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Outcomes following elective resection of congenital pulmonary airway malformations are equivalent after 3 months of age and a weight of 5 kg

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ABSTRACT

Purpose: Resection of congenital pulmonary airway malformations (CPAMs) is often performed to reduce the risk of recurrent infection and malignant transformation. However, there is substantial variation in the timing of resection. This study was performed to determine the association of age and weight on outcomes following elective resection of CPAMs.

Methods: The American College of Surgeons National Surgical Quality Improvement Program-Pediatric database from 2012 to 2014 was queried for infants undergoing elective resection of a CPAM. Infants were categorized based on age (0–3 months, 3–6 months, 6–9 months, 9–12 months, and >12 months) and weight (0–5 kg, 5–10 kg, and >10 kg). Groups were compared for baseline characteristics and outcomes including a morbidity composite of pneumonia, reintubation, ventilator days >0, reoperation, readmission, hospital length of stay >7 days, and mortality.

Results: A total of 311 infants met study criteria. The morbidity composite was significantly more common among infants <3 months of age compared to infants >3 months of age (31.3% vs. 15.6%, $p = 0.01$) and among infants <5 kg as compared to infants >5 kg (37.5% vs. 15.8%, $p < 0.01$).

Conclusions: Infants should be observed until three months of age and a weight of five kilograms prior to elective resection of CPAMs.

Level of evidence: Level III.

The optimal timing of surgical resection of congenital lung lesions (CLAs) continues to remain poorly defined, particularly in the setting of an increased use of thoracoscopy. These lesions include Congenital Pulmonary Airway Malformations (CPAMs), historically referred to as congenital cystic adenomatoid malformations (CCAMs), pulmonary sequestration, and congenital lobar emphysema [1–3]. The majority of CLAs are diagnosed before birth through routine prenatal ultrasound, although the ability to predict growth and prenatal symptoms of these lesions remains limited. [1,2,4,5] Owing to the risk of recurrent infection, and to a lesser extent malignant transformation, it is recommended that these lesions be resected electively within the first few years of life unless an urgent indication requires earlier intervention [1].

Although many surgeons recommend resection of asymptomatic CPAMs prior to one year of age, there is disagreement regarding the timing of resection within this period [6,7]. Proponents of delayed resection cite poor pulmonary compliance in neonatal lungs and an increased requirement for postoperative ventilator support, as well as a reduction in anesthetic risk [1,5]. Conversely, delayed resection may lead to a more inflamed lung owing to recurrent asymptomatic infections, as well as risk symptomatic infections and other cardiopulmonary symptoms [1,7–9]. To help address this question, we used the American College of Surgeons National Surgery Quality Improvement Program-Pediatric (NSQIP-Ped) database to determine the association of infant age and weight on outcomes following elective resection of CPAMs in order to better determine the optimal age and size for resection of these lesions.

1. Materials and methods

1.1. American College of Surgeons National Surgical Quality Improvement Program-Pediatric

Since the 1990s, Department of Veterans Affairs has developed a program for monitoring and improving outcomes among veterans throughout the United States. The success of this program led hospitals

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in the private sector to enroll in the ACS NSQIP since the early 2000s [10]. In addition to tracking and monitoring outcomes to aid quality improvement, the ACS NSQIP provides important multi-institutional data which can be used for a variety of research initiatives. Owing to this success, ACS NSQIP partnered with the American Pediatric Surgical Association (APSA) in 2008 to develop ACS NSQIP Pediatric [11]. This allows centers to compare surgical outcomes with other centers, but also provides a robust clinical database for research purposes.

1.2. Patient population

Infants receiving a pulmonary resection (defined by current procedural terminology codes 32100, 32140, 32440, 32480, 32482, 32484, 32663, 32670, and 32669) for a CPAM (defined by international classification of diseases ninth revision codes 748.4, 748.5, and 748.8) between 2012 and 2014 were selected. No exclusion criteria were applied initially.

1.3. Variables

The primary predictors of interest were age in months and weight in kilograms at the time of operation. Age was divided into five groups; less than three months, three to six months, six to nine months, nine to twelve months, and greater than twelve months. Weight was divided into less than five kilograms, five to ten kilograms, and greater than ten kilograms. The two outcomes of interest were mortality and a morbidity composite. The morbidity composite was created owing to the low number of events when investigating individual outcomes and therefore a reduced power to determine a difference between groups. The morbidity composite included postoperative pneumonia (defined as a radiographic finding including a new or progressive persistent infiltrate, a consolidation or opacity, a cavitation, or a pneumatocele in addition to a sign or symptoms including fever, leukopenia, a positive culture or bronchoalveolar lavage, or new purulent sputum worsening cough or dyspnea, rales or bronchial breath sounds, or worsening gas exchange), 30-day reintubation, bleeding requiring blood transfusion within 72 h of operation, intubation beyond 24 h, 30-day reoperation, 30-day readmission, hospital length of stay longer than 7 days, and operative mortality (defined as in-hospital or within 30 days).

Other baseline variables of interest included gestational age, sex, race, and nutritional support. Operative variables of interest included minimally invasive approach (only available for 2013 and 2014), operative time, and case type.

1.4. Statistical analysis

First, outcomes of the overall group were summarized. Next, infants undergoing elective operations were selected. Infants who were ventilator or oxygen dependent were also removed from this portion of the analysis in order to further ensure only elective operations were being selected. Baseline characteristics, operative characteristics, and outcomes were compared between groups based on age and weight among these infants. Continuous variables were compared using the Wilcoxon rank sum test while categorical variables were compared using Fisher's exact test or the chi-square test as appropriate. Spearman's rank correlation coefficient was utilized to compare continuous variables. A p-value of <0.05 was used to define statistical significance. All statistical analyses were performed using R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

2. Results

A total of 344 infants met study criteria, of which 328 (95.3%) underwent an elective procedure. From the total cohort, 17 (4.9%) infants were oxygen dependent at the time of surgery and 13 (3.8%) were ventilator dependent. A slight majority of cases were performed by open thoracotomy (54.2%, n = 136) and the median operative time was 150 min (interquartile range [IQR]: 107, 209). Nearly a quarter of infants (23.8%, n = 82) met the morbidity composite driven strongly by a transfusion requirement (7.8%, n = 27), postoperative ventilator requirement (11.0%, n = 38), and a postoperative length of stay longer than 7 days (13.8%, n = 47). Only 2 patients had an in-hospital or 30-day mortality, both of which were not performed electively. When comparing infants undergoing elective surgery to those undergoing urgent or emergent surgery, infants undergoing elective surgery had a significantly lower incidence of the morbidity composite than those undergoing urgent or emergent surgery (21.3% vs 75.0%, $p < 0.01$). Infants undergoing urgent or emergent surgery also had high rates of transfusion requirements (12.5%), ventilator use postoperatively (62.5%), and length of stay longer than 7 days (61.5%).

Of the 311 infants who underwent elective resection and were not oxygen or ventilator dependent at the time of surgery, 48 (15.4%) were between 0 and 3 months of age, 71 (22.8%) were between 3 and 6 months of age, 81 (26.0%) were between 6 and 9 months of age, 36 (11.6%) were between 9 and 12 months of age, and 75 (24.1%) were greater than 12 months of age (Table 1, Fig. 1). There was no significant difference in gestational age between groups. Operative time increased significantly as infant age increased, with a median time of 110 minutes in infants between 0 and 3 months and 172 minutes in those greater than 12 months (Table 2).

Upon investigation of outcomes by age at time of operation, there was a nonsignificant trend towards increased bleeding in infants less than 3 months, with 12.5% (n = 6) of these infants requiring blood within 72 h of the operation compared with 4.9% (n = 13) of infants greater than 3 months ($p = 0.09$). There was also an increased use of ventilation postoperatively in the infants younger than 3 months (14.6%, n = 7) as compared to infants greater than 3 months (2.7%, n = 7, $p < 0.01$). There was a nonsignificant trend towards increased 30-day reoperation (4.5% vs 1.0%, $p = 0.10$) and 30-day readmission (7.2% vs 3.0%, $p = 0.10$) among infants receiving an operation after 9 months of age as compared to those younger than 9 months. The overall morbidity composite was significantly more common among infants less than 3 months of age at time of operation (31.3%) as compared to infants greater than 3 months of age (15.6%, $p = 0.01$).

When investigating the 311 infants who underwent elective CPAM resections by weight at the time of the procedure, 32 (10.3%) were <5 kg, 204 (65.6%) were 5–10 kg, and 75 (24.1%) were greater than 10 kg (Table 3, Fig. 2). There was no significant difference by gestational age or gender between groups; however, infants who were >10 kg were significantly more likely to have developmental delay or impaired cognitive status as compared to infants less than <10 kg (8.0% vs 1.3%, $p < 0.01$). A nonlinear association between weight and the use of a minimally invasive approach was seen, similar to that seen with regards to age, with only 30% of infants less than 5 kg and 36.4% of infants more than 10 kg having an attempted minimally invasive approach as compared to 55.4% of infants between 5 and 10 kg (Table 4). Also there was again a nonsignificant trend towards increasing operative times with increased weight, starting at a median of 94 min for infants less than 5 kg but increasing to 158 min for infants between 5 and 10 kg and 170 min for infants >10 kg. When comparing operative time and weight as continuous variables, there was a significant correlation (rho = 0.22, $p < 0.01$).

Infants < 5 kg had significantly increased requirements for blood transfusion within 72 h of the operation as compared to infants >5 kg (15.6% vs 5.0%, $p = 0.03$) and they also had significantly increased ventilator use postoperatively (21.9% vs 2.5%, $p < 0.01$). Postoperative length of stay was greater than 7 days for significantly more infants <5 kg as compared to those >5 kg (25.0% vs 6.8%, $p < 0.01$). Lastly, the morbidity composite was significantly more common among infants <5 kg as compared to infants <5 kg (37.5% vs 15.8%, $p < 0.01$). There was no significant difference in the morbidity composite among infants between 5 and 10 kg and among infants greater than 10 kg (14.2% vs 20.0%, $p = 0.27$).

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