Objectives To evaluate the incidence of direct admission of infants with Down syndrome to the postnatal ward (well newborn nursery) vs the neonatal intensive care unit (NICU), and to describe the incidence of congenital heart disease (CHD) and pulmonary hypertension (PH).

Study design This retrospective cohort study of Down syndrome used the maternal/infant database (2011-2016) at the Rotunda Hospital in Dublin, Ireland. Admission location, early neonatal morbidities, outcomes, and duration of stay were evaluated and regression analyses were conducted to identify risk factors associated with morbidity and mortality.

Results Of the 121 infants with Down syndrome, 54 (45%) were initially admitted to the postnatal ward, but 38 (70%) were later admitted to the NICU. Low oxygen saturation profile was the most common cause for the initial and subsequent admission to the NICU. Sixty-six percent of the infants (80/121) had CHD, 34% (41/121) had PH, and 6% died. Risk factors independently associated with primary NICU admission included antenatal diagnosis of Down syndrome, presence of CHD, PH, and the need for ventilation.

Conclusions Infants with Down syndrome initially admitted to the postnatal ward have a high likelihood of requiring NICU admission. Overall, high rates of neonatal morbidity were noted, including rates of PH that were higher than previously reported. Proper screening of all infants with Down syndrome for CHD and PH is recommended to facilitate timely diagnoses and potentially shorten the duration of the hospital stay. (J Pediatr 2018;193:21-6).

In Ireland, the incidence of Down syndrome is 1 in 444 live births, the highest rate in Europe. Down syndrome is associated with significant cardiovascular and pulmonary morbidity and mortality in children, including congenital heart disease (CHD), pulmonary vascular disease, pulmonary hypertension (PH), chronic hypoxemia, and recurrent respiratory illnesses. Compared with the general population, infants with Down syndrome have an increased propensity to develop severe PH secondary to CHD or airway obstruction. This type of PH typically develops over time, but newborn infants with Down syndrome without CHD also are at increased risk for persistent PH that may be symptomatic after birth. Although PH in infants with Down syndrome without CHD has been described in up to 5% of newborn infants, this condition has not been thoroughly investigated, and the advent of a more systematic approach to the diagnosis of PH using objective echocardiography techniques may reveal a higher incidence in this population.

Currently, infants with confirmed or suspected Down syndrome are encouraged to remain with their mothers on the postnatal ward to promote early maternal–infant bonding and establishment of feeding, unless critical CHD is suspected or cardiopulmonary compromise arises. The impact of this approach on short-term outcomes is not well-described and warrants further study. Although the incidence of admission of an infant with Down syndrome to the neonatal intensive care unit (NICU) at any time point after birth has been reported at 46%, the overall incidence of direct NICU admission vs admission to the NICU from the postnatal ward is unknown.

We hypothesized that infants with a confirmed or suspected diagnosis of Down syndrome with and without CHD have a high incidence of PH identified on echocardiography performed in the first 3 days of age that may necessitate NICU admission. In this study, we studied the rates of PH, CHD, and other clinically relevant conditions in infants with Down syndrome.
relevant comorbidities in a cohort of infants with Down syndrome over a 5-year period in a tertiary neonatal center in Ireland, and described their early management and short-term outcomes.

### Methods

This retrospective study included all infants born with an antenatally confirmed diagnosis of Down syndrome, or a suspected clinical diagnosis of Down syndrome later confirmed with karyotyping. The study was conducted over a 5-year period between January 2011 and June 2016 at the Rotunda Hospital, Dublin, Ireland. The Rotunda Hospital is a stand-alone tertiary maternity and neonatal center with over 8500 annual births. The incidence of live births with Down syndrome in the Rotunda Hospital ranged between 2 to 4 per 1000 over the last 5 years. Data collection was approved by the Rotunda Hospital Clinical Audit Department.

Maternal and neonatal clinical and demographic data were collected from the medical records. Antenatal details collected included maternal age and parity at delivery, the presence of a documented antenatal scan, identified anomalies, and antenatal testing for Down syndrome. We identified common morbidities associated with Down syndrome, including the presence of CHD, PH in infants with CHD, PH in infants without CHD, gastrointestinal malformations, and hematological disturbances. The details of each infant’s hospital stay was collected including initial and subsequent place of admission (NICU vs postnatal ward), the use of inotropes and inhaled nitric oxide, first blood gas, full blood count, parenteral nutrition, duration of hospital stay, and death before discharge.

Low oxygen saturation levels as an indication for admission was defined as persistent pulse oximetry preductal oxygen saturation levels of 85% or lower for a period of 5 minutes in the presence of a clear signal while the infant was in a resting state.

### Echocardiography Evaluation

Echocardiography was obtained in all infants with Down syndrome during their initial hospital stay before discharge, and performed using a commercially available ultrasound imaging system (Vivid S6; GE Medical Systems, Milwaukee, Wisconsin). Two designated trained cardiac sonographers obtained all echocardiographic images using a phased-array transducer (7.5-12 MHz). The echocardiographic images were acquired using a standardized image acquisition protocol in the supine position during a restful period without changing the position of the infant or disturbing the hemodynamic condition to minimize heart rate and respiratory variation during image acquisition.

All scans were reviewed by a pediatric cardiologist to identify the presence of CHD and PH. An atrial septal defect was defined as an interatrial communication >8 mm in diameter on echocardiogram and requiring long-term follow up by our pediatric cardiologist. A patent ductus arteriosus (PDA) was labeled pathologic if it measured >3 mm with unrestricted flow.

PH was defined as the presence of systemic or suprasystemic pulmonary pressures occurring beyond the first 24 hours of age and the presence of one or more of the following: a right-to-left shunt across the PDA, interventricular septal bowing into the left ventricle, or the presence of a tricuspid regurgitant jet estimating the right ventricular pressure to be greater than the systemic systolic pressure.

### Statistical Analyses

Continuous data were presented as medians (IQR) and categorical data were presented as counts (percentage). Two group analyses were conducted using Mann-Whitney U tests or χ²/Fisher exact tests as appropriate. The cohort was divide into 3 groups: (1) infants admitted directly to the NICU (primary NICU), (2) infants placed with their mothers on the postnatal ward who were subsequently admitted to the NICU (NICU after postnatal ward), and (3) infants who were managed entirely at the mothers’ bedside on the postnatal ward (postnatal ward only). Three group analyses were conducted using the Kruskal-Wallis test. Logistic regression analysis was conducted to assess the independent effect of relevant variables (gestational age, any CHD, and PH) on the need for ventilation (first model) and mortality (second model) in this population. SPSS (IBM, Version 23, Armonk, New York) was used to conduct the analysis. P < .05 defined statistical significance.

### Results

One hundred twenty-four infants with Down syndrome were identified during the study period. Complete medical charts were available for 121 infants who were included in this study. The median gestational age was 38.3 weeks (IQR, 36.5-39.1) and the birth weight was 2.94 kg (IQR, 2.57-3.34). There were 62 male infants (51%). Forty-nine infants (41%) were born by caesarean deliveries with a median maternal age of 37 years (IQR, 33-39) and parity of 2 (IQR, 1-3). Eleven infants were born prematurely (less than 37 weeks of gestation) with a gestation of 30.3 weeks (IQR, 28.4-32.2) and birth weight 1.45 kg (IQR, 1.14-1.94).

Thirty-one mothers had a presumed or confirmed antenatal diagnosis giving an overall detection rate of 26%. A fetal ultrasound scan was available for 114 infants (94%), with the initial scan performed at a gestational age of 13 weeks (IQR, 12-16). Fetal anomalies were identified in 39 infants (32%). The most common anomaly diagnosed on ultrasound was atrioventricular septal defect (n = 12), followed by intraterine growth restriction (n = 8), increased nuchal thickness (n = 5), and a double gastric bubble (n = 5). Prenatal diagnostic testing confirmed the diagnosis of Down syndrome in 56% of this subgroup. Postnatal diagnosis was confirmed in all cases with karyotype testing.

### NICU vs Postnatal Ward Admission

Sixty-seven infants (55%) were admitted directly to the NICU, including most of the infants with a known antenatal diagnosis (n = 28, 90%). The most common reason for primary...
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