Interventions and outcomes in children with hypoplastic left heart syndrome born in England and Wales between 2000 and 2015 based on the National Congenital Heart Disease Audit

Survival for HLHS in England and Wales since 2000

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Amongst congenital heart diseases (CHD) none has undergone a more drastic change in diagnostic approach, management and outcomes over the last 30 years than hypoplastic left heart syndrome (HLHS) with 'comfort care' replaced as the predominant form of management by a palliative surgical treatment pathway[1]. The outcomes of palliative procedures for HLHS have been well documented but the longer-term picture is less clear.

The UKs National Congenital Heart Diseases Audit (NCHDA) captures every procedure undertaken for CHD and updated life status for patients resident in England and Wales based on death certifications. From this dataset we identified patients born between 2000 and 2015 who fulfilled the criteria for HLHS: a small left ventricle, stenosis or atresia of the left sided heart valves, normally aligned great arteries and no common atrioventricular junction[2]. All HLHS patients require surgical palliation with a traditional Norwood or hybrid pathway or heart transplantation to survive and hence we were able to use procedure information in combination with diagnostic information to identify HLHS patients within the NCHDA dataset using the International Paediatric and Congenital Cardiac Codes. As the NCHDA is a procedure-based dataset, patients with HLHS who did not undergo any interventional treatment are not included. Since the Hybrid procedure was introduced in the UK in 2006, we considered two eras for analyses dating up to and after 2006.

The surgical and catheterization procedures undertaken were classified as:

- **Pathway procedures** consistent with HLHS treatment including the Norwood (Stage 1), Glenn (Stage 2) and Fontan (Stage 3) procedures of traditional surgical palliation; the hybrid procedure, the comprehensive Stage 2; and transplantation procedures.
- **Pre-pathway procedures** either required to stabilise very sick HLHS neonates such as pulmonary artery banding and interventions for restrictive atrial septum or interventions to the aortic valve or arch in neonates with hypoplastic left ventricle where a failed biventricular approach was evident based on subsequent events.
- **Off-pathway procedures** that may be required in patients with HLHS such as revision of arterial shunt or Sano or stenting or dilation of residual or re-coarctation[3].

Whilst we report transplant procedures within our description of pathways and outcomes for HLHS, transplant did not represent an endpoint in our primary analysis of condition-based survival. Survival analysis was carried out using the Kaplan-Meier approach, with death representing failure. Data were analysed using the Stata 13 statistical software package.

The study was approved by the NCHDA Research Committee and by the National Health Service (NHS) Healthcare Quality Improvement Partnership (Study number 14CONG03). Further ethics committee approval and patient consent were waived.

Of 976 patients with HLHS, 9.6% had a pre-pathway intervention, this carrying the highest in-hospital mortality of 34.0%, 89.5% embarked on a traditional surgical pathway of staged palliation and 6.4% of smaller and more complex infants embarked on a hybrid pathway[4].

The outcomes among patients that followed different trajectories are shown in Figure 1. For 20 of the patients lost to follow-up, survival was censored at the last known hospital discharge.

The in-hospital mortality for the primary procedure (Norwood or hybrid) was 22.9% (95% CI 20.2%-25.7%), for Stage 2 Glenn was 3.6% (95% CI 2.2%-5.4%) and for Stage 3 Fontan was 1.2% (95% CI 0.3%-3.1%). The interstage mortality between primary procedure and Stage 2 (or comprehensive Stage 2) was 13.0% (95% CI 10.6%-15.6%) and between Stage 2 (or comprehensive Stage 2) and Stage 3 was 7.3% (95% CI 5.2%-9.9%). On comparison of outcomes by era, the only statistically significant change in mortality at different stages was a reduction in in-hospital mortality following Norwood (Stage 1) surgery.

Kaplan-Meier survival inclusive of all patients was 60.7% (95% CI 57.5%-63.7%) at 1 year and 56.3% (95% CI 53.0%-59.5%) at 5 years. The log rank test suggested better survival in patients undergoing a traditional surgical pathway (including all those undergoing pre-pathway procedures) in the later era (p=0.088). Since the hybrid procedure was introduced in 2006 (and noting the increased complexity amongst patients undergoing hybrid pathway), survival on the traditional pathway has been higher (p=0.050).

There was at least one off-pathway procedure in 44.6% of patients. The rate for off-pathway cardiac surgery was 6 per 100 patient-years and the rate for off-pathway interventional catheterization was 16 per 100 patient-years, with a significant increase between eras ($p<0.001$).

The mandatory national audit of cardiac procedures and the independent tracking of survival were essential prerequisites for this population based study, which captures the outcomes for all patients with HLHS who underwent at least one cardiac procedure between 2000 and 2015 in England and Wales. Early post-operative survival rates have improved over time and are now inadequate as indices of quality, or to inform clinicians and families about outcomes and events following a diagnosis of HLHS.

Treatment pathways amongst patients with HLHS are highly variable and complex. The analysis of longer-term outcome based on diagnosis gives a more complete and useful picture than short-term outcomes based on procedure, and may inform quality improvement initiatives. The outcome for HLHS treated in the England and Wales compares well with international standards[3,5].

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Disclosures

KB and RF sit on the steering committee of NCHDA. No other conflicts to declare.

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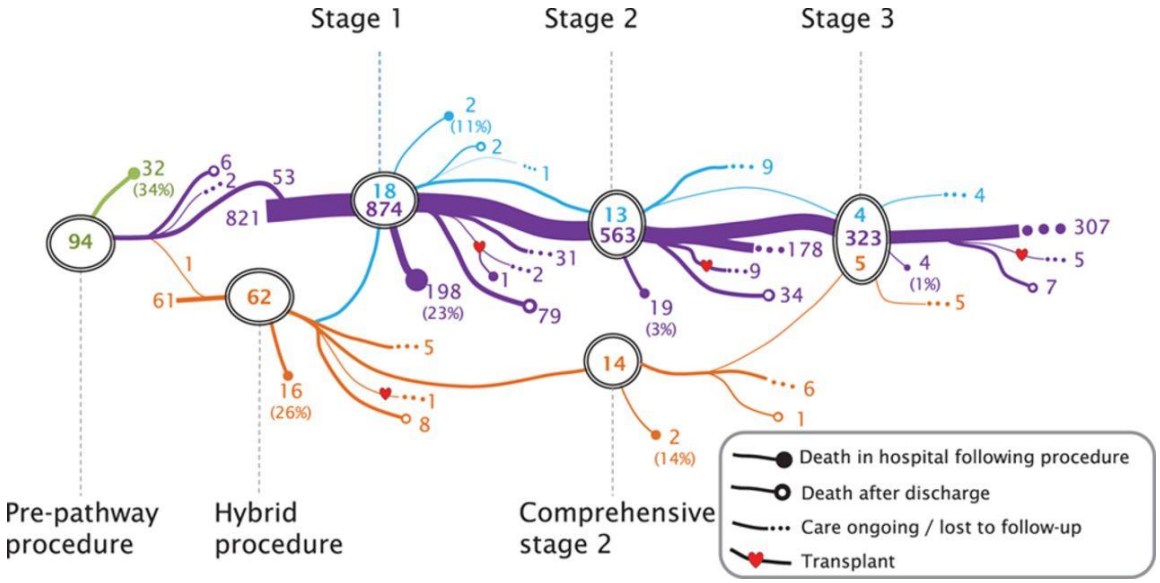
Figure 1: Interventions and outcomes for 976 English and Welsh patients with HLHS between 2000 and 2015. All patients who embarked on the traditional surgical treatment pathway (874, 89.5%of the cohort) are shown in purple, those who embarked on a hybrid pathway (62, 6.4% of the cohort) in orange. Patients who had a Stage 1 procedure following their hybrid procedure (18, 29.0% of hybrids) are shown in blue from that point. The trajectories of patients that had pre pathway procedures (94, 9.6% of the cohort) are shown in green to the point where they join the traditional or hybrid pathway. Heart transplants are represented with a heart symbol

Fig1


Stage 1
Stage 2
Stage 3
94
32
(34%)
6
2
53
821
1
61
62
18
874
2
(11%)
2
1
198
(23%)
31
2
1
79
16
(26%)
5
1
8
13
563
9
178
9
34
19
(3%)
14
2
(14%)
6
1
4
323
5
4
(1%)
5
4
307
5
7
Pre-pathway procedure
Hybrid procedure
Comprehensive stage 2
Death in hospital following procedure
Death after discharge
Care ongoing / lost to follow-up
Transplant