Indian Journal of Thoracic and Cardiovascular Surgery
https://doi.org/10.1007/s12055-018-0669-4

REVIEW ARTICLE

Mini Bentall operation: technical considerations

Marco Di Eusanio[1] · Mariano Cefarelli[1] · Carlo Zingaro[1] · Filippo Capestro[1] · Sacha Marco Luciano Matteucci[1] · Alessandro D'alfonso[1] · Michele Danilo Pierri[1] · Marco Luigi Aiello[1] · Paolo Berretta[1]

Received: 1 September 2017 / Revised: 11 February 2018 / Accepted: 6 March 2018

Abstract
Bentall operation via median sternotomy has been largely shown to be safe and long-term efficacious and currently represents the "gold standard" intervention in patients presenting with aortic valve and root disease. However, over the last years, minimally invasive techniques have gained wider clinical application in cardiac surgery. In particular, minimally invasive aortic valve replacement through ministernotomy has shown excellent outcomes and becomes the first choice approach in numerous experienced centers. Based on these favorable results, ministernotomy approach has also been proposed for complex cardiac procedures such as aortic root replacement and arch surgery. Herein, we present our technique for minimally invasive Bentall operation using a ministernotomy approach.

Keywords Aortic root surgery · Minimally invasive techniques · Bentall operation

Since its introduction, aortic root replacement using Bentall technique [1] has been proven to be a safe and effective technique and has been considered the "gold standard" in the surgical treatment of combined aortic valve and root pathologies [2–5]. As initially described by Bentall and De Bono, the classic approach for root replacement involved a longitudinal median sternotomy to expose the heart and the great vessels. However, over the last years, minimally invasive techniques have gained wider clinical application in cardiac surgery. In particular, minimally invasive aortic valve replacement (AVR), through ministernotomy (MS) or minithoracotomy, has gradually been recognized as a less traumatic approach compared to median sternotomy, becoming the first choice approach in several experienced centers [6]. The growing expertise in mini AVR techniques, coupled with increased patient demand for less invasive therapies, has motivated aortic surgeons to apply minimally invasive approach to more challenging procedures, such as aortic root replacement and arch surgery [7–12].

Herein, we present our technique for minimally invasive Bentall operation through MS approach.

✉ Paolo Berretta
p.berretta@icloud.com

[1] Cardiac Surgery Unit, Cardiovascular Department, Ospedali Riuniti, Politechnic University of Marche, Via Conca 71, 60126 Ancona, Italy

Published online: 02 April 2018

Surgical technique

Preoperative planning

Preoperative screening and planning do not considerably differ from the standard Bentall procedure through conventional median sternotomy. A careful review of contrast-enhanced three-dimensional computed tomography imaging is required to assess the anatomy of the aorta and the aortic valve morphology to evaluate the degree and sites of either atheromatous or calcific aortic wall disease, in order to plan the most appropriate surgical incision, cannulation strategy, and cross clamp site. Furthermore, in patients with severe chest wall deformities, a meticulous preoperative imaging assessment is mandatory to estimate safety and feasibility of the minimally invasive approach.

Patient setup

Operative setup is similar to conventional surgery. In addition to basic standard monitoring—ECG 12 leads, invasive blood pressure, central venous pressure, core temperature, SpO_2, end-tidal CO_2, urine output, intermittent arterial blood samples, and activated clotting time or hemostasis management system for heparin monitoring—just external defibrillator pads are required. Trans-esophageal echocardiography (TEE) probe is set up for intraoperative evaluation of aortic

root morphology and function and to detect any left ventricular distension during cardioplegia delivery or cardiopulmonary bypass (CPB) weaning, as well as to ensure complete deairing after aortic declamping.

Prior to skin incision, the jugular notch, the sternal midline (from the angle of Louis to just above the 4th intercostal space), and the xiphoid are marked (Fig. 1a) in order to facilitate surgical incision and accelerate conversion to full sternotomy in case of unexpected complications.

Operation

General anesthesia is applied according to the standard protocol used for mini AVR. Fentanyl (5 mcg/kg) and propofol 1% (1.5–2.5 mg/kg) are given for anesthesia induction, and a short-acting volatile agent (Sevoflorane) is used to maintain anesthesia before and after CPB. Cisatracurium (induction dose 0.15 mg/kg; maintenance dose 0.1–0.4 mg/kg) or rocuronium (induction dose 0.45–0.6 mg/kg; maintenance dose 0.1–0.2 mg/kg) is used for neuromuscular block.

A 5–6-cm midline skin incision is made from the sternomanubrial junction to just above the 4th intercostal space. Subcutaneous tissues are divided with the electrocautery. The right-side 4th intercostal space is identified and dissected close to the sternal edge to avoid injuries of the mammary pedicle. The center of the sternum and right interspace is scored using electrocautery. An upper "J" ministernotomy is performed using a conventional sternal saw from the notch to the selected intercostal space. Just before proceeding to sternotomy, the patient's lungs are deflated to avoid accidental pleura opening. Accurate sternal hemostasis is achieved using cautery and bone wax, in the usual fashion. A minimally invasive sternal retractor (Ultravision CT™ Retractor System, TeDan Surgical Innovations, Sugar Land, USA) is placed and opened up progressively to avoid sternal and costal fractures and to decrease postoperative pain. The brachiocephalic vein is identified and carefully mobilized, and the pericardium is opened longitudinally from the innominate vein to the lowest point visible caudally.

Six pericardial stay sutures are placed, as deep as possible, and the retractor is then repositioned over the pericardial edges to elevate the pericardium and anteriorize the ascending aorta. Yet, care must be taken in opening the retractor gradually by monitoring hemodynamics, as stretching excessively the pericardium up may reduce preload and cause hypotension. This occurrence can be easily managed by placing the operating table in Trendelenburg position (to increase venous return) and infusing intravenous fluid. The aortic root, the proximal arch, the right atrium, and the right superior pulmonary vein are adequately exposed, and systemic heparinization is achieved according to the individual patient's response to heparin estimated by the Hepcon/HMS system (Medtronic Inc., Minneapolis, USA). Two 3-0 polyester purse-string sutures for the aortic cannula are placed in the proximal arch (between the innominate artery and the left carotid artery) by applying downward traction via an Adson clamp placed on the aortic adventitia to improve exposure and facilitate cannulation maneuvers. This cannulation site is distal enough on the aorta to allow the placement of the cross clamp and resection of the whole aneurysm and proximal enough to achieve an easy and safe control in case of unexpected complications such as bleeding or aortic rupture/dissection. The aorta is carefully cannulated using a low profile cannula with a longer body (EOPA™ Arterial Cannula, Medtronic Inc., Minneapolis, USA) that allows for an easy insertion from a distance and provides an unencumbered operative field. A 4-0 polypropylene purse-string pledgeted suture is placed on the right atrial appendage, and a dual stage venous cannula (Mc2® venous

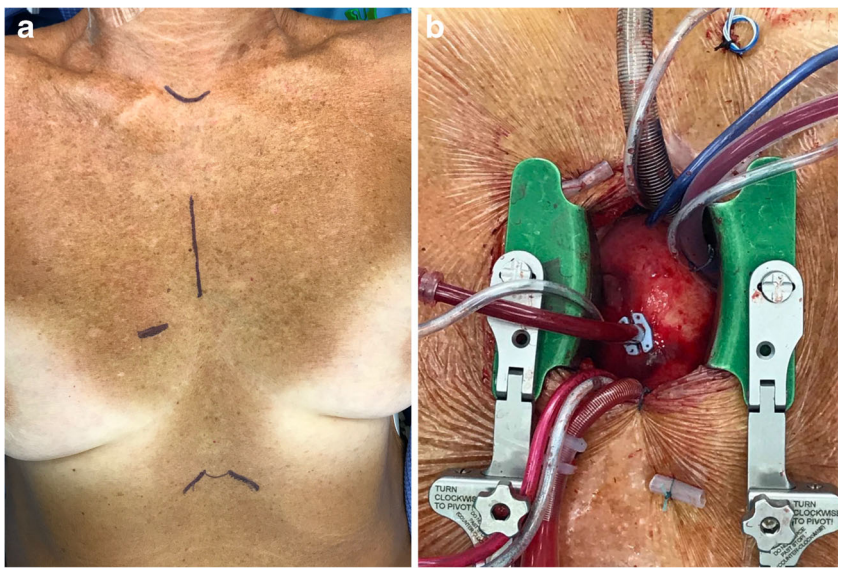

Fig. 1 **a** Operative setup. Prior to skin incision, the positions of the jugular notch, the sternal midline (from the angle of Louis to just above the 4th intercostal space), and the xiphoid are marked. **b** Cardiopulmonary bypass is established by means of standard central cannulation sites (proximal arch and right atrium)

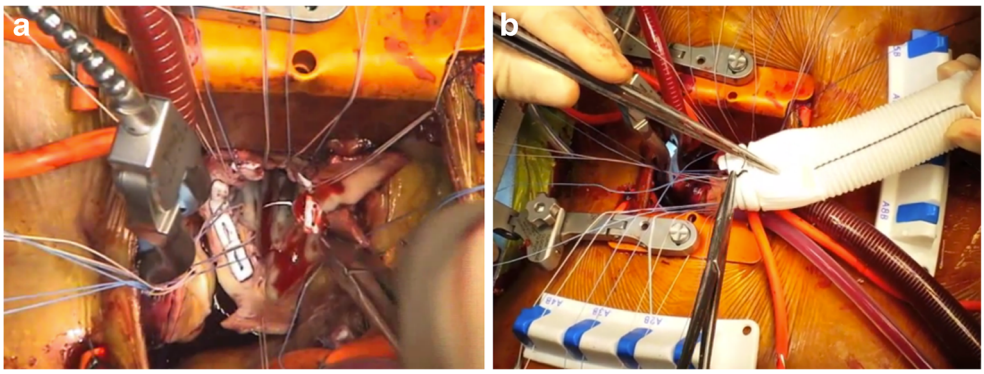

Fig. 2 Valve conduit implantation. The graft is sutured to the aortic annulus using 2-0 interrupted U-sutures with Teflon pledgets on the aortic side (**a**). The same stitches are then passed through the sewing ring of the composite graft (**b**)

cannula, Medtronic Inc., Minneapolis, USA) is positioned with the tip in the inferior vena cava. Standard central cannulation represents our first-choice technique for CPB institution because it avoids additional skin incisions and potential vascular and embolic complications that may be associated with peripheral cannulation [13]. Nevertheless, in patients with very large aneurysms, which virtually occupy the entire pericardial space and hamper a safe and well controllable access to the central cannulation sites, a femoral or axillary approach should be preferred.

The right superior pulmonary vein is cannulated (DLP® vent cannula, Medtronic Inc., Minneapolis, USA), through a 4-0 polypropylene pledgeted U-stitch, for left ventricle venting, in all cases. Normothermic CPB is started, using vacuum assisted drainage if necessary (Fig. 1b). With an empty heart, a 19 Fr subxiphoid spiral drain is placed, to continuously inflate carbon dioxide (CO_2) into the pericardial cavity. The same drain is used as a pericardial drain at the end of the procedure. Under a low-flow condition, an atraumatic minimally invasive clamp (Cygnet® Flexible Clamps, Vitalitec, Plymouth, USA) is applied across the distal ascending aorta. Cold crystalloid cardioplegia (Custodiol, Koehler Chemie, Alsbach-Haenlein, Germany) is delivered in antegrade fashion via the aortic root or directly into the coronary arteries in the presence of significant aortic regurgitation.

The aneurysm is opened three centimeters above the right coronary ostium, and the ascending aorta is completely transected keeping 2 cm of aortic tissue proximal to the cross clamp. This remnant aortic tissue will facilitate the distal anastomosis and improve hemostasis. Importantly, three 2-0 polyester traction sutures are placed on each commissure in order to optimize exposure of the aorta. The aortic root is extensively freed from the surrounding tissue with electrocautery, taking care to secure absolute hemostasis. Both coronary ostia are carefully prepared retaining a generous button of aortic wall and subsequently suspended by a 5-0 polypropylene suture passed through the top end of the coronary button flap to provide gentle traction. Full mobilization of the left coronary button from the surrounding tissues and from the right pulmonary artery is strongly recommended to prevent distortion and kinking of the coronary during the reattachment and reduce the tension of the anastomosis. The aortic sinuses are resected up to a rim of approximately 3–5 mm of the aortic wall. The aortic valve is removed and the annulus debrided. An appropriate mechanical or biological [14] valve conduit is selected by measuring the aortic annulus with a dedicated sizer. In this setting, using a conduit with a Dacron Valsalva graft (Vascutek Ltd., Renfrewshire, Scotland), which mimics aortic sinuses, can optimize coronary arteries perfusion and may help in performing a tension-free coronary artery reattachment by reducing the distance between the coronary ostia and the graft itself [15]. The valve conduit is sutured to the ventriculo-aortic junction using 2-0 polyester interrupted U-sutures with Teflon pledgets on the aortic side (Fig. 2a). Suture placement is started in the left coronary sinus and working clockwise. Pledgets are used to reduce the tension of the

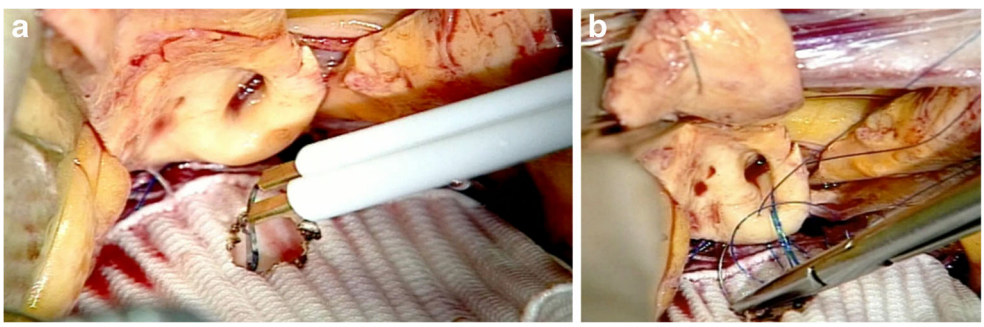

Fig. 3 Right coronary artery reimplantation. An appropriate hole for coronary button re-attachment is made in the Dacron graft (**a**), and a parachute anastomosis is performed with a 5/0 polypropylene running suture (**b**)

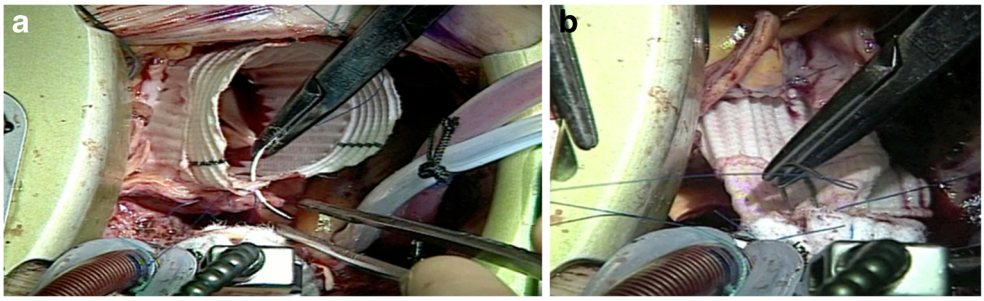

Fig. 4 The valve conduit is anastomosed to the distal aorta with a continuous 4-0 polypropylene running suture (**a**), incorporating an external Teflon felt strip, using parachute technique (**b**)

suture and to ensure a definitely hemostatic proximal suture line. Then, the same stitches are evenly distributed through the sewing ring of the composite graft (Fig. 2b). The conduit is parachuted to a subannular position, and the sutures are tied-down one by one and subsequently cut. A 4-0 polypropylene running suture is used to approximate the aortic remnant to the sewing ring of the composite graft in order to improve hemostasis [16]. Bites should not be too generous at the level of the left coronary annulus to avoid either tearing or rupture of the left ventricular outflow tract that may be very arduous to fix at this site once the cross-clamp is taken off.

A hole for left coronary button re-implantation is made in the Valsalva graft using battery-operated cautery (Fig. 3a). Appropriately sized opening assists in creating the anastomosis. The coronary button is trimmed, keeping a 2–3-mm aortic cuff, and a parachute anastomosis is performed with a 5/0 (or 6/0) polypropylene running suture. The right coronary artery is then re-attached in the same manner (Fig. 3b). The proper position (on the graft) for coronary re-attachment is marked with the heart entirely loaded. This maneuver allows for avoiding subsequently tension and/or rotation of the anastomosis. Proximal suture line and coronary reattachments are then verified by pressurizing the aortic root with cardioplegic infusion. Successively, suture lines are sealed by means of fibrin glue (Tisseel Baxter Healthcare Corp., Glendale, USA) to enhance hemostasis and tissue adhesion. [17]. The distal end of the Valsalva graft is shortened to approximate the distal end of the aorta and patient rewarming is begun. The valve conduit is sutured to the distal aorta with a continuous 4-0 polypropylene running suture, incorporating an external 4–5 mm Teflon felt strip, using parachute technique (Fig. 4a, b). The suture is adequately pulled with a hook. While Teflon felt strip is not essential routinely, in minimally invasive approach, it is strongly recommended to optimize hemostasis.

Before releasing the aortic clamp, two pacing wire electrodes are sutured to the right ventricle, the operating table is tilted, with the patient's head down, and CO_2 insufflation is discontinued. The graft is vented with a 21-gauge needle and the left ventricle meticulously de-aired by filling the heart and gently inflating the lungs. Perfusion flow rate is temporarily diminished as the aortic clamp is released. TEE is performed to prevent left ventricular over-distension and assess adequate de-airing and valve function. CPB is weaned off (Fig. 5), protamine given, and, once the hemostasis is satisfactory, the pericardium is closed above the graft and the innominate vein to enhance the safety of subsequent sternal re-opening. Finally, the sternum is closed with four single steel wires and absorbable sutures are used for closing subcutaneous tissue and the skin.

Indications and contraindications

All adult patients with combined severe aortic valve and root pathologies that require composite aortic root replacement [18] are eligible for mini Bentall operation. In our Institution, contraindications are as follows: (1) urgent and emergency surgery, (2) previous cardiac surgery, (3) severe chest wall deformities, (4) infective endocarditis, and (5) concomitant procedures (mitral surgery, coronary bypass surgery, etc.). In addition, mini Bentall procedure should be approached cautiously in patients with giant ascending aorta or root aneurysm.

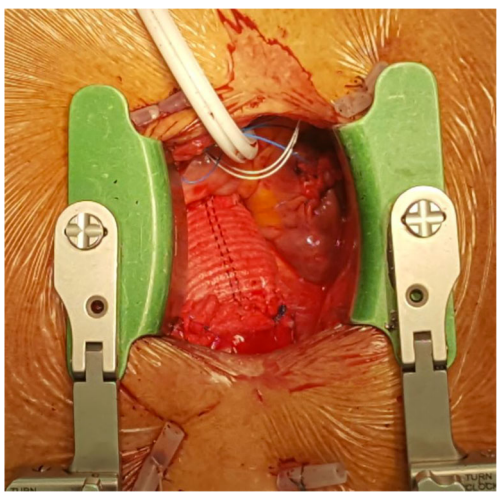

Fig. 5 Final result

Comment

Minimally invasive cardiac surgery has been increasingly accepted in the surgical community as a valid alternative to conventional full sternotomy, with benefits of decreased hospitalization, faster functional recovery, less blood transfusion, and wound/sternal complications. While MS is the most common approach for minimally invasive aortic valve replacement, it is yet an established approach for root surgery only in a few experienced centers [8, 9, 12, 19, 20]. However, MS approach is very similar to standard sternotomy and it provides good exposure of the entire proximal aorta, requiring no specialized techniques, equipment, and only a minimal learning curve. Indeed, as described above, mini Bentall operation is performed in the same manner as a standard sternotomy approach. Furthermore, MS allows for easy and safe conversion to full sternotomy in case of unexpected complications or unpredicted technical problems. Nevertheless, it must be stressed that a meticulous surgical technique to secure impeccable hemostasis is essential in minimally invasive root surgery.

Conclusions

Minimally invasive root replacement can be performed successfully without compromising the proven efficacy and safety of Bentall operation. However, further clinical trials with a large patient cohort are needed to evaluate the potential clinical benefits over conventional surgery.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Bentall H, De Bono A. A technique for complete replacement of the ascending aorta. Thorax. 1968;23:338–9.
2. Berretta P, Di Marco L, Pacini D, et al. Reoperations versus primary operation on the aortic root: a propensity score analysis. Eur J Cardiothorac Surg. 2016:ezw250.
3. Gleason TG, David TE, Coselli JS, Hammon JW Jr, Bavaria JE. St. Jude Medical Toronto biologic aortic root prosthesis: early FDA phase II IDE study results. Ann Thorac Surg. 2004;78:786–93.
4. Sioris T, David TE, Ivanov J, Armstrong S, Feindel CM. Clinical outcomes after separate and composite replacement of the aortic valve and ascending aorta. J Thorac Cardiovasc Surg. 2004;128:260–5.
5. Zehr KJ, Orszulak TA, Mullany CJ, Matloobi A, Daly RC, Dearani JA, et al. Surgery for aneurysms of the aortic root: a 30-year experience. Circulation. 2004;110:1364–71.
6. Nguyen TC, Terwelp MD, Thourani VH, Zhao Y, Ganim N, Hoffmann C, et al. Clinical trends in surgical, minimally invasive and transcatheter aortic valve replacement†. Eur J Cardiothorac Surg. 2017;51:1086–92.
7. Totaro P, Carlini S, Pozzi M, Pagani F, Zattera G, D'Armini AM, et al. Minimally invasive approach for complex cardiac surgery procedures. Ann Thorac Surg. 2009;88:462–6.
8. Tabata M, Khalpey Z, Aranki SF, Couper GS, Cohn LH, Shekar PS. Minimal access surgery of ascending and proximal arch of the aorta: a 9-year experience. Ann Thorac Surg. 2007;84:67–72.
9. Hillebrand J, Alshakaki M, Martens S, Scherer M. Minimally invasive aortic root replacement with valved conduits through partial upper sternotomy. Thorac Cardiovasc Surg. 2017; https://doi.org/10.1055/s-0037-1598196.
10. Shrestha M, Krueger H, Umminger J, Koigeldiyev N, Beckmann E, Haverich A, et al. Minimally invasive valve sparing aortic root replacement (David procedure) is safe. Ann Cardiothorac Surg. 2015;4:148–53.
11. Goebel N, Bonte D, Salehi-Gilani S, Nagib R, Ursulescu A, Franke UFW. Minimally invasive access aortic arch surgery. Innovations (Phila). 2017;12:351–5.
12. Deschka H, Erler S, Machner M, el-Ayoubi L, Alken A, Wimmer-Greinecker G. Surgery of the ascending aorta, root remodelling and aortic arch surgery with circulatory arrest through partial upper sternotomy: results of 50 consecutive cases. Eur J Cardiothorac Surg. 2013;43:580–4.
13. Benedetto U, Raja SG, Amrani M, et al. The impact of arterial cannulation strategy on operative outcomes in aortic surgery: evidence from a comprehensive meta-analysis of comparative studies on 4476 patients. J Thorac Cardiovasc Surg. 2014;148:2936–43.
14. Di Eusanio M, Murana G, Cefarelli M, Mazzola A, Di Bartolomeo R. The Bentall procedure with a biological valved conduit: substitute options and techniques. Multimed Man Cardiothorac Surg. 2014;2014
15. De Paulis R, De Matteis GM, Nardi P, Scaffa R, Colella DF, Chiarello L. A new aortic Dacron conduit for surgical treatment of aortic root pathology. Ital Heart J. 2000;1:457–63.
16. Copeland JG, Rosado LJ, Snyder SL. New technique for improving hemostasis in aortic root replacement with composite graft. Ann Thorac Surg. 1993;55:1027–9.
17. Rousou JA. Use of fibrin sealants in cardiovascular surgery: a systematic review. J Card Surg. 2013;28:238–47.
18. Erbel R, Aboyans V, Boileau C, et al. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J. 2014;35:2873–926.
19. Roselli EE. Interventions on the aortic valve and proximal thoracic aorta through a minimally invasive approach. Ann Cardiothorac Surg. 2015;4:81–4.
20. Wachter K, Franke UF, Yadav R, et al. Feasibility and clinical outcome after minimally invasive valve-sparing aortic root replacement. Interact Cardiovasc Thorac Surg. 2017;24:377–83.