Clinical outcomes of prophylactic Damus-Kaye-Stansel anastomosis concomitant with bidirectional Glenn procedure

Masatoshi Shimada, MD,[a] Takaya Hoashi, MD,[a] Koji Kagisaki, MD,[a] Isao Shiraishi, MD,[b] Toshikatsu Yagihara, MD,[a] and Hajime Ichikawa, MD[a]

Objective: We evaluated prophylactic Damus-Kaye-Stansel (DKS) anastomosis in association with the timing of a bidirectional Glenn (BDG) procedure as second-stage palliation aiming at Fontan completion to prevent late systemic ventricular outflow tract obstruction.

Methods: Between 1996 and 2005, 25 patients (14 boys; median age, 12 months) underwent a BDG procedure concomitant with DKS anastomosis. All had a systemic ventricular outflow tract through an intraventricular communication or morphologically developed subaortic conus and had previously undergone pulmonary artery banding. Enlargement of intraventricular communication and/or resection of a subaortic conus were not performed before or during the operation.

Results: Twenty-one (84%) patients subsequently underwent a Fontan operation, with a follow-up period of 6.8 ± 1.9 years (range, 4-11 years), with no mortalities after the Fontan operation. Cardiac catheterization showed that systemic ventricular end-diastolic volume was significantly decreased from 187% ± 74% of normal before BDG to 139% ± 35% after ($P = .038$) and to 73% ± 14% at 4.3 years after the Fontan operation ($P < .001$). However, the pressure gradient across the systemic ventricular outflow tract remained at 0.5 ± 0.8 mm Hg after DKS anastomosis and 0.6 ± 2.3 mm Hg at 4.6 years after the Fontan operation. None of the patients showed more than moderate aortic or neoaortic regurgitation, except 1 who progressed to pulmonary regurgitation after DKS anastomosis and required a reoperation for a systemic ventricular outflow tract. No anatomic properties affected late neoaortic valve function.

Conclusions: Regardless of a significant reduction in systemic ventricular volume, DKS anastomosis concomitant with a BDG procedure shows promise for a nonobstructive systemic ventricular outflow tract after a Fontan operation. (J Thorac Cardiovasc Surg 2012;143:137-43)

Supplemental material is available online.

In patients with a functionally single ventricle and specific anatomic properties, systemic ventricular outflow tract obstruction (SVOTO) can progress after reduction of systemic ventricular volume during staging for a Fontan strategy, resulting in an increase in systemic ventricular end-diastolic pressure and failure of Fontan circulation.[1] One possible anatomic group has a systemic ventricular outflow tract (SVOT) through an intraventricular communication such as a ventricular septal defect (VSD) or bulboventricular foramen (BVF), whereas another has a morphologically developed subaortic conus.

Representative surgical options for management of SVOTO are BVF/VSD enlargement and subaortic conus resection. However, those procedures may cause surgical heart block, ventricular dysfunction, and recurrent stenosis. Another option is application of a so-called Damus-Kaye-Stansel (DKS) anastomosis,[2-4] for which several technical modifications have been reported. The basic concept of these methods is use of both outflow tracts as a single systemic outflow by anastomosis between the main pulmonary trunk and ascending aorta.[5]

The midterm to long-term efficacy of DKS anastomosis is now widely recognized[6-9]; thus, the next issue is determination of optimal operative timing and anatomic indications. Since 1996, we have performed prophylactic DKS anastomosis concomitant with a bidirectional Glenn (BDG) procedure as a second-stage palliation procedure as part of a staging Fontan strategy to prevent late SVOTO. The purpose of the present study was to evaluate the clinical outcomes of DKS anastomosis performed concomitant with a BDG procedure.

PATIENTS AND METHODS

Patients

Between 1996 and 2005, 142 patients with a functionally single ventricle underwent a BDG procedure at our institution. Of those, 25 (14 boys

From the Departments of Pediatric Cardiovascular Surgery[a] and Pediatric Cardiology,[b] National Cerebral and Cardiovascular Center, Suita, Japan.

Disclosures: Authors have nothing to disclose with regard to commercial support.

Read at the 91st Annual Meeting of The American Association for Thoracic Surgery, Philadelphia, Pennsylvania, May 7–11, 2011.

Received for publication May 8, 2011; revisions received July 13, 2011; accepted for publication Sept 15, 2011; available ahead of print Oct 13, 2011.

Address for reprints: Takaya Hoashi, MD, PhD, 5-7-1 Fujishiro-dai, Suita, Osaka, Japan 565-0873 (E-mail: thoashi@surg1.med.osaka-u.ac.jp).

0022-5223/$36.00

doi:10.1016/j.jtcvs.2011.09.009

Abbreviations and Acronyms

BDG = bidirectional Glenn
BVF = bulboventricular foramen
DKS = Damus-Kaye-Stansel
PA = pulmonary artery
SVOT = systemic ventricular outflow tract
SVOTO = systemic ventricular outflow tract obstruction
%VOT = ventricular outflow tract indexed by the normal value
VSD = ventricular septal defect

and 11 girls) underwent concomitant DKS anastomosis in a side-by-side fashion and were followed up for more than 5 years (Table 1). The median age and body weight at the operation were 12 months old (range, 5-120 months) and 7.6 kg (range, 3.8-27.5 kg), respectively. This study was approved by the National Cerebral and Cardiovascular Center Institutional Review Board.

All patients underwent pulmonary artery (PA) banding to regulate pulmonary high blood flow before the BDG procedure. Banding tape was placed just below the pulmonary bifurcation during PA banding to avoid injury to the pulmonary valve. Including these 25 patients, a total of 47 patients underwent PA banding for single-ventricle physiology during the same period. Four of 22 patients, including 3 with atrial isomerism and total anomalous pulmonary venous connection, died before the second-stage BDG. In the remaining 18 patients, SVOTO did not develop during the study period.

Eleven of 25 patients had previously undergone repair of coarctation of the aorta or an interrupted aortic arch. No patients underwent enlargement of the VSD or BVF nor subaortic conus resection before or during the operation. Since 2003, we have been anastomosing a very short expanded polytetrafluoroethylene tube to the inferior wall of the right and/or left PA for use as a "pouch" as preparation for a subsequent Fontan operation without cardiopulmonary bypass.[10]

Anatomic Properties for Prophylactic DKS Procedure

On the basis of our institutional experience and previous reports, we identified 2 anatomic properties to designate patients at high risk for SVOTO during staging for a Fontan strategy or after Fontan completion (Table 2). The first group of patients had a SVOT through the VSD or BVF. In these, the aorta usually arises from a rudimentary or hypoplastic ventricle (Figure E1, *A*). The second group had a morphologically developed subaortic conus (Figure E1, *B*).

Operative Procedures

All patients underwent DKS in a side-by-side fashion without additional patch materials to augment the anastomosis.[5,7] In brief, the proximal great arteries were transected at the level of the PA band above the sinuses. The facing walls of the proximal great arteries were incised in a V shape and then anastomosed, after which end-to-end anastomosis of the distal ascending aorta was performed and a ventricular outlet created.

In the past, we performed end-to-side anastomosis in some patients, although semilunar valve dysfunction sometimes occurred owing to enlargement of the sinus of Valsalva, which might be caused by turbulent flow and distortion of the sinus itself. Now, we use a side-by-side anastomosis to maintain the shape of the native sinus of Valsalva and obtain a straight blood flow stream to preserve the function of the semilunar valve.[11]

TABLE 1. Patient characteristics

Male/female (n)	14:11
Age (mo) at operation, median (range)	12 (5-120)
Body weight (kg) at operation, median (range)	7.6 (3.8-27.5)
Previous PA banding (n)	25/25
Previous CoA/IAA repair (n)	11/25
Method of BDG (n)	
BDG	21
Bilateral BDG	3
Total cavopulmonary shunt (Kawashima)	1
Concomitant procedures (n)	
ASD creation/enlargement	17
PA plasty	12
Atrioventricular valve repair	6
Placement of PA pouch	6
VSD/BFV enlargement	0
Subaortic conus resection	0

PA, Pulmonary artery; *CoA,* coarctation of the aorta; *IAA,* interrupted aortic arch; *BDG,* bidirectional Glenn procedure; *ASD,* atrial septal defect; *VSD,* ventricular septal defect; *BVF,* bulboventricular foramen.

Study Method

We retrospectively evaluated patient records, as well as catheter and echocardiography reports, in regard to the following variables: (1) overall results: cumulative survival, rate of Fontan completion, and freedom from reoperation for SVOTO; (2) serial changes in systemic ventricular end-diastolic pressure and percentage of normal systemic ventricular end-diastolic volume measured by a catheter examination before and after BDG with DKS and 4.3 ± 1.5 years after the Fontan operation; and (3) postoperative semilunar valve function estimated by echocardiographic findings obtained at 5.0 ± 1.3 years after the Fontan operation.

Statistical Analysis

Data are expressed as the mean ± standard deviation or the median (range), as appropriate, and were analyzed using SPSS software (SPSS Institute, Inc, Chicago, Ill). Actuarial survival and freedom from reoperation for SVOTO were estimated using the Kaplan-Meier method.

TABLE 2. Anatomic indications

	No.
A. SVOT through VSD/BVF	
1. TA or severe TS with VA discordant	5
2. MA or severe MS with normal AV and VA connection	1
3. DILV with rudimentary RV and VA discordant	3
4. Hypoplastic LV with VA concordant	4
5. DORV or VA discordant and balanced two ventricles with unsuitable VSD(s) for biventricular repair	4
B. Morphologically developed subaortic conus	
1. MA and DORV	4
2. DIRV with rudimentary LV and DORV	3
3. DORV with hypoplastic LV	1

SVOT, Systemic ventricular outflow tract; *VSD,* ventricular septal defect; *BVF,* bulboventricular foramen; *TA,* tricuspid atresia; *TS,* tricuspid stenosis; *VA,* ventriculoatrial; *MA,* mitral atresia; *MS,* mitral stenosis; *AV,* atrioventricular; *DILV,* double-inlet left ventricle; *RV,* right ventricle; *LV,* left ventricle; *DORV,* double-outlet right ventricle; *VSD,* ventricular septal defect.