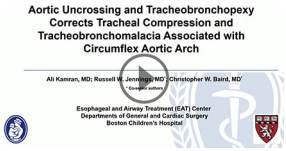
This study is the largest review of aortic uncrossing in the literature and highlights the use of regional perfusion to avoid circulatory arrest and includes tracheobronchopexy and airway reconstruction procedures as needed to optimize airway outcomes. Given the complexity of this patient population, treatment and long-term follow-up is best done in multidisciplinary specialized centers for individualized patient care. This study is limited by the single-center, retrospective nature of the work and the relatively short-term and variable follow-up intervals. Further studies to follow long-term outcomes are certainly warranted and are ongoing.

CONCLUSIONS

Aortic uncrossing is indicated for patients with a circumflex aortic arch who require the aorta reposition to relieve symptomatic airway compression. The aortic uncrossing procedure can be performed safely in patients of all ages without circulatory arrest. Concomitant procedures addressing the residual TBM and/or tracheal cartilage deformation may also be required to optimally open the airways.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://aats.blob.core.windows.net/media/19%20AM/Saturday_May4/202BD/202BD/S35%20-%20Airway%20Surgery%20in%20Children/S35_6_webcast_024452252.mp4.



Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Planche C, Lacour-Gayet F. Aortic uncrossing for compressive circumflex aorta: 3 cases. *Presse Med*. 1984;13:1331-2.
2. Russell HM, Rastatter JC, Backer CL. Aortic uncrossing procedure for circumflex aorta. *Oper Tech Thorac Cardiovasc Surg*. 2013;18:15-31.
3. Backer CL, Mongé MC, Russell HM, Popescu AR, Rastatter JC, Costello JM. Reoperation after vascular ring repair. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2014;17:48-55.
4. Fraga JC, Calkoen EE, Gabra HOS, McLaren CA, Roebuck DJ, Elliott MJ. Aortopexy for persistent tracheal obstruction after double aortic arch repair. *J Pediatr Surg*. 2009;44:1454-7.
5. Bairdain S, Smithers CJ, Hamilton TE, Zurakowski D, Rhein L, Foker JE, et al. Direct tracheobronchopexy to correct airway collapse due to severe tracheobronchomalacia: short-term outcomes in a series of 20 patients. *J Pediatr Surg*. 2015;50:972-7.
6. Shieh HF, Smithers CJ, Hamilton TE, Zurakowski D, Rhein LM, Manfredi MA, et al. Posterior tracheopexy for severe tracheomalacia. *J Pediatr Surg*. 2017;52:951-5.
7. Ngerncham M, Lee EY, Zurakowski D, Tracy DA, Jennings R. Tracheobronchomalacia in pediatric patients with esophageal atresia: comparison of diagnostic laryngoscopy/bronchoscopy and dynamic airway multidetector computed tomography. *J Pediatr Surg*. 2015;50:402-7.
8. Torre M, Carlucci M, Speggiorin S, Elliott MJ. Aortopexy for the treatment of tracheomalacia in children: review of the literature. *Ital J Pediatr*. 2012;38:62.
9. Weber TR, Keller MS, Fiore A. Aortic suspension (aortopexy) for severe tracheomalacia in infants and children. *Am J Surg*. 2002;184:573-7.
10. Mitchell ME, Rumman N, Chun RH, Rao A, Martin T, Beste DJ, et al. Anterior tracheal suspension for tracheobronchomalacia in infants and children. *Ann Thorac Surg*. 2014;98:1246-53.
11. Lee S-Y, Kim S-J, Baek J-S, Kwak J-G, Lee C, Lee C-H, et al. Outcomes of aortopexy for patients with congenital heart disease. *Pediatr Cardiol*. 2013;34:1469-75.
12. Bairdain S, Zurakowski D, Baird CW, Jennings RW. Surgical treatment of tracheobronchomalacia: a novel approach. *Paediatr Respir Rev*. 2016;19:16-20.
13. Peng E, McAllister K, Walker A, Savage T, Hunter L. Surgical approach for hypoplastic mirror circumflex aortic arch. *Ann Thorac Surg*. 2019;107:e313-5.
14. Svetanoff WJ, Zendejas B, Smithers CJ, Prabhu SP, Baird CW, Jennings RW, et al. Great vessel anomalies and their impact on the surgical treatment of tracheobronchomalacia. *J Pediatr Surg*. August 6, 2019 [Epub ahead of print].
15. Herrin MA, Zurakowski D, Fynn-Thompson F, Baird CW, Del Nido PJ, Emani SM. Outcomes following thoracotomy or thoracoscopic vascular ring division in children and young adults. *J Thorac Cardiovasc Surg*. 2017;154:607-15.
16. Humphrey C, Duncan K, Fletcher S. Decade of experience with vascular rings at a single institution. *Pediatrics*. 2006;117:e903-8.
17. Woods RK, Sharp RJ, Holcomb GW. Vascular anomalies and tracheoesophageal compression: a single institution's 25-year experience. *Ann Thorac Surg*. 2001;72:434-9.
18. Backer CL, Mongé MC, Popescu AR, Eltayeb OM, Rastatter JC, Rigsby CK. Vascular rings. *Semin Pediatr Surg*. 2016;25:165-75.

Key Words: circumflex aorta, aortic uncrossing procedure, airway compression, tracheobronchomalacia (TBM), tracheobronchopexy

Discussion

Presenter: Dr Ali Kamran

Carl L. Backer *(Chicago, Ill)*. Very nice presentation; thank you. Among the take-away messages here is that preoperative imaging is so very important. A circumflex aorta is a much more complicated vascular ring than a so-called simple right aortic arch. Dividing the ligamentum in a patient with a circumflex aorta will not necessarily resolve the patient's symptoms. When the aorta crosses posteriorly above the carina, you need to consider the aortic uncrossing operation.

Our results are similar to yours, but our operative strategy was different. All of our aortic uncrossings have been done under deep hypothermic circulatory arrest, which I think

facilitates the operation. How do you do regional cerebral perfusion when you have 4 separate arch vessels; in other words, you don't have an innominate artery. Do you just cannulate a carotid artery?

Dr Ali Kamran *(Boston, Mass)*. The cannulation was on the ascending aorta at the take-off of the innominate or the right subclavian artery.

Dr Backer. So you cannulate both the right subclavian artery and the right carotid artery separately?

Dr Kamran. No.

Dr Christopher W. Baird *(Boston, Mass)*. So for all of these patients, we cannulated the aorta at the base or the take-off of the innominate artery.

Dr Backer. Some of these patients don't have an innominate artery because they've got 4 separate vessels coming out of the arch.

Dr Baird. Yes, but usually, at least in our experience, if you cannulate the distal ascending aorta, we can divide just below the take-off of the right subclavian. So in our experience, it really hasn't mattered; you just cannulate as distal in the ascending aorta as you can and you're going to perfuse all of the head vessels. The caveat to that is that if you have an aberrant right subclavian artery.

Dr Backer. Correct, most of my patients have had an aberrant.

Dr Baird. Then your right subclavian is going to come off more distal. And then in that case, we had I think 1 in this series, we divided the subclavian artery and reimplanted it in the innominate artery. So for the most part, we didn't have a problem with perfusion. Another option is to just divide the aorta a little farther distal beyond the subclavian.

Dr Backer. The other issue is whether you really need to do the tracheopexy. In our 8 patients, there was only 1 patient who may have benefited from this. He came to me with a tracheostomy after 2 previous operations and stayed in the hospital for 30 days before we finally sent him home. All of our other patients have been extubated and gone home within about 6 to 8 days, and we haven't had a problem with tracheomalacia. We also do a preoperative bronchoscopy on all our patients. With many of them, we've done postoperative imaging and postoperative bronchoscopies and the area of compression definitely improves. They get discharged without symptoms. So I don't know if we have 2 different populations, or how to explain that.

Dr Baird. Yes. I suspect that is it. We don't advocate doing the uncrossing operation if there are no tracheal symptoms preoperatively—so I think that's first and foremost. We do intraoperative bronchoscopy. We also do a study in which you put negative pressure on the airway to see how much collapse there is. But I think the most important thing is, we try to evaluate the symptoms preoperatively. If the airway is not involved, it may not require tracheal intervention. So we're not advocating for a tracheopexy in every patient who gets an uncrossing operation. However, if the trachea is involved, at least in our experience, it has been.

Dr Backer. I think in our series, there was probably just 1 patient who would have benefited from that. Final question: You have 2 patients with bilateral recurrent laryngeal nerve injuries. We had 1 in our series who had temporary bilateral recurrent laryngeal nerve palsy. Have you done anything differently since these 2 patients?

Dr Baird. Yes. That was probably related to being too aggressive with electrocautery. The left recurrent nerve is quite easy and obvious to see—whereas the right is sometimes a little bit higher and more difficult to see. There has been some suggestion about using a different type of cautery such as bipolar; however, I'm not sure if that's necessary. But clearly, we were very aggressive on the mobilization before. Now we have toned down the aggressiveness with electrocautery. We have also recently employed the use of a nerve stimulator/monitor.

Dr Backer. I think this is something you really have to pay attention to, and even though we probably both pay attention to it, you have to be really careful. Thanks for a nice presentation.

Dr Petros V. Anagnostopoulos *(Madison, Wis)*. Chris, do you guys do the tracheopexy through the sternotomy and the esophageal? Dissection through the sternotomy?

Dr Baird. Yes, actually most of that part is pretty straightforward through the sternotomy. Once you divide the aorta and pull it under the trachea—and again, I can't emphasize enough the benefit of Dr Jennings' experience with the esophagus; I don't have to worry about how aggressive I can be; he can manhandle the esophagus, for lack of a better way to put it, and it does okay. So once we get the esophagus out of the way, it gives us complete access to the spine and the posterior trachea. It is a little tricky, because you're trying to look down and around, under and up on the airway. That's where the intraoperative bronchoscopy helps. So actually, you're putting the stitches in, but looking at the bronchoscopy images on the screen to determine exactly where they go.

Dr Anagnostopoulos. I would imagine the double row of stitches, the left side of sutures, are difficult to see, right?

Dr Baird. Yes, it's often very hard to gauge how far left or right you are.