Surgery for simple and complex subaortic stenosis in children and young adults: Results from a prospective, procedure-based national database

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Objective: To identify the outcomes of surgically treated subaortic stenosis in a national population.

Methods: From 2000 to 2013, 1047 patients aged < 40 years underwent 1142 subaortic stenosis procedures. Of the 1047 patients, 484 (46.2%) were considered to have complex stenosis (CS) because at or before the first operation they had mitral valve (MV) disease, aortic valve disease, aortic coarctation or an interrupted aortic arch.

Results: The 30-day mortality was 0.7% for simple stenosis (SS), 2.3% for CS ($P = .06$), and 1.6% overall. Age < 1 year ($P < .01$), MV procedure ($P = .02$) and an interrupted aortic arch at the index procedure ($P < .01$) were risk factors for early death. Konno-type procedure early mortality was 2.4%. The 12-year survival was 97.1%, with a significant difference between SS and CS (hazard ratio [HR], 4.53; $P = .02$). Having MV disease alone (HR, 4.11; $P = .02$), MV disease plus aortic coarctation (HR, 6.73; $P = .008$), and age < 1 year (HR, 6.72; $P < .001$) were risk factors for late mortality. Freedom from subaortic reintervention overall was 92.3% and 88.5% at 5 and 12 years, respectively, much greater with CS than with SS (HR, 4.91; $P < .0001$). The independent risk factors for reintervention were younger age at the index procedure (HR, 0.1/y; $P = .002$), concomitant MV procedure (HR, 2.68; $P = .019$), ventricular septal defect plus interrupted aortic arch (HR, 3.19; $P = .014$), and ventricular septal defect plus aortic coarctation (HR, 2.41; $P = .023$). Undergoing a concomitant aortic valve procedure at the index procedure was protective (HR, 0.29; $P = .025$).

Conclusions: Patients with SS had excellent outcomes. However, those with CS had worse long-term survival and freedom from reintervention, with morbidity and mortality greatest in young patients with multiple lesions. Additional evaluation in large-scale prospective studies is warranted. (J Thorac Cardiovasc Surg 2014;148:2618-26)

Subaortic stenosis (SAS) is a polymorphic condition. Anatomically, it can range from an isolated discrete stenosis to complex forms of left ventricular (LV) outflow tract obstruction. Other anatomic associations have been well described, including septal malalignment and multilevel obstruction. Not all defects will be present simultaneously; some adjacent lesions, such as aortic valve (AV) disease, evolve after primary treatment of SAS. Surgical treatment is generally successful; however, a risk of recurrence exists, which has been reported at 7.2% to 27%.[1-6] Many factors influence the long-term outcomes, including patient age and size, preoperative gradient, surgery timing, performance of myectomy, and anatomic complexity. Single-institution studies have been restricted by patient numbers, and multicenter studies are better placed to offer more insight.

In the United Kingdom, the Central Cardiac Audit Database (CCAD), hosted by the National Institute for Cardiovascular Outcomes Research, has collected data from congenital UK centers from 2000 onward. It captures all pediatric cardiac surgical and catheter procedures and all adult congenital cardiac procedures (defined as those performed for a cardiac defect present from birth). The audit database has limited clinical information; nevertheless, through complete procedure coverage and linkage with survival statistics, it has provided a unique opportunity to examine the outcomes of all patients undergoing certain procedures.

The objectives of the present SAS study were to (1) describe the early- and long-term survival and freedom from reintervention in a national population of consecutive,

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Abbreviations and Acronyms

- AV = aortic valve
- AVR = AV replacement
- CCAD = Central Cardiac Audit Database
- CI = confidence interval
- CoA = aortic coarctation
- CS = complex stenosis
- HR = hazard ratio
- IAA = interrupted aortic arch
- LV = left ventricular
- MV = mitral valve
- SAS = subaortic stenosis
- SS = simple stenosis
- VSD = ventricular septal defect

unselected cases; (2) examine how the outcomes of simple stenosis (SS) and complex stenosis (CS), further defined in subsequent section, differ; and (3) describe the influence of AV procedures such as AV replacement (AVR), Ross, and Konno. The results are presented in aggregate for the cohort and for the various subgroups.

METHODS

Data Set

The National Institute for Cardiovascular Outcomes Research brings together analysts and clinicians with the aim of providing data about surgical and catheter-based heart procedures and outcomes. The results are obtained by collecting key validated data from all UK heart units into cardiovascular registries (available at: https://nicor4.nicor.org.uk/). The National Institute for Cardiovascular Outcomes Research mechanism for congenital data capture, cleaning, and validation is similar to that adopted for adult cardiac surgery.[7] Using linkage with census records at the Office of National Statistics, the audit reports survival at 30 days and 1 year after the index procedure. Distilled information from the core database is reported online. The data represent a ‘‘real world’’ picture. CCAD data are actively audited, both internally and externally. About 15% of the patients will have no follow-up data beyond their hospital stay, because linkage with survival registries of Northern Ireland and Scotland cannot be done consistently with a National Health Services number, 5% will be foreign patients, and the remainder will have social data errors.

The indications for the primary subaortic (index) procedure and subsequent reinterventions were provided by multidisciplinary groups at each center. The submitted procedure codes are those recorded in each center’s logs and are audited regularly. The additional diagnoses were those selected by the reporting clinicians; the concordance between the procedure performed and the diagnosis reported was also audited, with the overall key data quality index >95%.

Recruitment into the study continued until April 2012, when the last set of validated data was available. The data were anonymized, and the need for patient-level consent was waived by the CCAD research board. The procedures performed for degenerative causes associated with hereditary conditions (eg, Marfan syndrome) were not considered congenital. Coexisting complex heart abnormalities were excluded (ie, univentricular conditions, valvular atresia, atrioventricular septal defect, transposition of the great arteries, common arterial trunk, Fallot and Fallot-type defects, severe vascular abnormalities [eg, major aortopulmonary collaterals], or isomerism). Patients with aortic coarctation (CoA) and interrupted aortic arch (IAA) were included owing to the clinical significance in the context of multilevel left-sided obstruction. The patients were considered to have SS or CS according to the definitions listed in Table 1. Of the 1047 patients, 58 had MV or AV abnormalities noted during follow-up (but not before the index procedure) that led to uncertainty regarding the initial diagnosis of the pathologic entity. We believe that, in principle, they satisfied the conditions of CS; however, having incomplete diagnosis and clinical history data, we preferred that such patients remain unassigned to either group (but their data were still included in the aggregate analysis because of valid survival data). All tests involving comparisons between CS and SS were performed initially including these patients in the CS group and then excluding them, with insignificant differences in the results. Thus, the reported results are from the analyses without such patients. Because of the usage of 2 ambiguous procedure codes (ie, 120822 [subaortic obstruction relief] and 120713 [LV outflow tract obstruction relief]), it was not possible to determine the proportion of patients with myectomy.

Statistical Analysis

The frequencies are given as the absolute numbers and percentages, continuous values as the mean ± standard deviation, or median and interquartile range. Short-term mortality was calculated per procedure, reported according to the discharge status and 30-day life status (where available). The estimates of long-term survival were made using the Kaplan-Meier method, with all-cause mortality as the failure event. Freedom from reintervention was estimated using the Kaplan-Meier method and a competing risks method (‘‘stcompet’’ routine for STATA; StataCorp, College Station, Tex) using reintervention and death as competing events. The predictor variables for short-term mortality were determined using the Fisher exact test or logistical regression analysis. For long-term survival and freedom from reintervention, we performed univariable analysis using the variables listed below. To identify independent risk factors, we used a multivariable Cox proportional hazards regression model and a competing risks regression model[8] (1 variable/10 events) with stepwise forward selection and backward elimination (with significant variables from univariable analysis, $P < .1$). Age (continuous) and categorical (<1 and >1 year), sex, concomitant procedures (mitral valve [MV] or AV procedures, ventricular septal defect [VSD] closure, CoA repair), other abnormalities present at the index surgery (MV, AV, CoA, VSD, or associations such as VSD+CoA, MV+CoA, and VSD+IAA), Konno-type procedure, and genetic disorders were examined. The results from the Cox and competing risks regression analyses were similar; thus, we chose to report only the hazard ratio (HR) and not the sub-HRs for practical reasons. Complex versus simple SAS comparisons were performed separately, independent of the multivariable model. Stratification by center was used, as appropriate. Adjusted HRs are given when bivariable or multivariable models were used. The proportional hazard assumption was tested visually and also using Schoenfeld residuals. The population characteristics were compared using the Mann-Whitney *U* test, *t* test, and chi-square test. Statistical analyses were performed using STATA/IC, version11.2 (StataCorp LP).

RESULTS

A total of 1673 patients with a SAS relief procedure performed from April 1, 2000 to March 31, 2012 were analyzed initially. Those with complex heart abnormalities (n = 456), age > 40 years (n = 77), hypertrophic cardiomyopathy (n = 37), transcatheter approach (n = 15), unknown age at the index procedure (n = 41) were eliminated, resulting in a final group of 1047 patients. The completeness of the data is presented in Table 2.

These 1047 patients underwent 1142 subaortic relief procedures, with 82 a Konno-type operation (including

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