30 Hybrid Approach: Ventricular Septal Defect Closure

Gareth J. Morgan

30.1 Introduction

The hybrid approach to closure of ventricular septal defects is applicable in a wide range of muscular ventricular septal defects. The key anatomical relationships to consider on the right ventricular aspect are the tricuspid valve, the moderator band, proximity to the free wall of the right ventricle and the pulmonary valve in the case of outlet defects. On the left side, obstruction of the aortic valve or left ventricular outflow tract may be an issue in outflow defects. The mitral valve is rarely a problem, but in cases where the mitral valve has abnormal attachments or where the anatomy is that of a repaired AVSD with a residual VSD, the left-sided valve structures can become relevant.

30.2 Clinical Scenarios, Indications and Patient Selection

1. *The patient is too small to consider transcatheter closure of the septal defect.* Transcatheter VSD closure is usually reserved for patients greater than 10 kg. This weight is not usually achieved by children with the physiological handicap of heart failure until after 1 year of age.
2. *Relative contraindication to cardiopulmonary bypass.* This may be due to an ongoing neurological concern, renal dysfunction or thrombotic/thrombophilia tendency. In the vast majority of cases, hybrid VSD closure can be performed without cardiopulmonary bypass.
3. *The anatomical location of the defect is such that a surgical or transcatheter approach may be difficult.* Defects, whose RV exit points are placed in the more extreme regions of the ventricular septum, such as apical, anterior mid-muscular and those closely associated with the moderator band, may be more amenable to a hybrid approach (Fig. 30.1).

30.3 Case Example

Clinical scenario: Postoperative perimembranous VSD closure. Haemodynamically significant additional muscular VSD. Patient weight, 4.8kg. Unable to progress from ITU/respiratory support care despite maximal anti-failure treatment. Chest radiograph is consistent with a large left-to-right shunt. Echocardiogram shows a dilated left side of the heart and significant left-to-right flow across the ventricle septum. The tricuspid valve regurgitant velocity suggests an RV pressure which is approx. 75% systemic.

Anatomy: Surgically repaired perimembranous VSD. Separate muscular defect positioned apical to the moderator band and measuring 5 mm on transthoracic echocardiogram.

Treatment options: Before embarking upon any definitive therapy, appropriately aggressive medical management should be implemented to ensure that a definitive procedure is necessary at this stage.

Option 1: Surgical device closure: The patient is within 2 weeks of his/her initial cardiopulmonary bypass run. The position of the defect in this weight of infant is likely to provide a major challenge to the surgeon.

Option 2: Percutaneous transcatheter device closure. Although a theoretically feasible option, the practicalities at this weight in this clinical scenario are likely to be prohibitive. Assuming that the defect could be crossed from the left side with a wire and catheter, manipulating a stiff delivery sheath through the right side of the heart and accurate device delivery would be very challenging.

The original version of this chapter was revised. A correction to this chapter can be found at https://doi.org/10.1007/978-3-319-72443-0_46

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-319-72443-0_30) contains supplementary material, which is available to authorized users.

G. J. Morgan (✉)
The Heart Institute, Children's Hospital of Colorado, University of Colorado, Denver, CO, USA

G. Butera et al. (eds.), *Atlas of Cardiac Catheterization for Congenital Heart Disease*,
https://doi.org/10.1007/978-3-319-72443-0_30

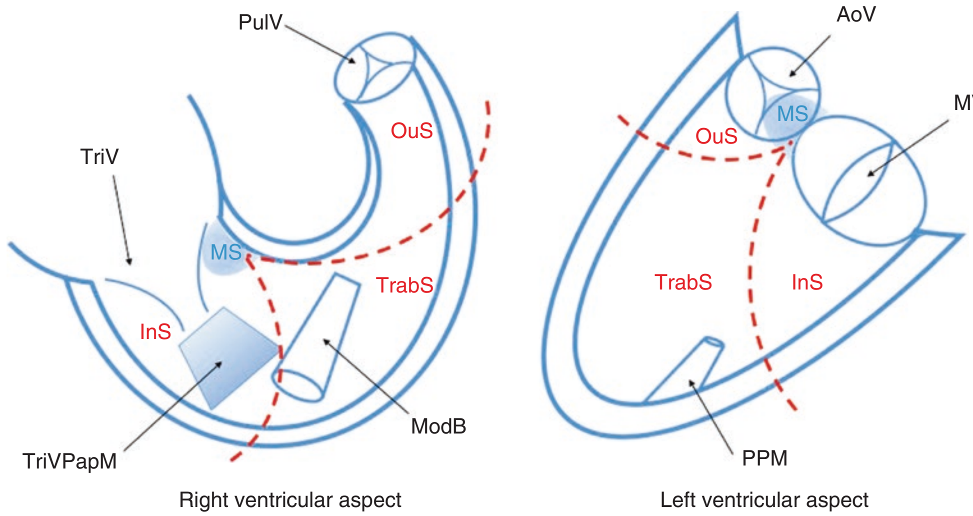

Fig. 30.1 The right ventricular aspect of the ventricular septum is more complex than the left, partly explaining why disc conformation on the left side is rarely an issue but always a concern for the right-sided disc. The diagrams show the potentially problematic structures in each corresponding portion of the septum on either ventricular aspect. *TriPapM* tricuspid valve papillary muscles; *InS* inlet septum; *TrabS* trabecular septum; *OuS* outlet septum; *ModB* moderator band; *PPM* posterolateral papillary muscle; *MS* membranous septum)

Option 3: Hybrid periventricular VSD device closure. Given the patient weight, the position of the defect and the clinical condition, this may be an attractive option, as discussed below.

Pre-procedural imaging: (a) High-quality transthoracic echocardiogram alone; (b) if the key features cannot be delineated, then transoesophageal echocardiography (TOE) may help to delineate the anatomy further (Fig. 30.1, right panel). 3D echo imaging can add useful information in these cases; (c) angiographic delineation of the ventricular septum may be particularly useful in larger patients with complex multiple defects.

Key features: (1) Size and position of the target lesion. (2) Relationship to structures such as the moderator band (the defect may straddle the moderator band), the tricuspid valve and its septal attachments and mitral valve apparatus. (3) Proximity to the apex and the cavity size on either side of the defect (i.e. how much practical space there is to deploy the left and right discs). (4) The presence and significance of any additional defects—do these also require closure? If not, then they need to be recognized to ensure that the correct defect will be crossed.

30.4 Technique (Step by Step)

1. The ideal place to perform hybrid procedures is in a fully specified hybrid operating facility. A biplane angiographic imaging equipment should be available in case angiography becomes necessary during the case. The room should have full cardiopulmonary bypass and deep hypothermic circulatory arrest capabilities. TOE imaging is mandatory. Depending on patient size and defect position, epicardial echocardiography can also provide imaging guidance (Fig. 30.2, panel b).
2. When cardiac position and connections are normal, a sternotomy is usually the optimal approach; however, thoracotomy or subxiphoid approach may be used in cases where the anatomical orientation is favourable.
3. After locating and delineating the defect on echocardiography, the correct position to puncture the right ventricle is identified. A combination of angle towards the septum, cavity space for device deployment, proximity to the moderator band and the space constraints to allow the operators to manipulate the catheters and sheaths needs to be considered. Practically this is easily done by indenting different parts of the RV free wall with a finger whilst observing the echo image.
4. Prior to puncturing the RV, the occlusion device should be selected, prepared and loaded, ready for insertion into the sheath. The correct device size usually has a waist diameter of 2 mm larger than the maximum measured diameter of the defect. The most frequently used device is the St Jude Amplatzer muscular VSD occluder (Fig. 30.3 panel a+b). In particular cases the use of a single disc "duct-type" device may be particularly important if the defect is close to the free wall of the right ventricle or abutting the moderator band; the lack of RV disc should allow better conformation of the disc and reduce the chance of the device interfering with and damaging the ventricular free wall (Fig. 30.4 and 30.5)
5. Once the RV wall position is identified and the device prepared, a purse string is placed on the RV free wall. Hundred

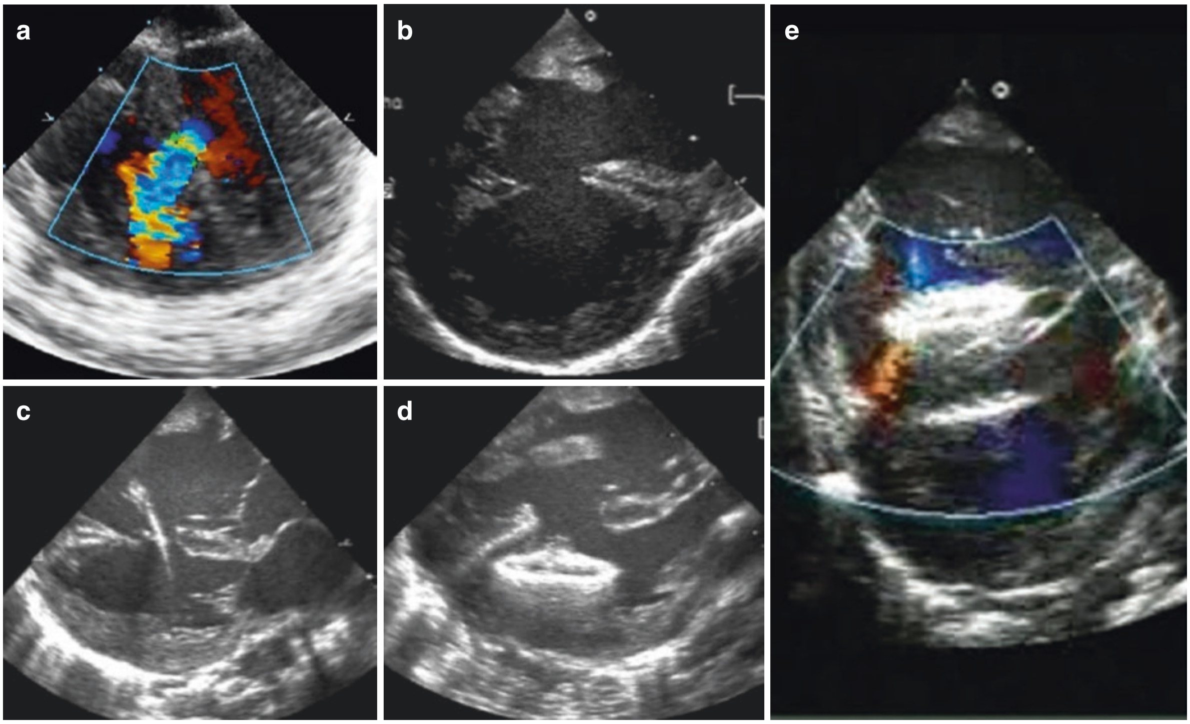

Fig. 30.2 Panel (**a**) shows a mid-muscular VSD delineated with epicardial echo in a 4.8 kg patient. Epicardial echo can be useful as the probe can be used to mimic the angle and direction desired for the wire and sheath passage. Panel (**b**) shows the corresponding TOE view with 2D imaging and colour flow Doppler. Panel (**c**) shows the sheath across the defect, and panels (**d**) and (**e**) show the deployment of the left and right ventricular discs, respectively

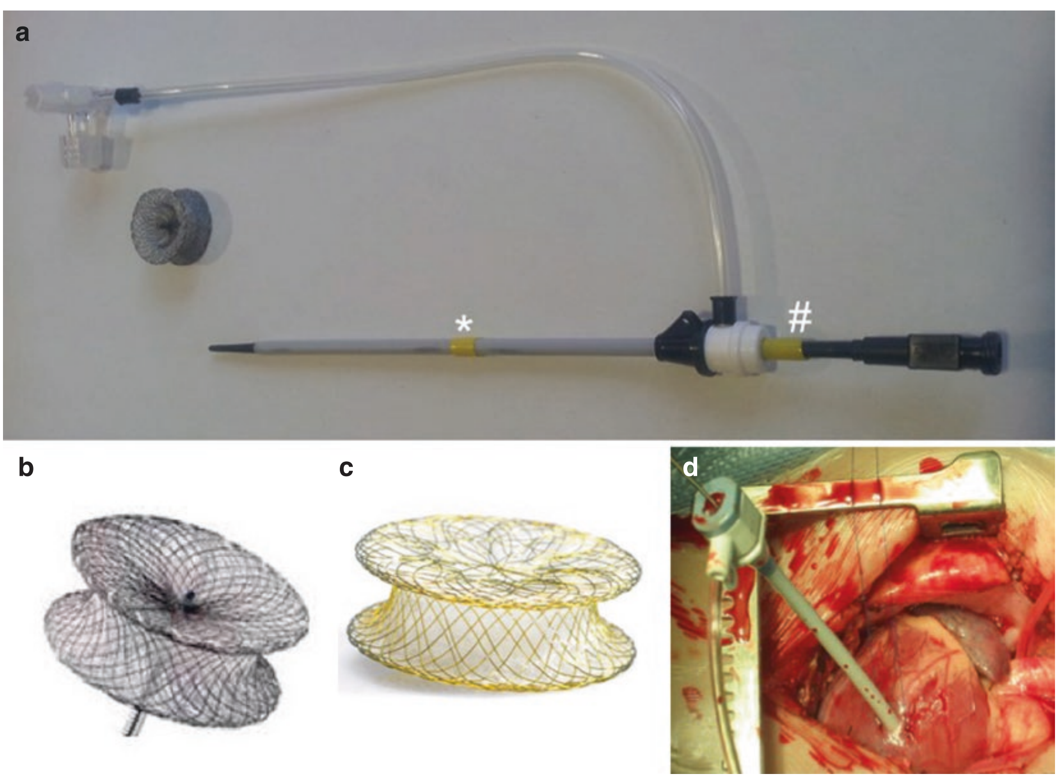

Fig. 30.3 Panel (**a**) illustrates preparation of the short delivery sheath with a rubber shod placed to lessen the chance of the stiff dilator being pushed towards the posterior wall of the left ventricle (#) and another placed (*) to guide and monitor the distance the sheath is inserted through the free wall of the RV. Panel (**b** and **c**) show the AGA muscular VSD device and the Occlutech muscular VSD device, both of which can be used in the method above. Panel (**d**) shows a typical surgical view of the sheath placed in the RV with a purse string suture in place (Panel **d** image courtesy of Prof Neil Wilson, University of Colorado)

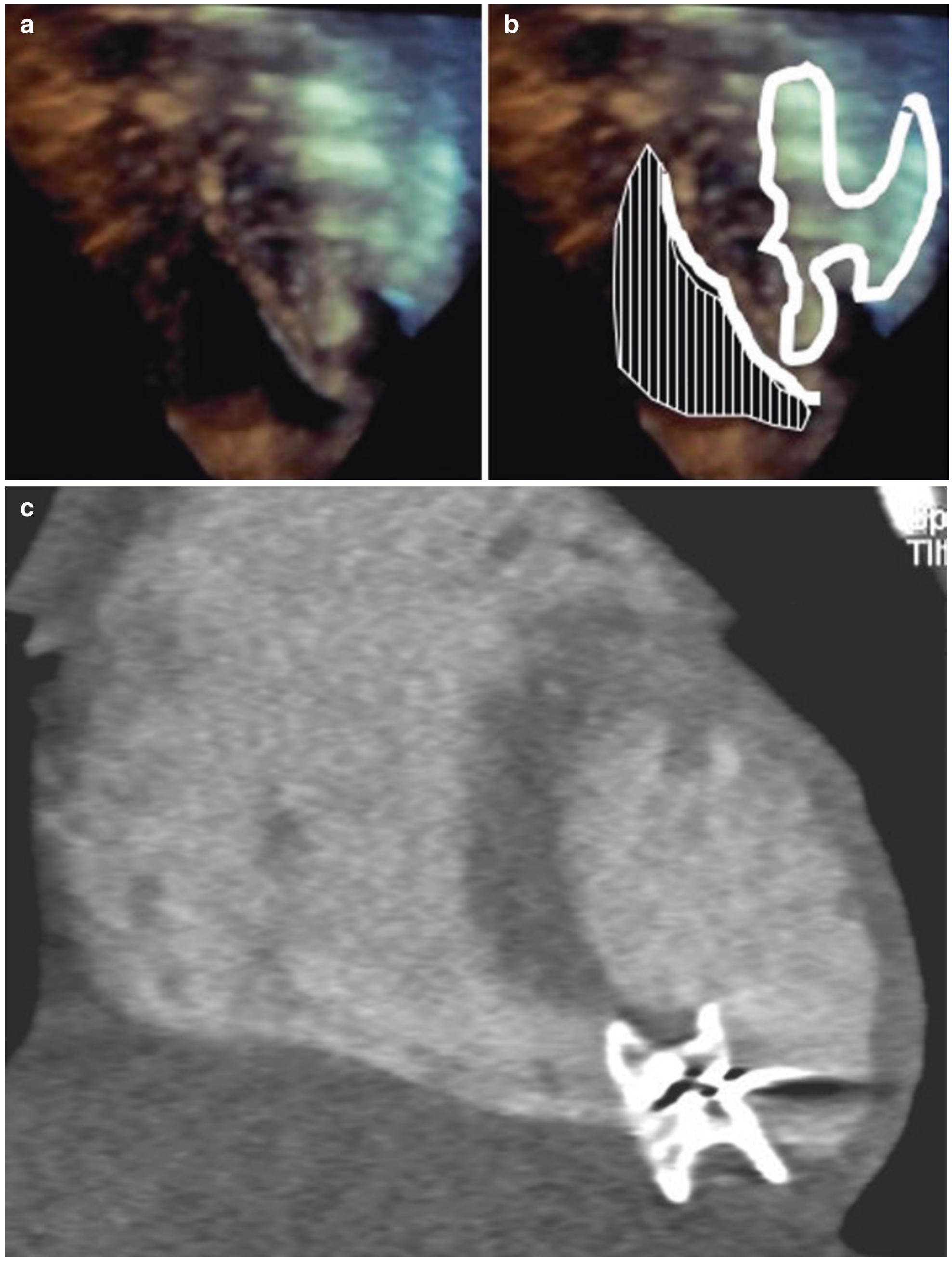

Fig. 30.4 Images of an apically placed occluder close to the right ventricular free wall with a related pericardial effusion. Panel (**a**) is a still frame from live 3D echo imaging showing the device, the external surface of the RV and a pocket of pericardial fluid. Panel (**b**): Schematic overlay for illustrative purposes. The striped area denotes the effusion; the thick white line defines the epicardial aspect of the RV; and the irregular shape represents the apposed aspect of the muscular VSD device. CT imaging (Panel **c**) was carried out in an attempt to rule out perforation and help to assess risk of future perforation

units per kilogram of heparin should be administered at this stage. Under TOE guidance, the RV is punctured using an 18-gauge needle and a 035″ Terumo J-tip hydrophilic wire guided across the defect and into the LV cavity. The wire will ideally be directed out the left ventricular outflow tract to minimize the possibility of interference with the mitral papillary muscles and direct the sheath away from the posterior wall of the LV (Fig. 30.5). A short sheath (approx. 10 cm), large enough to accommodate the prospective device (usually between 6 French and 10 French), is then advanced over the wire and across the VSD to sit in the LV cavity (Fig. 30.2, panel c; Fig. 30.3 panel d). A perpendicular approach from the free wall to the ventricular septum is important in order not to distort the anatomy and enable successful deployment.

6. Under careful echocardiographic guidance, the LV disc should be deployed in the mid-cavity and the entire apparatus withdrawn to appose the LV disc onto the septum (Fig. 30.2, panel d). Then, the waist of the device and subsequently the RV disc should be uncovered by withdrawal of the sheath. It may take several attempts to correctly conform the RV disc; therefore, care should be

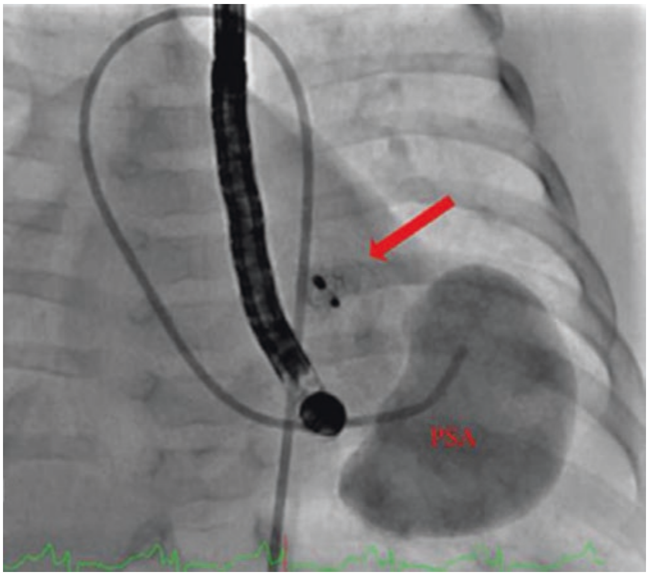

Fig. 30.5 LV pseudoaneurysm secondary to hybrid VSD closure. During the procedure the wire was noted to have excessive contact with the posterior wall of the LV. This led to the development of a large pseudoaneurysm within 2 weeks of the procedure which was initially treated with percutaneous occlusion but was later surgically resected. The red arrow indicates the muscular VSD device, remote from the pseudoaneurysm which is labelled “PSA” (Image courtesy of Dr. Damien Kenny, Dublin, Ireland)

taken not to pull the sheath out of the RV during the initial deployment. Indeed the RV disc may not completely conform on the RV septal aspect due to trabeculations, moderator band and limited chamber size near the apex. The operators must then decide whether the RV disc has formed adequately to allow defect occlusion and device stability even if it looks constrained (Fig. 30.2, panel e).

7. The device can be released in the standard manner. Echocardiography may be supplemented by angiography at any stage; however, this is rarely necessary with high-quality echo imaging.
8. The sheath can then be withdrawn and the purse string closed.

Video 1 Hybrid muscular VSD closure. TEE monitoring of the procedure showing the various steps (video courtesy of Dr. Butera Gianfranco, Milan, Italy) (MOV 31404 kb)