 11 patients electively treated in our Department for a TBCAD were retrospectively enrolled. All cases were treated with TEVAR for false lumen aneurysm of the thoracic descending aorta. For digital subtraction angiography (DSA) series post-processing, a newly implemented PCC algorithm was used to turn consecutive two-dimensional images into a single color-coded picture (syngo iFLOW, Siemens AG, Forchheim, Germany). In consensus reading, two clinicians experienced in vascular imaging evaluated the DSA series in blinded assessment and compared them to the color-coded images. PCC was assessed for its accuracy in identifying the true and false lumen as well as whether it could provide improved visualization in pre-deployment stent grafting and the final evaluation of treatment.

RESULTS: PCC facilitated the visualization of the aortic dissection angioarchitecture in terms of contemporary true and false lumen vision in 81.8% of the cases. In 72.7% of the procedures, Q-DSA was estimated to improve aorta information assessment in terms of false lumen viewing, and it was possible to identify the proximal entry tear position in 45.4% of the cases. After stent graft deployment, in 72.7% of the cases (all 8 patients in which the aortic arch false lumen was visible in pre-treatment), Q-DSA confirmed the absence of early false lumen reperfusion.

CONCLUSIONS: Our results indicate that Q-DSA could be useful in the intraprocedural evaluation of patients with aortic dissection during TEVAR procedures without additional x-ray costs and contrast exposure.

Key Words:
Quantitative digital subtraction angiography, Parametric color coding, Aortic dissection, TEVAR.

Introduction

The thoracic endovascular aortic repair (TEVAR) technique was demonstrated to be an effective treatment in type B chronic aortic dissection (TBCAD) complicated by aneurysmal degeneration[1,2].

The first endovascular procedure was not intended to treat the entire dissected aorta but to promote remodeling in the most dilated segment with the covering of a proximal entry tear.

However, the endovascular procedure for TBCAD may be very demanding and may present technical problems. Technical difficulties due to the narrow space of work within the true lumen may prevent safe endovascular navigation[3].

All needed information can be easily and accurately obtained with pre-operative CT-angiographic examinations. However, angiographic assessment of type B chronic aortic dissection (TBCAD) can be complex in TEVAR procedures due to a variable flow pattern. Challenging identification of the true

Corresponding Author: Giovanni Tinelli, MD; e-mail: giovanni.tinelli@policlinicogemelli.it

and false lumen in order to obtain a precise and correct deployment of the endograft are hotspots in the dissections endovascular treatment[4].

Furthermore, a good visualization of endoluminal details, including abnormal changes in the intimal tear, is essential for assessing treatment[5].

Parametric color coding (PCC) is a developed tool for measuring flow dynamics in a digital subtraction angiography (DSA) series and can provide quantitative information. In a single image, the quantitative DSA (Q-DSA; software syngo iFLOW; Siemens, Forchheim, Germany) displays objective information on the history of contrast medium through vessels[6-8].

The potential value of color in these parametric images was recognized for visualizing complex flow patterns[6,9]. However, to date, there has been published only a case report on the application of Q-DSA in patients with aortic dissection during endovascular treatment[10].

Based on this background, this study evaluated the potential role of Q-DSA with PCC during TEVAR in patients with TBCAD.

Patients and Methods

Study Design

This study was a retrospective, single-center pilot study enrolling all patients with TBCAD admitted to our institution from May 2015 to June 2017 who were electively treated with an endovascular approach. The indication for treatments was based on a multidisciplinary cardiovascular board evaluation. The study was also approved by the local Ethics Committee and the Institutional Review Board. Written informed consent was obtained from all patients prior to any treatment.

Study Population

A total of 11 consecutive patients were enrolled. The demographic data, comorbidities and operative data are shown in Table I. All cases were treated in an elective setting with TEVAR for proximal entry tear coverture due to an aortic aneurism false lumen.

Table I. Characteristics of 11 patients treated by TEVAR.

Mean Age (y)	71.09 (range 65-78)
Gender (male)	8
Mean graft length (mm)	159.09 (range 100-200)
Aneurysms diameter	64.18 (60-72)
Proximal landing	
Zone 3	8
Zone 2 (previous carotid-sublclavian bypass)	3

Imaging Protocol

All procedures were performed under general anesthesia in a hybrid room with the same angiographic system (Artis Zeego; Siemens Healthcare GmbH, Forchheim, Germany) under active monitoring for heart rate and blood pressure, especially during device deployment.

Standard angiographic techniques were used with a 5 Fr diagnostic catheter positioned via transfemoral access in the true lumen up to the proximal ascending aorta to obtain standard antero-posterior and latero-lateral projections (2D series) with a rate of 4 frames/s. DSA images were obtained by injecting an intravenous bolus of 20 ml of contrast medium (Iomeron 350, Bracco Imaging, Konstanz, Germany) at a flow rate of 10 ml/s using a dedicated contrast medium injector (ACIST™ Injection System; ACIST Medical Systems, Eden Prairie, Minnesota). During DSA runs, the frame rate, catheter and table position remained unchanged. We performed three DSA acquisitions during the TEVAR procedure:

Visceral aorta, in an antero-posterior projection: when the catheter reached the visceral aorta, an angiogram was performed to confirm its presence in the true lumen (identified by early opacification of visceral arteries perfused by the true lumen). Generally, to confirm the correct position, after the ascending aorta cannulation, a 6 Fr / 90 cm introducer sheath was advanced into the arch and then slowly pulled back while injecting small volumes of contrast to confirm the wire position in the true lumen.

Thoracic aorta (pre-deployment): in an oblique projection, a left angulation enabled a correct arch view in accordance with the preoperative planning (Figure 1). This DSA showed the proximal sealing zone before device deployment while keeping the proximal entry tear in view when possible and the visualization of more information.

Final DSA of the thoracic aorta (post deployment): this DSA confirmed the correct stent graft deployment with the entry tear covering evaluating any early false lumen reperfusion.

Postprocessing of DSA (Quantitative DSA)

The DSA data were evaluated using a dedicated workstation (Leonardo, Healthcare Sector,

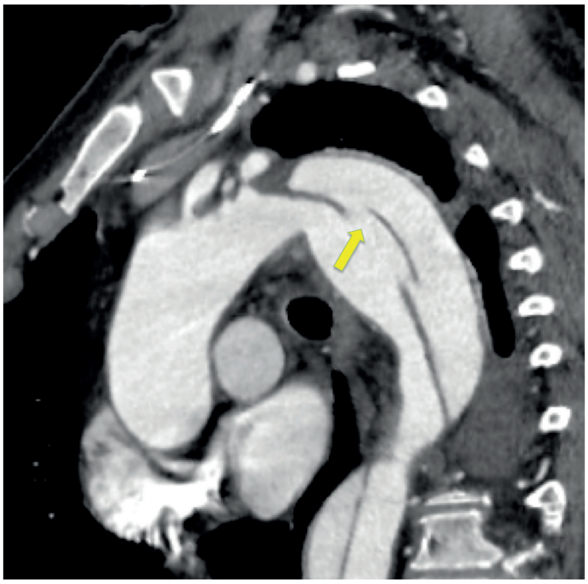

Figure 1. Multi Planar Reconstruction (MPR) of pre-operative CT for a thoracic aneurysm in a chronic type B aortic dissection. This projection showed the true and false lumen with the proximal sealing zone and the entry tear (yellow narrow).

Siemens AG, Forchheim, Germany) to obtain PCC images with syngo iFLOW. Strother et al[6] previously described the underlying mathematic model for iFLOW. This software application elaborates all of the scenes of a defined DSA sequence to generate a color map that displays the progress of contrast medium through the vessels over time. The delay between contrast medium injection and maximum contrast peak (MCP) is defined for each pixel. This time delay is converted into a specific color range from red (early maximum density) to blue (late maximum density). A time intensity sequence enables the creation of an opacification curve diagram for the time in which the benchmarks are at peak opacification, the period leading up to maximum opacification, called the "time-to-peak", and the area under the curve. The changes in the slope of the density curves and in the level of maximum opacification should also provide information to visualize flow alterations during and after the treatment. Variations in curve characteristics demonstrate pre-procedural flow abnormalities and their changes after the treatment[6].

Image Analysis

Additional flow analysis was performed in all patients, and corresponding time–intensity curve diagrams were generated. Two clinicians experienced in vascular imaging evaluated the DSA series to discriminate MCP and the Q-DSA image in blinded assessment, respectively. The readers later compared the image information obtained by the DSA series with that obtained by the color-coded images to evaluate the accuracy of Q-DSA.

In a consensus reading, they answered the following points with either "yes" or "no"[11,12]:

– Does Q-DSA of the visceral aorta facilitate the visualization of TBCAD angioarchitecture with a simultaneous view of a true and false lumen, thereby providing an observer with more information on the position of the guide/catheter in the true lumen?
– Does Q-DSA in the pre-deployment stent graft improve the visualization of the aortic arch by providing more details for viewing the false lumen and the proximal entry tear position compared with a standard DSA?

The readers then compared all procedural and post-interventional DSA series with the color-coded images to assess the tear covering result:

– Does Q-DSA reveal changes in the pattern of true lumen flow after treatment in terms of the coverture of proximal entry tear and residual early false lumen reperfusion?

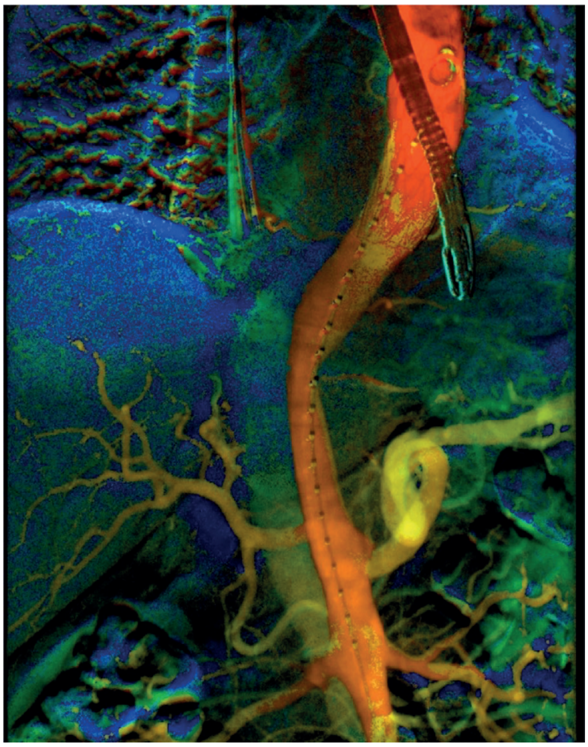

Figure 2. Other case of Q-DSA elaboration of visceral aorta with contemporary true and false lumen enhancement. Perfect catheter detection into the true lumen to confirm the right position.

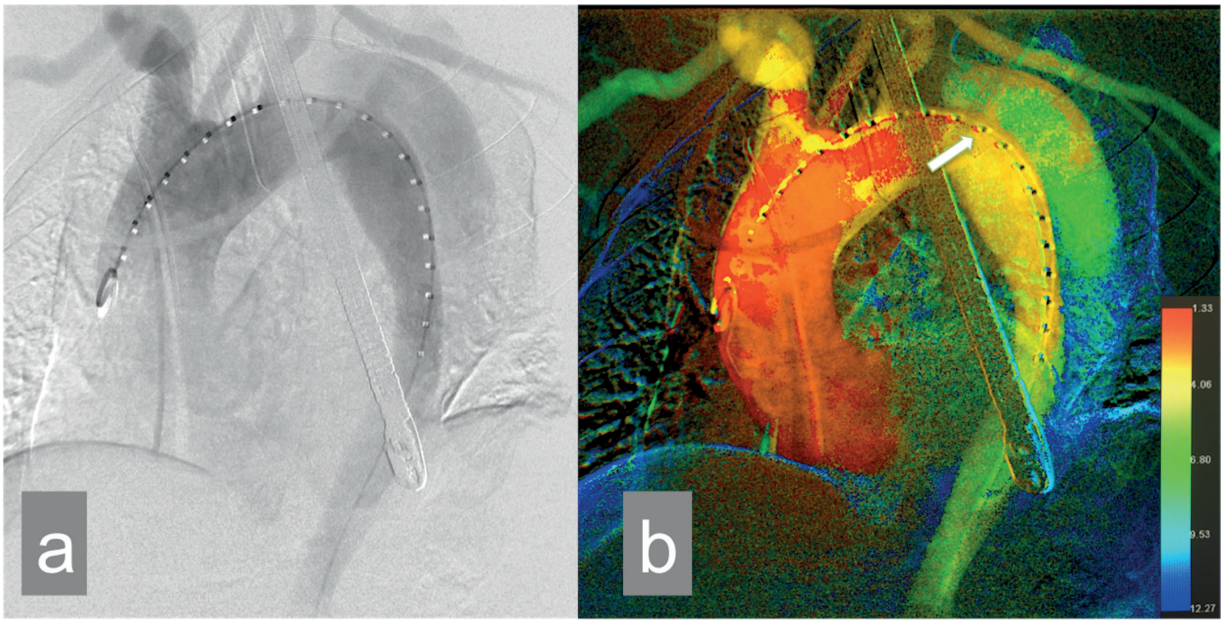

Figure 3. The same case of Figure 1. Maximum intensity peak of thoracic aorta DSA with the device in pre-deployment position in zone 2 (carotid-subclavian bypass previously): good opacification of distal ascending aorta, entire arch and proximal part of descending thoracic aorta (a). The Q-DSA elaboration shows more details: the proximal ascending aorta, the distal part of descending aorta, the false lumen with the position of the proximal entry tear (white narrow) (b).

Results

The DSA series was performed in all cases in the visceral and thoracic aorta during pre- and post-device deployment. A Q-DSA was feasible in all cases and immediately provided high quality images. The time required for Q-DSA processing was 2-3 s. The observers rated the comparison between the DSA series and the color-coded images as follows:

In 81.8% of the cases (9 patients), compared with the original DSA, PCC elaboration showed the contemporary visualization of the aortic dissection angioarchitecture related to the true and false lumen at the level of the visceral aorta. The Q-DSA was rated to increase the accuracy of the dissection shape because the true lumen was clearly highlighted by a different color than the false lumen (Figure 2). This could facilitate the rapid and intuitive identification of the correct guide position in the true lumen in a single image compared to the DSA series according to the variations in contrast medium diffusion in the true and the false lumen. This technique could confirm the precise position of the guide in the true lumen without additional x-ray and contrast injections.

In 72.7% (8 patients) of the procedures, Q-DSA was estimated to improve aorta information assessment in terms of false lumen viewing, and it was possible to identify the proximal entry tear position in 45.4% (5 patients) of the procedures. In the DSA series and specific MCP, the tears were often not visible. In the PCC elaboration, the spread of contrast medium through the tear was emphasized by a color change according to different diffusion times between the true and false lumen (Figure 3).

After stent graft deployment, the color-coded images showed flow changes following tear coverings. In 72.7% of the cases (all 8 patients in which the aortic arch false lumen was visible in pre-treatment), Q-DSA confirmed the absence of early false lumen reperfusion. Correct tear covering after device deployment eliminates proximal false lumen perfusion. Q-DSA allowed the evaluation of early or late false lumen reperfusion (Figure 4).

Discussion

Approximately 30% of patients with chronic aortic dissections developed progressive aneurysmal dilation[13]. In the setting of a chronic dissection, Verhoeven et al[14] described the staged management of TBCAD using an initial TEVAR endograft to cover a proximal entry

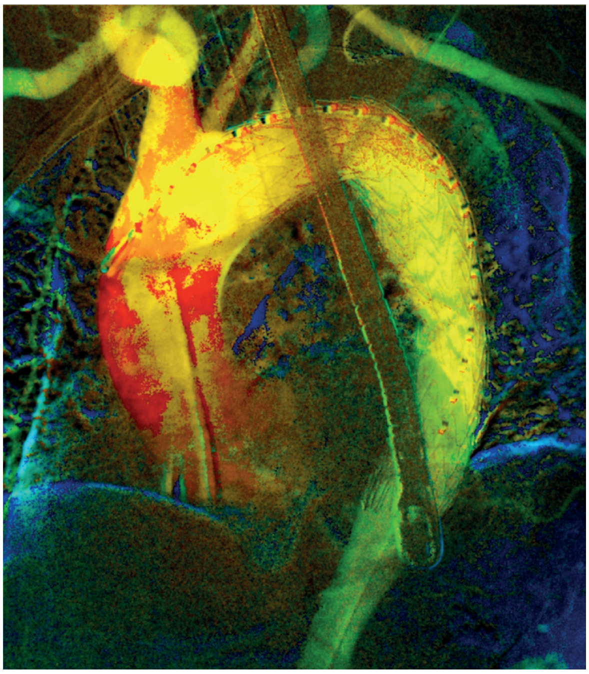

Figure 4. Q-DSA in post TEVAR procedure. After TEVAR, we can confirm a good sealing of the device with the correct entry tear coverture. The parametric color-coding showed a good contrast medium diffusion (orange-yellow color coding) in true lumen ad the absence of early false lumen reperfusion.

tear in the descending thoracic aorta and subsequently a second procedure to exclude the remaining segment of dissection. The clear identification of the true and false lumen remained a challenge in TEVAR and required further contrast medium and x-ray to confirm them before device deployment[4].

The use of PCC images in the endovascular field has been described in the literature, especially in interventional neuroradiology, making complex vascular architectures easier to recognize[12,15-17].

The Q-DSA software shows dynamic information in a colorful static image in which differences in color indicate the pathway of the contrast medium through vessels[8].

In our case series, Q-DSA increases the accuracy of the angiographic assessment of TBCAD during TEVAR. In most cases of our series, Q-DSA enabled the simultaneous identification of the true and false lumen in a single static image. This was used to confirm the guide position in the true lumen. The physiologic differences in blood flow in the true and false lumen display different parametric color codings with notable contrast. This is very useful in cases of non-uniformity of opinion between operators or for less experienced clinicians[6].

Regarding the aortic arch view for the pre-deployment stent graft, PCC elaboration confirmed improved visualization of the true and false lumen in 72.7% of cases. In 5 patients (45.4%), it was possible to identify the exactly entry tear position. This result is explained by the complexity of aortic dissection in terms of the number and size of entry tears. Small and multiple entry tears do not allow sufficient contrast medium transition for a parametric color-coding view. However, where visible, the exact entry tear position was important before device deployment to confirm the preoperative planning strategy. In emergency settings, when preoperative planning is unsatisfactory, this information is essential to achieve the best intra-procedural strategy. Knowing the exact entry tear position led to correct device length selections during TEVAR, considering the starching vessels phenomenon by the stiff guides and device sheath into the vessels.

Q-DSA is not simply a pixel-coded perfusion map. A single image provides a complete temporal history of contrast agent diffusion through the vessels. Several authors have reported that parametric-color coding may improve procedure assessment, as well as provide improved post-treatment hemodynamic information. However, nothing has been published regarding the application of this software in patients undergoing aortic dissection during endovascular treatments[6,12,17,18]. In our case load, Q-DSA indicates the efficacy of the treatment by demonstrating the disappearance of early false lumen perfusion. In 8 patients (72.7%), it was possible to confirm the efficacy of TEVAR by comparing the pre- and post-treatment Q-DSA. PCC allowed the assessment of the correct treatment in terms of the absence of early reperfusion of the false lumen in cases in which it was previously visible. The results also depended on the complexity of the angioarchitecture in the aortic setting resulting from the number and position of secondary entry tears. In the field of endovascular imaging, comparisons with other imaging techniques are arduous. The fusion imaging technique performed by skilled operators is more appropriate and provides more accurate results than intraprocedural angiography. Unfortunately, a 3D-3D fusion technique is needed to detect our target artery or vascular landmarks for endovascular procedures. A 2D-3D fusion technique with overlapping preoperative volume rendering-CT was not very accurate in depicting the stretching vessels phenomenon. In the 2D-3D fusion technique, we nonetheless required an angiogram to confirm the anatomical variations and vascular structures for a precise graft deployment. We, thus, required more x-ray and contrast medium exposure to obtain more information[19-21].

The PCC is a direct software elaboration of the DSA series without additional costs in terms of x-ray and contrast medium exposure. These color-coded images with quantitative measurements are obtained immediately after capturing the DSA series. In our study, the post processing imaging elaboration software required approximately 3 s and was thus a Real-time tool[7].

We early confirmed that color-coding in DSA improved the value of DSA findings[6]. This technique was particularly useful given a complex aortic flow pattern and for evaluating pre- and post-treatment acquisitions.

The main limitation of this study is its retrospective analysis and the small number of cases. The study is only in part balanced by the prospective data collection and thus has missing information. Furthermore, the study employs a subjective method. The consensus reading method is very opinion-driven and is reached by "consensus"; our goal was to test this technique in a potentially "real clinical routine" in which quantitative objective analyses are not performed and prompt action is required. However, these preliminary findings can be a stepping-stone for a future prospective multicenter study. A related quantitative analysis and comparison with pre-procedural imaging could also further address the value of this technique in a clinical setting.

Conclusions

Q-DSA appears to be a useful Real-time application tool to support the angiographic evaluation of TBCAD during TEVAR. This technique also eliminates the need for more x-ray and contrast exposure. Visualizing complex aortic dissection architecture can be simplified, and the flow analysis improves entry tear assessment, thereby increasing diagnostic confidence and accuracy. Intra- and post-procedural hemodynamic changes hidden on DSA series can be easily detected. Further studies with larger populations are needed to confirm and support our preliminary data.

Conflict of Interest

The Authors declare that they have no conflict of interests.

References

1) Andersen ND, Keenan JE, Ganapathi AM, Gaca JG, McCann RL, Hughes GC. Current management and outcome of chronic type B aortic dissection: results with open and endovascular repair since the advent of thoracic endografting. Ann Cardiothorac Surg 2014; 3: 264-274.
2) Rodriguez JA, Olsen DM, Lucas L, Wheatley G, Ramaiah V, Diethrich EB. Aortic remodeling after endografting of thoracoabdominal aortic dissection. J Vasc Surg 2008; 47: 1188-1194.
3) Sobocinski J, Patterson BO, Clough RE, Spear R, Martin-Gonzalez T, Azzaoui R, Hertault A, Haulon S. Treatment options for postdissection aortic aneurysms. J Cardiovasc Surg (Torino) 2016; 57: 202-211.
4) Spear R, Sobocinski J, Settembre N, Tyrrell MR, Malikov S, Maurel B, Haulon S. Early experience of endovascular repair of post-dissection aneurysms involving the thoraco-abdominal aorta and the arch. Eur J Vasc Endovasc Surg 2016; 51: 488-497.
5) Patterson BO, Vidal-Diez A, Karthikesalingam A, Holt PJ, Loftus IM, Thompson MM. Comparison of aortic diameter and area after endovascular treatment of aortic dissection. Ann Thorac Surg 2015; 99: 95-102.
6) Strother CM, Bender F, Deuerling-Zheng Y, Royalty, K, Pulfer KA, Baumgart J, Zellerhoff M, Aagaard-Kienitz B, Niemann DB, Lindstrom ML. Parametric color coding of digital subtraction angiography. AJNR Am J Neuroradiol 2010; 31: 919-924.
7) Zhang XB, Zhuang ZG, Ye H, Beilner J, Kowarschik M, Chen JJ, Chi JC, Xu JR. Objective assessment of transcatheter arterial chemoembolization angiographic endpoints: preliminary study of quantitative digital subtraction angiography. J Vasc Interv Radiol 2013; 24: 667-671.
8) Yamamoto K, Nakai G, Azuma H, Narumi Y. Novel software-assisted hemodynamic evaluation of pelvic flow during chemoperfusion of pelvic arteries for bladder cancer: double-versus single-balloon technique. Cardiovasc Intervent Radiol 2016; 39: 824-830.
9) Cole BL, Maddocks JD, Sharpe K. Visual search and the conspicuity of coloured targets for colour vision normal and colour vision deficient observers. Clin Exp Optom 2004; 87: 294-304.
10) Tinelli G, De Nigris F, Minelli F, Vincenzoni C, Flex A. Quantitative digital subtraction angiography during type B chronic aortic dissection endovascular repair. Vasc Med 2017 Oct 1:1358863X17737167. doi: 10.1177/1358863X17737167. [Epub ahead of print]
11) Bankier AA, Levine D, Halpern EF, Kressel HY. Consensus interpretation in imaging research:

is there a better way [editorial]. Radiology 2010; 257: 14.

12) Gölitz P, Struffert T, Lücking H, Rösch J, Knossalla F,Ganslandt O, Deuerling-Zheng Y, Doerfler A. Parametric color coding of digital subtraction angiography in the evaluation of carotid cavernous fistulas. Clin Neuroradiol 2013; 23: 113-120.

13) Song JM, Kim SD, Kim JH, Kim MJ, Kang DH, Seo JB, Lim TH, Lee JW, Song MG, Song JK. Long-term predictors of descending aorta aneurysmal change in patients with aortic dissection. J Am Coll Cardiol 2007; 50: 799-804.

14) Verhoeven EL, Paraskevas KI, Oikonomou K, Yazar O, Ritter W, Pfister K, Kasprzak P. Fenestrated and branched stent-grafts to treat post-dissection chronic aortic aneurysms after initial treatment in the acute setting. J Endovasc Ther 2012; 19: 343-349.

15) Gölitz P, Struffert T, Rösch J, Ganslandt O, Knossalla F, Doerfler A. Cerebral aneurysm treatment using flow-diverting stents: in-vivo visualization of flow alterations by parametric colour coding to predict aneurysmal occlusion: preliminary results. Eur Radiol 2015; 25: 428-435.

16) Gupta V, Chinchure S, Goel G, Jha AN, Gupta A, Narang KS. Coil embolization of intracranial aneurysms with ipsilateral carotid stenosis: technical considerations. Turk Neurosurg 2014; 24: 587-592.

17) Lin CJ, Luo CB, Hung SC, Guo WY, Chang FC, Beilner J, Kowarschik M, Chu WF, Chang CY. Application of color-coded digital subtraction angiography in treatment of indirect carotid-cavernous fistulas: initial experience. J Chin Med Assoc 2013; 76: 218-224.

18) Saad WE, Anderson CL, Kowarschik M, Turba UC, Schmitt TM, Kumer SC, Matsumoto AH, Angle JF. Quantifying increased hepatic arterial flow with test balloon occlusion of the splenic artery in liver transplant recipients with suspected splenic steal syndrome: quantitative digitally subtracted angiography correlation with arterial Doppler parameters. Vasc Endovascular Surg 2012; 46: 384-392.

19) Schulz CJ, Schmitt M, Böckler D, Geisbüsch P. Feasibility and accuracy of fusion imaging during thoracic endovascular aortic repair. J Vasc Surg 2016; 63: 314-322.

20) De Ruiter QM, Reitsma JB, Moll FL, Van Herwaarden JA. Meta-analysis of cumulative radiation duration and dose during EVAR using mobile, fixed, or fixed/3D fusion C-arms. J Endovasc Ther 2016; 23: 944-956.

21) Hertault A, Maurel B, Sobocinski J, Martin Gonzalez T, Le Roux M, Azzaoui R, Midulla M, Haulon S. Impact of hybrid rooms with image fusion on radiation exposure during endovascular aortic repair. Eur J Vasc Endovasc Surg 2014; 48: 382-390.