OBJECTIVES
To determine rates of reintervention after repair of common arterial trunk in the neonatal and early infant periods.

BACKGROUND
With improving success in the early treatment of common arterial trunk, the need for reinterventional procedures in older children, adolescents and adults will become an increasingly widespread concern in the treatment of these patients.

METHODS
We reviewed our experience with 159 infants younger than four months of age who underwent complete primary repair of common arterial trunk at our institution from 1975 to 1998, with a focus on postoperative reinterventions.

RESULTS
Of 128 early survivors, 40 underwent early reinterventions for persistent mediastinal bleeding or other reasons. During a median follow-up of 98 months (range, 2 to 235 months), 121 reinterventions were performed in 81 patients. Actuarial freedom from reintervention was 50% at four years, and freedom from a second reintervention was 75% at 11 years. A total of 92 conduit reinterventions were performed in 75 patients, with a single reintervention in 61 patients, 2 reinterventions in 11 patients and 3 reinterventions in 3 patients. Freedom from a first conduit reintervention was 45% at five years. The only independent variable predictive of a longer time to first conduit replacement was use of an allograft conduit at the original repair ($p < 0.05$), despite the significantly younger age of patients receiving an allograft conduit ($p = 0.001$). Reintervention on the truncal valve was performed on 22 occasions in 19 patients, including 21 valve replacements in 18 patients and repair in 1, with a freedom from truncal valve reintervention of 83% at 10 years. Surgical ($n = 29$) or balloon ($n = 12$) reintervention for pulmonary artery stenosis was performed 41 times in 32 patients. Closure of a residual ventricular septal defect was required in 13 patients, all of whom underwent closure originally with a continuous suture technique. Eight of 16 late deaths were related to reintervention.

CONCLUSIONS
The burden of reintervention after repair of common arterial trunk in early infancy is high. Although conduit reintervention is inevitable, efforts should be made at the time of the initial repair to minimize factors leading to reintervention, including prevention of branch pulmonary artery stenosis and residual interventricular communications. (J Am Coll Cardiol 2000;35:1317–22) © 2000 by the American College of Cardiology

Over the past 30 years, the prognosis of patients born with a common arterial trunk (truncus arteriosus) has improved dramatically. Advances in surgical and medical management have transformed this condition from a disease that was fatal early in life in >50% patients to one in which neonatal repair is routine and carries a mortality of around 5% (1–11). As with many other complex congenital cardiovascular anomalies, our increasing success with early management and repair will force us more than ever to confront the exigencies of caring for a population of older children, adolescents and adults with postoperative congenital heart disease. With anatomic repair of functionally biventricular heart defects, late mortality appears to be low. The more pervasive concerns with these patients relate to their functional status and need for reinterventions. After early repair of anomalies in which an extracardiac right ventricle to pulmonary artery conduit is employed, as with common arterial trunk, patients will almost universally require removal and replacement of the conduit, as somatic growth renders the nonviable conduit inadequate to support pulmonary outflow without placing an excessive load on the right ventricle. Moreover, the tendency of the leaflets in bioprosthetic valves to deteriorate often results in free regurgitation and consequently a substantial volume load on the ventricle as well.

Early repair of common arterial trunk has been performed at our institution for 25 years. In the present report, we
show the patterns of early and late reintervention among infants who underwent complete primary repair of common arterial trunk before four months of age.

METHODS

Patients. Between 1975 and 1998, 159 infants younger than four months of age underwent complete primary repair of common arterial trunk at the University of California, San Francisco Medical Center. Some of these patients have been included in prior reports (3,12,13). The median age at surgery was 61 days (range, 2 to 121 days), with 42 patients younger than 1 month. The median weight was 3.5 kg (range, 2.1 to 6.1 kg). In most patients (all but three), the pulmonary arteries arose from the common arterial trunk either as a single artery that divided at or soon after its origin, or as separate left and right branches from the posterior, posterolateral or lateral aspect of the trunk. The other three patients had origin of one branch pulmonary artery from the common trunk while the other arose from the underside of the aortic arch. In 10 patients, there was concomitant interruption of the aortic arch with a widely patent arterial duct providing flow to the descending aorta. Prior palliation of the interrupted arch had been performed in two patients, both of whom had a tube graft from the common trunk to the descending aorta, with ligation of the arterial duct.

Operative procedures. Techniques of repair evolved over the course of our experience, but in all patients consisted of the standard components of complete correction, including separation of the pulmonary arteries from the common trunk, closure of the ventricular septal defect (VSD) through an incision in the right ventricular infundibulum and reconstruction of right ventricle to pulmonary arterial continuity with a valved conduit. Repair was performed on cardiopulmonary bypass in all patients. For reconstruction of right ventricle to pulmonary arterial continuity, a xenograft valve housed in a synthetic conduit was used almost exclusively from 1975 to 1986, while valved allograft conduits were used in all patients undergoing surgery from 1987 to 1998. Xenograft valves were placed in 98 patients and cryopreserved valved allografts were used in the other 61. Of the allograft conduits, 44 were of aortic origin and 17 were of pulmonary arterial. Patients who received allograft conduits were significantly younger than those who received xenograft conduits (74 ± 25 vs. 39 ± 34 days, p < 0.001). The median diameter of the implanted valve was 12 mm (range, 9 to 20 mm).

From 1975 to 1989, the VSD was closed with a continuous suture technique. From 1990 onward, an interrupted suture technique was employed. A variety of patch materials were used for closure of the defect over the course of the experience.

Additional lesions were repaired as indicated, including repair of an interrupted aortic arch in 8 patients and replacement (n = 6) or repair (n = 5) of a moderately or severely regurgitant truncal valve in 11.

Data analysis. Preoperative and perioperative data were collected on retrospective review of patient records. Cross-sectional follow-up was carried out by means of physician and/or patient contact, and was completed by July 1999. Results classified as “early” are those that occurred before hospital discharge or within 30 days of surgery if the patient was discharged from the hospital before this duration. Specific software SPSS for Windows version 7 (SPSS Inc.; Chicago, Illinois) was used to perform statistical calculations. Data are expressed as median and range. Chi-square analysis was used to compare dichotomous variables. Non-parametric analysis involving ordinal variables was conducted with the Wilcoxon signed-rank test. Independent samples t test was used for comparison of mean values between dichotomous groups. Kaplan-Meier and Cox proportional hazards models were used for actuarial survival analysis and analysis of freedom from reinterventions. For actuarial analysis of freedom from reinterventions, patients were censored at the time of death or most recent follow-up.

RESULTS

Early outcomes and reinterventions. There were 128 early survivors (75%). Forty of these patients (31%) underwent early reoperations, including 35 reoperations for bleeding and 5 for other reasons (not including delayed sternal closure). These included placement of a permanent epicardial pacemaker in two patients, surgical reexploration for ventricular dysfunction in two patients and replacement of a failed conduit in one patient. The rate of reoperation for bleeding was significantly higher before 1985 than after (p = 0.01), and the rate of other reinterventions was higher among infants younger than one month of age than older patients (p = 0.01).

Late outcomes and reinterventions. Cross-sectional follow-up was obtained at a median of 98 months postoperatively (range, 2 to 235 months), and was complete in all but seven patients who were unavailable for follow-up. During this time, there were 16 confirmed late deaths, 8 of which were directly related to reinterventions. Four patients died in the early postoperative period after conduit reinterventions, two following truncal valve replacement and two after closure of residual VSDs (details summarized in the following section).

All reinterventions. During the follow-up period, a total of 121 reinterventions was performed in 81 patients. In some cases, multiple procedures were performed at the time
of reintervention (e.g., closure of a residual VSD at the time of conduit replacement), so the total number of patients and reintervention procedures listed below will not total to 81 and 121, respectively. A single reintervention was carried out in 53 patients, while 23 patients had 2 reinterventions, 5 had 3 and 2 had more than 3. Actuarial freedom from first, second and third reinterventions is depicted in Figure 1.

**Conduit reinterventions.** A total of 92 conduit-related reinterventions were performed in 75 patients, with a single reintervention in 61 patients, 2 reinterventions in 11 and 3 reinterventions in 3. At the time of the first conduit reintervention, the median pressure gradient from the right ventricle to the pulmonary artery was 55 mm Hg (15 to 110 mm Hg). Reintervention consisted of removal of the previous conduit and replacement with an allograft-valved conduit in 57 of the 92 cases, with a xenograft-valved conduit in 11 and with a nonvalved synthetic tube in 15. In five cases, the conduit was augmented surgically with a patch, and in four cases percutaneous balloon dilation was performed. In seven patients, the conduit replacement included resection of a pseudoaneurysm of the existing conduit, which was an allograft in six cases (aortic = 4, pulmonary = 2). Actuarial freedom from first, second and third conduit reinterventions is depicted in Figure 2. The only independent variable significantly associated with a longer time to first conduit replacement was use of an allograft conduit at the original repair ($p = 0.05$, Fig. 2), despite the significantly younger age of patients receiving an allograft conduit. Four patients (39 to 82 days of age at initial repair) died following conduit replacement, performed from 11 to 139 months after repair of common arterial trunk. One of these patients had undergone two prior reoperations, including closure of a residual VSD, truncal valve replacement and two previous conduit replace-

ments. One day after the third reintervention, reoperation was required for bleeding, and the patient could not be weaned from cardiopulmonary bypass after multiple repairs of the friable ascending aorta. One patient could not be separated from cardiopulmonary bypass due to pulmonary hypertension and ventricular failure. The other two died on the first day after reintervention, one of ventricular dysfunction and cardiopulmonary arrest and one of a cerebral hemorrhagic event.

**Reinterventions on the truncal valve.** A total of 22 reinterventions on the truncal valve were performed in 19 patients. Twenty-one truncal valve replacements were performed in 18 patients, while 1 patient underwent truncal

![Figure 1](image1.png)

![Figure 2](image2.png)
valve repair. Two of these patients had the truncal valve repaired and one had undergone truncal valve replacement at the time of the initial correction of common arterial trunk. Late replacement was with a mechanical prosthesis in all but one patient, who underwent a second truncal valve replacement with an allograft aortic root. Actuarial freedom from reintervention on the truncal valve is depicted in Figure 3. The only independent variable to be associated significantly with shorter duration to truncal valve reintervention was severe truncal valve regurgitation at the time of the original repair ($p < 0.001$). Two patients, who underwent repair initially at two months of age, died in the early postoperative period following truncal valve replacement two and 34 months after the initial repair, respectively. The first died of acute left ventricular (LV) failure on the day of truncal valve replacement. The other could not be separated from cardiopulmonary bypass due to pulmonary hypertension and ventricular failure.

Reinterventions on the branch pulmonary arteries. Reintervention for stenosis of one or both branch pulmonary arteries was performed on 41 occasions in 32 patients. In almost all cases, the stenosis was at the site of anastomosis between the conduit and the branch pulmonary arteries. In 13 of these patients, at least one of the reinterventions was performed as an isolated procedure, while the remaining 19 patients had augmentation arterioplasty at the time of conduit reintervention. The pulmonary artery reintervention was surgical in 29 of the 41 cases and transcatheter balloon dilation was performed in the remaining 12. Actuarial freedom from reintervention on the pulmonary arteries is depicted in Figure 4.

Reinterventions for residual ventricular septal defect. Closure of a residual VSD was performed in 13 patients. In five of these patients, the residual interventricular defect was the primary indication for reintervention, while the other eight underwent closure of the defect in conjunction with conduit reintervention. All of the patients who required closure of a residual VSD had undergone closure originally with a continuous suture technique ($p = 0.03$). Actuarial freedom from closure of a residual VSD is depicted in Figure 4. Two patients, who initially underwent repair at 47 and 48 days of age and required closure of a residual VSD 4 and 3 months later, respectively, died following the reintervention. One developed pneumonia and cardiopulmonary arrest in the early postoperative period. The other could not be weaned from cardiopulmonary bypass due to pulmonary hypertension and ventricular failure.

Other reinterventions. Five patients underwent other interventional procedures, including closure of a secundum atrial septal defect in two patients, repair of a cleft mitral valve and cor triatriatum in one, resection of fibromuscular obstruction from the subvalvar LV outflow tract in one and transcatheter balloon angioplasty of arch obstruction in one patient who had undergone repair of interrupted aortic arch. All four of these interventions were performed at the time of conduit replacement.

**DISCUSSION**

Frequency and forms of medium-term and late reintervention. Reintervention after repair of common arterial trunk in early infancy is essentially inevitable. In the present series, actuarial freedom from reintervention was 50% at four years postoperatively, and 15% at seven years. The likelihood of multiple reinterventions is also high, as reflected by the 75% actuarial freedom from a second reintervention at 11 years postrepair. Most reinterventions were for conduit replacement, dilation or augmentation, although a substantial number of procedures were required for replace-
ment or repair of a significantly regurgitant truncal valve, closure of residual VSD or dilation/augmentation of stenotic branch pulmonary arteries.

There are few studies in the literature on long-term follow-up after repair of common arterial trunk, and none that focus on repair in neonates and young infants (4,7,11,12,14). Several series of older patients have found prolonged freedom from reoperation in comparison with the neonates and young infants in the present series (4,7,11). Although the range of reinterventions required in our patients was rather typical for this lesion, a significant indication for reoperation that did not occur among our patients was compression of the left mainstem bronchus or branch pulmonary arteries by the aortic arch after repair of common arterial trunk with an interrupted aortic arch. In the series reported by Brizard et al. (7), 3 of 10 patients who underwent repair of this complex lesion required four such reinterventions early after correction of the interrupted arch. In other series of young patients, an interrupted arch in patients with common arterial trunk was a significant predictor of early mortality (5,9). It was not stated in these series whether vascular or airway compression by the reconstructed arch was a factor in these patients’ deaths. Both the early mortality and mechanical complications that can occur after correction of common arterial trunk with an interrupted arch highlight the importance of prompt and careful management of this lesion. A variety of techniques have been reported for reconstruction of the arch in such patients. We have found success and minimal complications with a technique that employs division of the common trunk proximal and distal to the pulmonary arterial origins, resection of the arterial duct and reconstruction of the greater curvature of the arch with the left subclavian artery and the lesser curvature with a patch of allograft tissue (5). The patient who required balloon dilation of arch obstruction in the present series had undergone arch reconstruction with a more standard technique of direct anastomosis.

Reinterventions for truncal valve regurgitation. As we have discussed in a previous article, management of truncal valve regurgitation is a significant problem in the surgical treatment of patients with common arterial trunk (13). Repair of the truncal valve is an option that has been employed increasingly and successfully in recent years, both at the time of initial repair and at reintervention (8,13,15). Although truncal valve repair is an effective approach to early management in many cases, repair is not always a definitive procedure, given the marked dysplasia that affects the valvar leaflets in most patients with significant regurgitation (13,16–18). Thus, reintervention on the truncal valve will likely remain an important burden. In our series of infants younger than four months of age, there was an 83% freedom from reintervention in the truncal valve at 10 years postoperatively. Patients generally do well after intermediate and late replacement or repair of the valve.

Clinical impact of reinterventions after early primary repair. Despite the fact that most reoperations are for progressive conduit obstruction and/or regurgitation, and are not undertaken on an urgent basis, the morbidity and mortality associated with surgical reintervention are nevertheless potentially significant. As we have demonstrated previously, late mortality among patients who survive the early postoperative period after repair of common arterial trunk is excellent (12). The fact that half of the deaths in our patients were related to reoperation is a poignant reminder of the potential importance of reinterventions in the overall outcome of these patients. Mortality following reintervention for conduit replacement and truncal valve replacement has been reported by others as well (4,7), with a mortality rate of 22% after reoperation in one series (4). The relationship between late mortality and reoperations in our experience may have been due in part to the fact that nearly all of the patients who died following reoperation, three of whom could not be weaned from bypass after reoperation, underwent their original repair before the routine use of cardioplegia. In other series, older age at repair and the higher prevalence of pulmonary vascular obstructive changes were probably important factors as well (4). In the current era, the adverse effects of these factors are likely to be less pertinent.

As survival after repair of common arterial trunk has climbed to 90% to 95% at many large centers, the focus in treating these patients must be shifted to preservation of optimal functional status and minimization of late reinterventions and complications. Although reintervention is almost unavoidable in survivors of neonatal or early infant repair of common arterial trunk, efforts should be made to minimize the likelihood of preventable reinterventions, such as closure of residual VSDs and isolated branch pulmonary artery stenosis. All cases of residual VSD requiring repair in our experience were originally closed with a continuous suture technique. While this approach may decrease the duration of cardioplegic arrest, such a benefit is of questionable value if another intervention is required. Of course, most patients who underwent closure of the defect with a continuous suture technique did not require reintervention, so our statements should not be interpreted as denigrating this method of closure. Rather, our point is that such reinterventions are avoidable, and we should be cognizant of this fact. Similarly, all of the cases of branch pulmonary arterial stenosis requiring reintervention involved obstruction at the anastomosis between the native pulmonary arteries and the pulmonary outflow conduit. It may be of benefit to augment the proximal pulmonary arteries with extensions of allograft tissue from the conduit at the time of the original repair. In approximately half of our patients, reintervention on the pulmonary arteries was performed along with replacement of the right ventricle to pulmonary artery conduit, so a separate reintervention was not required. However, in the other 50%, a separate intervention was necessary, and although such reinterventions were not
associated with major morbidity in any patient, their impact should not be disregarded.

Applicability of the present study to patients undergoing repair in the current era. As the aforementioned considerations suggest, the applicability of our findings to patients undergoing repair in the current era is uncertain. Twenty-six percent of our patients and 30% of early survivors were neonates, and 38% were repaired with the use of an allograft conduit, features of management that are representative of the current state of therapy. Although age at repair is still identified in some series as a risk factor for early death in patients undergoing repair in early infancy (14), age per se does not appear to be associated with rate of reinterventions in such patients. The size of the conduit, which typically is related closely to age and for which age may serve a surrogate function, may be an important predictor of earlier reoperation, though the difference was small and the type of conduit was not a predictor of overall freedom from reintervention.

Acknowledgments
We would like to acknowledge the numerous physicians who have cared for the patients in this series, especially Drs. Paul A. Ebert and Kevin Turley, who performed the initial repair in many of them. We would also like to thank the physicians and families who provided follow-up information.

Reprint requests and correspondence: Dr. Doff B. McElhinney, Children’s Hospital of Philadelphia, 34th Street & Civic Center Blvd, Rm. 9557, Philadelphia, Pennsylvania 19104. E-mail: mcelhinney@email.chop.edu.

REFERENCES