12. Elkins RC, Lane MM, McCue C. Ross procedure for ascending aortic replacement. *Ann Thorac Surg.* 1999;67:1843-5; discussion 53-6.
13. Elkins RC, Lane MM, McCue C, Chandrasekaran K. Ross operation and aneurysm or dilation of the ascending aorta. *Semin Thorac Cardiovasc Surg.* 1999;11:50-4.
14. Luciani GB, Favaro A, Viscardi F, Bertolini P, Mazzucco A. Valve-sparing root replacement for pulmonary autograft dissection late after the Ross operation. *J Thorac Cardiovasc Surg.* 2004;128:753-6.
15. Kaya A, Heijmen RH, Vreuls W, Seldenrijk CA, Schepens MA. Chronic type A dissection in a pulmonary autograft. *J Heart Valve Dis.* 2007;16:162-4.
16. Brown JW, Ruzmetov M, Rodefeld MD, Mahomed Y, Turrentine MW. Incidence of and risk factors for pulmonary autograft dilation after Ross aortic valve replacement. *Ann Thorac Surg.* 2007;83:1781-7; discussion 7-9.
17. Brown JW, Fehrenbacher JW, Ruzmetov M, Shahriari A, Miller J, Turrentine MW. Ross root dilation in adult patients: is preoperative aortic insufficiency associated with increased late autograft reoperation? *Ann Thorac Surg.* 2011;92:74-81; discussion 81.
18. Sievers HH, Hanke T, Stierle U, Bechtel MF, Graf B, Robinson DR, et al. A critical reappraisal of the Ross operation: renaissance of the subcoronary implantation technique? *Circulation.* 2006;114:1504-11.
19. Charitos EI, Takkenberg JJ, Hanke T, Gorski A, Botha C, Franke U, et al. Reoperations on the pulmonary autograft and pulmonary homograft after the Ross procedure: an update on the German Dutch Ross Registry. *J Thorac Cardiovasc Surg.* 2012;144:813-21; discussion 21-3.
20. Stulak JM, Burkhart HM, Sundt TM 3rd, Connolly HM, Suri RM, Schaff HV, et al. Spectrum and outcome of reoperations after the Ross procedure. *Circulation.* 2010;122:1153-8.
21. David TE. Ross procedure at the crossroads. *Circulation.* 2009;119:207-9.
22. Elder RW, Quaegebeur JM, Bacha EA, Chen JM, Bournon F, Williams IA. Outcomes of the infant Ross procedure for congenital aortic stenosis followed into adolescence. *J Thorac Cardiovasc Surg.* 2013;145:1504-11.
23. Koul B, Al-Rashidi F, Bhat M, Meurling C. A modified Ross operation to prevent pulmonary autograft dilatation. *Eur J Cardiothorac Surg.* 2007;31:127-8.
24. Carrel T, Schwerzmann M, Eckstein F, Aymard T, Kadner A. Preliminary results following reinforcement of the pulmonary autograft to prevent dilatation after the Ross procedure. *J Thorac Cardiovasc Surg.* 2008;136:472-5.
25. Gebauer R, Cerny S. A modification of the Ross procedure to prevent pulmonary autograft dilatation. *Eur J Cardiothorac Surg.* 2009;36:195-7.
26. Bonhoeffer P, Boudjemline Y, Saliba Z, Hausse AO, Aggoun Y, Bonnet D, et al. Transcatheter implantation of a bovine valve in pulmonary position: a lamb study. *Circulation.* 2000;102:813-6.
27. Bini MND, Blackstone EH, Sievers H. *Kirklin/Barratt-Boyes Cardiac Surgery.* Vol 1. 2nd ed. London: Churchill Livingstone; 1993:34-5.
28. Vesely I, Casarotto DC, Gerosa G. Mechanics of cryopreserved aortic and pulmonary homografts. *J Heart Valve Dis.* 2000;9:27-37.
29. Hanke T, Stierle U, Boehm JO, Botha CA, Matthias Bechtel JF, Erasmi A, et al. Autograft regurgitation and aortic root dimensions after the Ross procedure: the German Ross Registry experience. *Circulation.* 2007;116:1251-8.
30. Horer J, Hanke T, Stierle U, Takkenberg JJ, Bogers AJ, Hemmer W, et al. Neo-aortic root diameters and aortic regurgitation in children after the Ross operation. *Ann Thorac Surg.* 2009;88:594-600; discussion 600.
31. Charitos EI, Hanke T, Stierle U, Robinson DR, Bogers AJ, Hemmer W, et al. Autograft reinforcement to preserve autograft function after the Ross procedure: a report from the German-Dutch Ross Registry. *Circulation.* 2009;120:S146-54.
32. Acar C, Varnous S. In response to Kazui T, Izumoto H, Yoshioka K, Kawazoe K. Dynamic morphologic changes in the normal aortic annulus during systole and diastole. *J Heart Valve Dis.* 2006;15:617-21, 843.
33. Nappi F, Spadaccio C, Castaldo C, Di Meglio F, Nurzynska D, Montagnani S, et al. Reinforcement of the pulmonary artery autograft with a polyglactin and polydioxanone mesh in the Ross operation: experimental study in growing lamb. *J Heart Valve Dis.* 2014;23:145-8.

EDITORIAL COMMENTARY

The continued evolution of a transformational operation: New options for wrapping the Ross autograft?

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See related article on pages 1134-42.

The Ross procedure for aortic valve replacement (AVR), first described by Donald Ross (Figure 1) in 1962¹ and formally performed by him in 1967, offers numerous

FIGURE 1. Donald Ross.

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advantages in terms of an autograft prosthesis with characteristics of freedom from late calcification and stenotic degeneration, low endocarditis risk, and the avoidance of anticoagulation. This option for AVR remains well accepted

in the pediatric population; however, it continues to be evaluated with controversy for use in adult patients. As such, it represents only 2% to 3% of AVR procedures performed worldwide.² Perhaps the most discussed concern regarding the pulmonary autograft is prosthesis dilation.

In this issue of the *Journal*, Nappi and colleagues³ present a valuable article focused on 2 objectives. First, they describe an experimental ovine model of the Ross operation. Second, they explore the efficacy of various synthetic absorbable and nonabsorbable compounds toward preventing pulmonary autograft dilation. In particular, this article is a continuation of previous work published by this group, which described the potential effectiveness of a resorbable reinforcement as an adjunct during the Ross procedure.⁴

The lack of any previously described models of autograft transposition and the overall need for a model that provides a reproducible platform to study various technical variations regarding autograft reinforcement lead to the most valuable components of the article. As with any animal model, limitations do exist. The lamb model described by Nappi and colleagues³ actually implants the harvested pulmonary autograft into the descending thoracic aorta through a left thoracotomy. As such, it does not have any component of coronary transfer and its associated technical impact on architectural changes within the sinuses of Valsalva. Nappi and colleagues³ attempt to address this limitation by creating full-thickness holes through the autograft and the reinforcement that is adherent to it to allow coronary reimplantation.

Challenges regarding length of follow-up preclude any animal model from allowing for a true understanding of surgical technical variations and their impact on long-term autograft architecture. Nappi and colleagues³ followed the lamb models for 6 months; they selected this period because most lambs reach full growth and size potential by this age. In addition, the group considered that by this time, any resorbable reinforcement would have undergone a complete resorption process. Unfortunately, many cases of autograft dilation occur further out than 6 months.

Finally, small sample sizes, as well as the lack of monitoring blood pressures and the associated inability to delineate the impact of antihypertensive agents on autograft dilation, limit the proposed animal model. Like all other limitations, these limitations are predictable, and although they create the ability to criticize the model, it would be unfortunate if they precluded the ability to find benefit in using such a strategy to investigate surgical technical modifications.

Ungerleider and colleagues⁵ have published work describing the value of wrapping the autograft in a nonabsorbable Dacron polyester fabric graft to prevent dilation.⁵ This article focuses on exploring the differences between

absorbable versus resorbable wrapping agents. The most powerful component of the groups work involves the echocardiographic and histopathologic examination of the autografts. This work allows Nappi and colleagues³ to extrapolate their findings toward findings that favor the use of resorbable wrapping materials.

In particular, bioresorbable materials appeared not only to prevent autograft dilation but also to interact with the living pulmonary artery tissue to induce a form of elastic remodeling of the vessel wall, which was thought to influence the hemodynamic function and ability of the autograft to manage a systemic pressure load. This remodeling process was thought to result in a thicker and stronger neovessel, which was demonstrated by not only the absence of aneurysmal degeneration but also a histologic finding of elastin reorganization.

The histoarchitectural rearrangement of the pulmonary autograft resembled that of the native aorta, with medial thickening and elastic remodeling in absence of a clear inflammatory reaction. Nappi and colleagues³ hypothesized that the use of a synthetic reinforcement material, as has been proposed by several authors to minimize dilation, may in fact compromise tissue viability as the result of a foreign-body reaction and associated inflammatory process.

The creation of animal models to evaluate the impact of technical strategies on anatomic, hemodynamic, and physiologic outcomes is often the foundation for evaluating new surgical strategies. These models are challenging to perfect and indeed are often judged with much critique. Although the model proposed by Nappi and colleagues³ has several limitations, it does provide a valuable mechanism by which to evaluate various surgical techniques used at the time of pulmonary autograft implantation to minimize prosthetic dilation. Continued refinement of the model and further investigations into technical options at the time of the Ross operation may not only diminish concerns for autograft dilation but also allow for a renewed evaluation by our surgical community regarding the potential value of this option for AVR.

References

1. Ross D. Homograft replacement of the aortic valve. *Lancet*. 1962;2:487.
2. Kalfa D, Mohammadi S, Kalavrouziotis D, Kharroubi M, Doyle D, Marzouk M, et al. Long-term outcomes of the Ross procedure in adults with severe aortic stenosis: single-centre experience with 20 years of follow-up. *Eur J Cardiothorac Surg*. 2015;47:159-67.
3. Nappi F, Spadaccio C, Fouret P, Hammoudi N, Chachques JC, Chello M, Acar C. An experimental model of the Ross operation: Development of resorbable reinforcements for pulmonary autografts. *J Thorac Cardiovasc Surg*. 2015;149:1134-42.
4. Nappi F, Spadaccio C, Castaldo C, Di Meglio F, Nurzynska D, Montagnani S, et al. Reinforcement of the pulmonary artery autograft with a polyglactin and polydioxanone mesh in the Ross operation: experimental study in growing lamb. *J Heart Valve Dis*. 2014;23:145-8.
5. Ungerleider RM, Ootaki Y, Shen I, Welke KF. Modified Ross procedure to prevent autograft dilation. *Ann Thorac Surg*. 2010;90:1035-7.