Design of an Android-Controlled Electric Fan System for Smart Clinical and Assisted Care Applications

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Abstract

Objective: A brief, resolved unexplained event (BRUE) in infancy is a common reason for visiting the emergency room. Yet, little is known about the long-term outcomes of such an event. This study evaluates future mortality, morbidity and/or developmental delay following BRUE.

Methods: A single-center retrospective study performed during 2009-2013. The study included 87 hospitalized infants (<1year old), fitting the AAP criteria of low-risk BRUE, with 2 exceptions: no time limit to duration of episode and no age limit of ≥ 60 days old. Hospitalized infants were followed-up for up to 5 year, via phone questionnaire to evaluate for mortality rates, developmental delay, neurological/cardiovascular morbidity and future hospitalizations.

Results: The majority (94%) of infants with BRUE were hospitalized before the age of 6 months. ***No cases of mortality*** occurred. In terms of developmental outcome, 1 child (1.15%) was diagnosed with global developmental delay, and 12 (13.7%) with language delay, similar to prevalence rates by age in the US. Three children (3.4%) were diagnosed in the spectrum of autistic disorders, comprising higher prevalence rates than the global average. Simple febrile and non-febrile seizures were seen at a rate similar to the general population. None of the children developed cardiovascular disease. Re-hospitalization occurred in 22% of cases: 90% for common acute pediatric causes and 10% for recurrent choking events secondary to gastroesophageal reflux disease

Conclusions: Low-risk hospitalized infants <1 year of age who experienced a BRUE appear to have a generally excellent prognosis.

Key Words: Brief resolved unexplained episode (BRUE); infants; developmental outcome **Introduction**

An episode described by a caretaker as an abrupt change in color or tone, loss of consciousness, altered responsiveness or transient respiratory distress in an infant, generally <1 year, is a frequent motive for visiting an emergency room. In the past, such an event might have been considered a low-risk "apparent life-threatening event" (ALTE). Most recently, the American Academy of Pediatrics suggested modifying the definition of such an event to a brief resolved unexplained event (BRUE), defined as "an event occurring in an infant <1 year of age when the observer reports a sudden, brief and now resolved episode of ≥1 of the following:

- Cyanosis or pallor
- Absent, decreased or irregular breathing
- Marked changes in tone
- Altered level of responsiveness" [1]

While a number of studies have investigated the *short-term* consequences of ALTE and subsequently the need for further work-up and hospitalization,[2-11] there is scant knowledge as to the *long-term* consequences following the discharge of an infant after a BRUE, differing from an ALTE in that resuscitative or stimulatory measures are not performed and the episode is not considered "life-threatening" by a clinician.

The goal of this study was to evaluate the long-term outcome of children following an episode of a BRUE that occurred in a lower-risk infant at <1 year, but yet was severe enough that a clinician considered it necessary to hospitalize the infant. Long-term outcome included an evaluation for future mortality /morbidity, developmental delay or development of other cardiovascular/neurological deficits.

Methods

This was a single center retrospective study. Infants aged ≤1 year hospitalized from 2009 to 2013 in the Schneider Children's Medical Center of Israel were included in this study for an episode defined as a BRUE. Being that BRUE is, as yet, not a codable diagnosis, patient records were searched for an admission diagnosis of "respiratory distress", "cyanosis", "suspected choking", "hypotonia episode" or "altered level of

consciousness". Patients were included if they fit the current clinical definition of BRUE, where the episode was brief, had rapidly resolved and where no qualifying explanation for the event following a history and physical exam could be offered. Patients included in this study fit the "low risk" stratification, per the AAP Clinical Practice Guidelines[1] with two exceptions: the length of the event was not limited to <1 minute and there was no age limit of >60 days for inclusion. Patients were excluded if they had a history of significant prematurity (born at ≤32 gestational weeks), fever or diagnosed with one of the following: chronic heart disease, congenital neurological disease or a chronic medical condition diagnosed prior to hospitalization for the BRUE episode.

Data was collected from the patient's electronic medical records and included demographic and clinical details of the infant's hospitalization due to the BRUE event. A follow-up investigation was performed via a telephone questionnaire with the infant's caretaker after obtaining informed consent. The phone questionnaire was conducted 6 months after the event and up to five years following the initial hospitalization for BRUE. The follow-up investigation examined whether there had been further hospitalizations (for BRUE and/or other causes) and if the child had developed a chronic disease, developmental delays, neurological deficits and/or other medical conditions. The study was approved by our institution's medical ethics committee.

Results

During the 5-year period between 2009-2013, 150 patients hospitalized at the Schneider Children's Medical Center of Israel were categorized as having experienced a BRUE. Thirty children were excluded from the study due to prematurity (gestational age of ≤32 weeks) or a chronic disease diagnosed prior to hospitalization. Of the 120 remaining children, 87 were available for follow-up via a telephone questionnaire.

Of the children remaining in the study, 35 (40.2%) were male and 52 (59.8%) female. Preterm infants (33-36 gestational weeks) comprised 13.7% of the study participants (n=12), of which 25% were boys and 75% were girls.

The ages of the infants at hospitalization are shown in Figure 1. The majority of our patient cohort were neonates: 85% were 2 months old or younger. Overall, 94% were <6 months. The presenting symptoms are shown in Table 1. Median age at the time of the follow-up questionnaire was 42 months (ranging from 8-64 months) (Table 2).

The results of the developmental consequences following a BRUE that required hospitalization are summarized in Table 3. Overall, of the 87 children in our study, 1 was diagnosed with global developmental delay by neurological assessment (by a pediatric neurologist/developmental pediatrician). A verbal developmental delay, as per parental report, was seen in 12 children (13.7% of the study population), of which 9 were boys and 3 were girls. Verbal delay was seen in 3 children at age 2 or younger; in 2 children aged 3; in 2 children aged 4 and in 5 children aged 5. No child exhibited fine- or gross-motor delay. Three children were diagnosed in with an autistic spectrum adisorder (one boy and 2 girls), representing 3.45% of the study population. The majority of children (81.6%) in our study developed normally. Seizures were recorded in 3 cases (3.45%) - simple febrile seizures in 2 children (2.3% of study population) and non-febrile seizures in one child (1.15%). There were no reported cases of cardiovascular disease on follow-up.

Following hospitalization for a BRUE, 22% of the patients experienced recurrent hospitalization (a total of 19 hospitalizations). The causes for most of the hospitalizations included common pediatric ailments, i.e., diarrhea, upper respiratory infections, bronchiolitis, urinary tract infections, and breath-holding spells. There was a single case of aseptic meningitis, without any neurological consequences. Two children were re-hospitalized due to choking events; in both cases, the etiology of the choking events was gastro-esophageal reflux.

It is important to note that there were no cases of mortality during our short- and long-term follow-up. Furthermore, no cases were found whereupon BRUE was the first sign of a chronic heart or lung disease.

Discussion

The present study described the long-term follow-up of young low-risk infants hospitalized due to a BRUE. During the 5-year study period, BRUE-related hospitalizations comprised 1.2% of all hospitalizations of infants ≤1 year in a pediatric department, being less than the 2% noted in previous studies of ALTE.[5-6]

In our study, most of the participants were young infants: 94% were <6 months old, in congruence with previous studies on ALTE.[5] This is possibly due to the fact that infants in the younger age groups were more likely to be hospitalized than older infants.

In terms of neurological consequences, a previous study noted that 4.9% of infants hospitalized for ALTE had adverse neurological outcomes, including chronic epilepsy and developmental delay.[7] In our study population, 2.3% had experienced febrile seizures and 1.15% non-febrile seizures. This is quite similar to the prevalence for febrile and non-febrile seizures, respectively, in the general population.[12] Furthermore, the prevalence of global developmental delay in our study was 1%, in proximity to the global prevalence rate, ranging from 1-3% of the total population.[13]

In terms of verbal development in the US, it is estimated that 10-15% of those <2 and 4-5% of those <3 years of age are diagnosed with verbal developmental delay[14] and approximately 6-8% of school children with language impairments.[15] In our study, 3 cases (3.4%) at age 2 and 2 (2.3%) at age 3 were diagnosed with verbal developmental delay. Similarly, 5 cases (5.7%) at age 5 suffered from a specific language impairment, similar to that found in the general population, but had outgrown it when they reached school-aged. As in other studies,[15] a male preponderance was noted in our study as well (9/12 cases).

It is also worth noting that in our study, there was a relatively large percentage (3.4%) of patients subsequently diagnosed with an autism spectrum disorder as opposed to the global average of 1.3%.[16] Given the relatively small number of participants in our study, future investigations should be performed to confirm this relationship. Moreover, the true global prevalence of this disorder remains quite dubious.

It is thus reasonable to say that in our study, a BRUE, even one considered severe enough to lead to hospitalization upon evaluation in the emergency department by a trained clinician, is *not* an ominous sign predicting the future development of severe neurological deficits, developmental delay or other chronic diseases. Moreover, these findings are true even when the hospitalized infants did not fully complete the “low risk” stratification of the AAP’s Clinical Practice Guidelines requiring that the BRUE episode be of short duration (<1 minute) and not in neonates (infants >60 days old). As such, it is important to note that our findings are in contrast to the bleak long-term consequences reported following ALTE including death in 1.1% of patients following discharge[10], chronic epilepsy in 3.6%[7], motor delay and severe learning disabilities in 7.1%[17] and minor developmental delay in up to 29%.[17]

Our study had several limitations. Firstly, it is a retrospective study. Secondly, the diagnosis of "BRUE" is not a codable diagnosis and therefore a search was made for diagnoses at admission that could fit the criteria of BRUE, which might have led to some potential loss of patients who would have otherwise been enrolled in the study. Thirdly, approximately 25% of the patients in our study were lost to follow-up.

In conclusion, hospitalized infants <1 year of age who experienced a BRUE, appear to have a generally excellent prognosis, no different than the general pediatric population.

Acknowledgements

The authors thank Mrs. Phyllis Curchack Kornspan for her editorial services.

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Legend to figure

Figure 1: Number of infants hospitalized for a brief resolved unexplained event (BRUE), by age in months