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Transcatheter Closure of an Anastomotic Leak after the Bentall Procedure with the Guidance of 3-Dimensional Printing

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Keywords:

Anastomotic leakage; Ascending aorta; Bentall procedure; 3-dimensional printing; Transcatheter

Abbreviations:

3D: 3-Dimensional; AL: Anastomotic Leak; BP: Blood Pressure; CTA: Computed Tomography Angiography; DSA: Digital Subtraction Angiography; NYHA: New York Heart Association; SHD: Structural Heart Diseases; TTE: Transthoracic Echocardiography

1. Abstract

1.1. Objective: We describe the use of 3-dimensional (3D) printing technology to guide the occlusion of an anastomotic leak (AL) in the ascending aorta.

1.2. Case Report: A 67-year-old woman underwent a Bentall procedure a year ago for an ascending aortic aneurysm. However, the patient recovered slowly after the surgery. Two months ago, the patient developed palpitations, shortness of breath, chest tightness, and chest pain after activities, and the symptoms continued to worsen. Transthoracic echocardiography showed an AL after the Bentall procedure. Computed tomography angiography showed a 4-mm AL distal to the ascending aortic prosthesis. After a comprehensive discussion among the surgeons, a 3D printing preoperative evaluation and digital subtraction angiography were used to guide the closure of the AL. After the procedures, postoperative digital subtraction angiography showed that the endoleak was completely isolated and the false lumen had disappeared. At the 30-day follow-up, the 3D printed model showed the ideal effect of the occlusion.

1.3. Conclusion: With the guidance of preoperative 3D printing, transcatheter closure of an AL after the Bentall procedure may achieve ideal results, thereby offering bright prospects.

2. Introduction

The Bentall procedure is an effective surgical method for treating an aortic root and an aortic dissection combined with aortic regurgitation [1] that may effectively remove the pathological aortic tissues. An anastomotic leak (AL) after the Bentall procedure is an extremely difficult complication because of the weak tissue at the anastomotic site or the comparatively poor vascular anastomosis technique. Although most patients with a small AL do not need to be treated, an AL of medium proportions can lead to hemolytic anemia, progressive heart failure, a pseudoaneurysm, and even serious consequences such as an aortic rupture in the late stage [2,3]. Surgical repair of an AL was the only effective treatment in the past, but the technical difficulty of the reoperation is high. Furthermore, intraoperative hemostasis is difficult, and the surgical risk is high: the mortality rate can be 7.0% to 33.3% [4]. In recent years, although the occlusive devices invented for treating structural heart diseases (SHD) have been used for the treatment of an AL after an aortic operation, preoperative planning still presents some difficult challenges. In this case report, we fully simulated and evaluated the anatomy of the patient with an AL after the Bentall procedure using 3-dimensional (3D) printing before performing the procedures, which enabled us to make a clear diagnosis and close the AL of the ascending aorta.

3. Baseline Information and Preoperative Imaging

A 67-year-old woman underwent the Bentall procedure a year ago for an ascending aortic aneurysm. However, the patient recovered slowly after the surgery. Two months ago, the patient developed palpitations, shortness of breath, and chest tightness and chest pain after activities, and the symptoms continued to worsen. Upon admission, the results of the physical examination showed that her blood pressure was 102/60 mmHg; she was New York Heart Association functional class III; and a systolic souffle-like murmur could be heard between the 3rd and 4th intercostal spaces of the right sternum. Transthoracic echocardiography showed an AL after the Bentall procedure (Figure 1A). Computed tomography angiography (CTA) showed a 4-mm AL distal to the ascending aortic prosthesis (Figure 1B).

4. 3-Dimensional Printing and Preoperative Simulations

The Digital Imaging and Communication of Medicine (DICOM) format of the patient's CTA data was imported into Materialise Mimics version 21.0 (Leven, Belgium) software, and the 3D reconstructed model of the ascending aorta was segmented by the threshold segmentation function. Using Materialise 3-Matic (Leven, Belgium) software, the 3D reconstructed model of the ascending aorta was processed digitally using shell extraction, cutting, smoothing and repair, and the anatomical structures, especially the false lumen, were completely restored (Figure 1C). Finally, the digital model was exported to Standard Tessellation Language (STL) format, and the files were imported into the Polyjet 850 multimaterial full-color 3D printer (Stratasys, Inc., Eden Prairie, MN, USA) for printing (Figure 1D, E). The 3D printed model of the ascending aorta was obtained by editing and printing different tissues with different materials. Then the procedures of AL closure were simulated during the bench test, including practicing the surgical approach, selecting the occluder size, and positioning the false lumen (Figure 1F, G). After the completing the occluder-simulated release, the morphology of the occluder and the perivascular conditions were observed (Figure 1H, I). By simulating the procedures with the preoperative 3D printed model, the surgeons could optimize the surgical strategy, accurately assess the related surgical risks, and improve the success rate and efficiency.

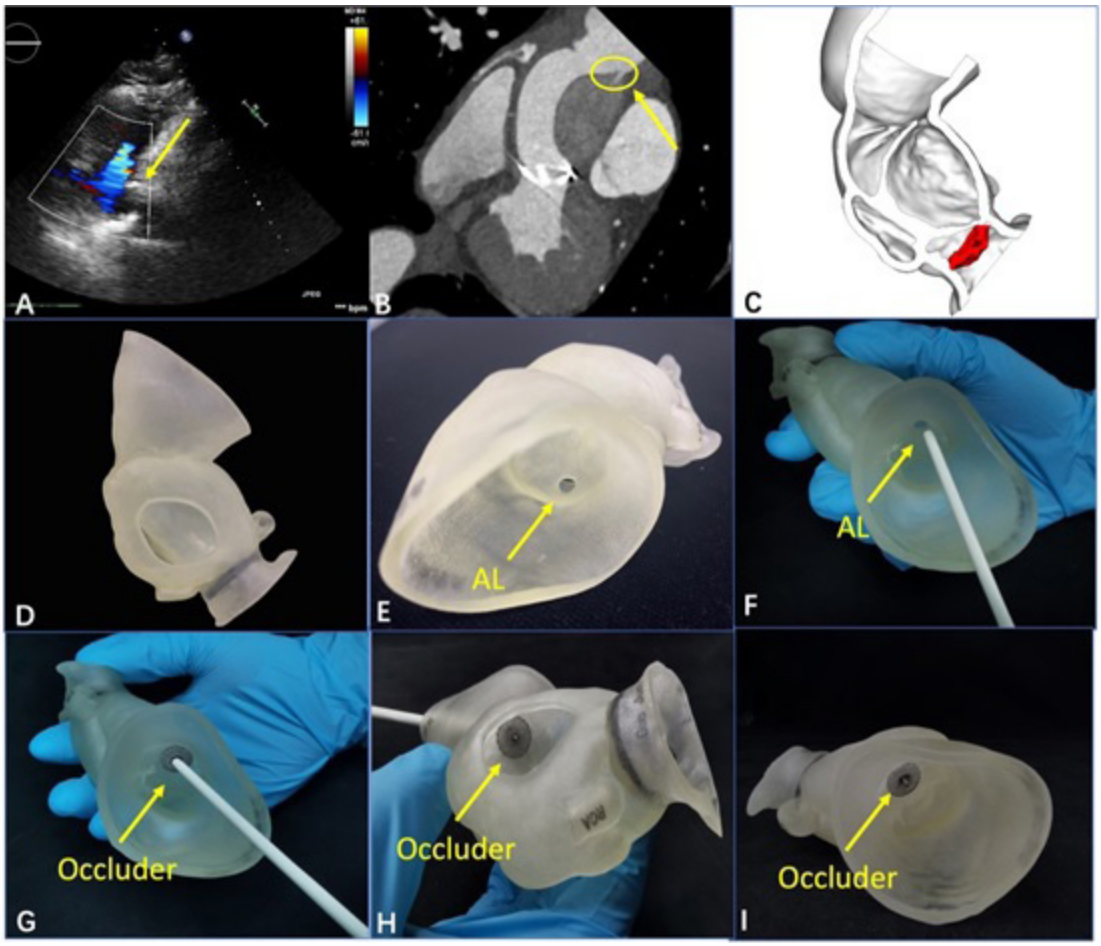

Figure 1. Preoperative imaging assessment: 3-dimensional printing and simulations were used to formulate the procedural strategy for this patient. (A-B) The anastomotic leak was clearly evident in transthoracic echocardiographic and computed tomography angiographic scans. (C) The 3-dimensional reconstructed model. (D-E) The 3-dimensional printed model (arrow shows the anastomotic leak). (F) The 3-dimensional printed model was used to simulate the closure of the anastomotic leak; the catheter went through the leak (arrow shows the location of the leak). (G) Different sizes of occluders were used to simulate the procedure and to select the appropriate device using the 3D printed model (arrow shows the occluder). (H-I) The 6-mm ADO II plug was selected, and the occluder was effective in stopping the leak (arrow shows the occluder).

5. Procedural Steps

Warfarin was stopped for 3 days before the surgery, and low-molecular-weight heparin was used to keep the international normalized ratio below 1.5. The right femoral artery and vein were used as puncture points, and 2% lidocaine was used for local anesthesia. After a successful puncture, a 6F arterial sheath was placed, and 5000 U heparin was used during the procedures. The 6F pig-tail catheter was inserted retrogradely into the ascending aorta, and digital subtraction angiography (DSA) showed that a high-speed bloodstream filled the false lumen (Figure 2A). A 2.6-m straight loach guide wire was made to enter the false lumen at the anastomosis site after only three attempts, and the single-bent catheter was moved to the false lumen. Afterwards, the Lunderquist guide wire was used to replace the false lumen and to exchange the 5F Cook catheter along the supporting guide wire to the false lumen (Figure 2B). A 6-mm ADO II plug was selected to occlude the AL (Figure 2C, D). After we created the occlusion, DSA and transesophageal echocardiography showed that the endoleak was completely isolated and that the false lumen had disappeared (Figure 2E, F). The entire procedures went smoothly, ending with 30 mL of intraoperative blood and 40 mL of contrast agent.

6. 30-Day Follow-Up

The patient was followed up on the 30th day after the procedures. The examination results showed that her blood pressure was 130/75 mmHg, and she was New York Heart Association functional class I. Transthoracic echocardiography and CTA examinations showed that the position and effect of the AL were ideal (Figure 3A, B). The 3D printed model of the ascending aorta was obtained using CTA data. It showed that the ascending aorta was in good shape and that the position of the occluder was ideal, and no complications such as occluder displacement, leakage enlargement, aortic injury, hemolysis, or thrombosis occurred (Figure 3C-F).

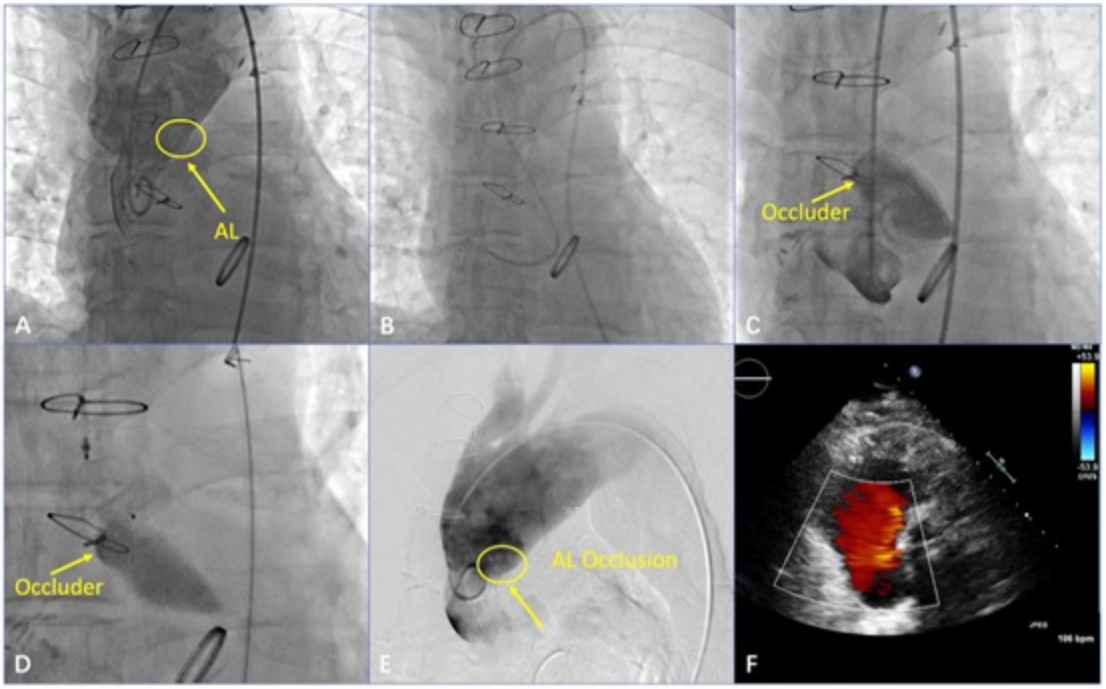

Figure 2. Intra- and postprocedural digital subtraction angiography images showing closure of the anastomotic leak. (A) Digital subtraction angiography showed the position of the anastomotic leak (arrow shows the anastomotic leak). (B) The catheters were exchanged after the guide wire went through the leak. (C) The position of the occluder was adjusted (arrow shows the occluder). (D) The occluder was released and could be seen clearly (arrow shows the occluder). (E) There was no regurgitation around the ascending aorta after the procedure (arrow shows the occlusion). (F) Transesophageal echocardiography suggested that the anastomotic leak almost disappeared.

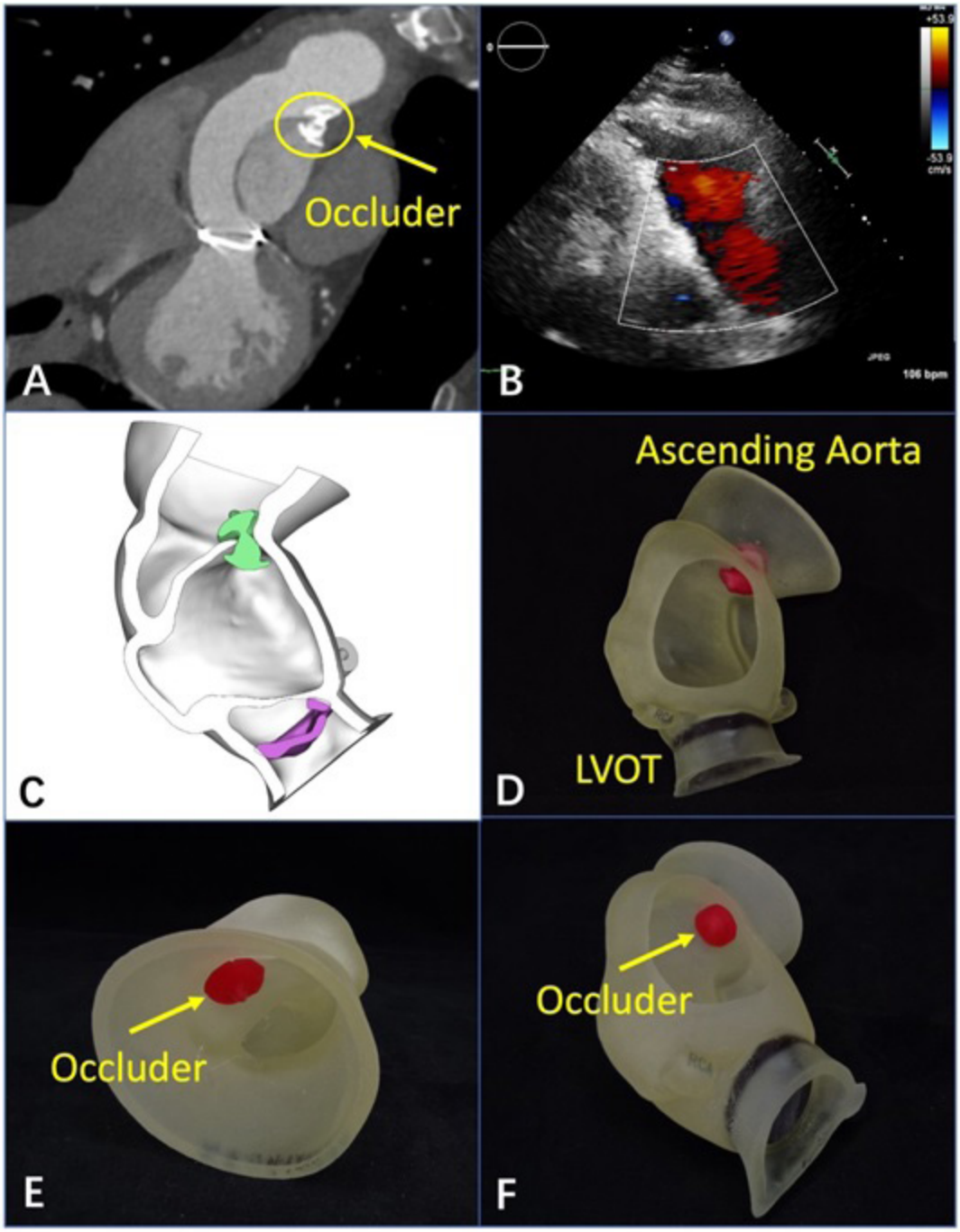

Figure 3. The 30-day follow-up images and the 3-dimensional printed model verified the position of the occluder located in the anastomotic leakage. (A-B) Transthoracic echocardiography and computed tomography angiography showed that the position and effect of the anastomotic leakage was ideal (arrow shows the occluder). (C) The 3-dimensional reconstructed model. (D-F) The 3D printed model (D. lateral view; E. Ascending aorta view; F. left ventricular view; Arrows show the occluder, and the red part is the printed occluder). LVOT: left ventricular outflow tract.

7. Discussion

In recent years, operations treating aorta diseases have developed rapidly. The surgical methods differ (including aortic replacement, the Bentall procedure, the David procedure, the Wheat procedure, and the Sun procedure) according to the anatomical characteristics of the lesions and the extent of involvement. A postoperative AL is relatively rare: Its occurrence is involved with the autologous vulnerable aorta (such as aortic dissection and Marfan's syndrome), infection, complex anatomical structures, and surgical anastomoses, which occur frequently at the anastomosis site of the artificial blood vessels and the proximal autologous aorta [5]. The hemodynamic characteristics of the AL are different at different locations, which leads to different clinical consequences. This patient was classified as having a type I AL [6]. The extreme pressure difference between the aorta and the right atrium (RA) may lead to a persistent left-to-right shunt. Moreover, the right cardiac system lacks the ability to compensate for the sudden increase in blood flow; the RA pressure is significantly increased;

and pulmonary hypertension progresses rapidly, resulting in early right heart failure [6]. In the past, the AL could be repaired only by reoperation, but the second surgery has a great impact on the patient, and it is difficult to stop the bleeding during the procedure. In addition, the location prone to an AL is comparatively deeper, which makes free exposure difficult and requires that the surgeon have extensive experience and skills [7]. In recent years, the occlusive devices invented for treating SHD have been used for the treatment of an AL after aortic operations. The second generation occluder for patent ductus arteriosus is a non-covered occluder woven with nickel-titanium wire, which may be released through a soft delivery system and is currently an ideal occluder for treating an AL [8,9]. However, developing a comprehensive preoperative strategy (including selecting a compliant, close-fitting occluder, minimizing the residual shunt, obtaining good stability at the high-speed shunt site, and choosing a delivery system that will pass easily) is still a challenge. The emergence of cardiovascular 3D printing opens a new field of vision to enhance the accuracy of the treatment of SHD, especially for patients with complex anatomies. The operative team can not only make full use of 3D printed models for measurement and observation but can also select printing materials with characteristics similar to those of the anatomical structures. The procedures can be simulated first during the bench test to provide a basis for the selection of the appropriate size of the implanted device and the formulation of a surgical plan and to permit prediction of the main complications that may occur during the procedures to reduce the risk of the operation [10]. In addition, the use of a 3D printed model for preoperative simulation may shorten the learning curve of the surgeons and also play a positive role in promoting the success rate of the operation and the prognosis of the patients. Therefore, for the patient with an AL after the Bentall procedure, we used a 3D printed model of the ascending aorta to visually display the anatomical structures, accurately measure the size of the AL, and select the corresponding size of the matching occluder. Furthermore, it is of great significance to use the 3D printed model for surgical simulation before performing the procedures to become familiar with the surgical approach, shorten the actual operating time, reduce the DSA time and the radiation amount, and effectively improve the success rate, which is of great significance for patients.

8. Conclusion

Overall, the results of this case show that the application of ADO II occluders to occlude an AL after an aortic operation may achieve satisfactory short-term results with the accurate measurement of preoperative images and simulations by using a 3D printed model to develop the specific surgical plan. Cardiovascular 3D printing technology may play an important role in the guidance of such procedures and has broad prospects for further clinical development.

9. Funding

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