Risk of Hospitalizations Following Gastrostomy in Children with Intellectual Disability

Peter Jacoby, MSc[1], Kingsley Wong, MBBS[1], Preeyaporn Srasuebkul, PhD[2], Emma J. Glasson, PhD[1], David Forbes, MBBS[3], Madhur Ravikumara, MBBS[4], Andrew Wilson, MBBS[1,5,6,7], Lakshmi Nagarajan, MD[1,8], Jenny Bourke, MPH[1], Julian Trollor, MD[2], Helen Leonard, MBChB[1], and Jenny Downs, PhD[1,7]

Objective To examine the frequency of hospital admissions before and after gastrostomy insertion in children with severe intellectual disability.

Study design We conducted a retrospective cohort study using linked health administrative and disability data from Western Australia (WA) and New South Wales (NSW). Children born between 1983 and 2009 in WA and 2002 and 2010 in NSW who had a gastrostomy insertion performed (n = 673 [WA, n = 325; NSW, n = 348]) by the end of 2014 (WA) and 2015 (NSW) were included. Conditional Poisson regression models were used to evaluate the age-adjusted effect of gastrostomy insertion on acute hospitalizations for all-cause, acute lower respiratory tract infections (LRTI), and epilepsy admissions.

Results The incidence of all-cause hospitalizations declined at 5 years after procedure (WA cohort 1983-2009: incidence rate ratio, 0.70 [95% CI, 0.60-0.80]; WA and NSW cohort 2002-2010: incidence rate ratio, 0.63 [95% CI, 0.45-0.86]). Admissions for acute LRTI increased in the WA cohort and remained similar in the combined cohort. Admissions for epilepsy decreased 4 years after gastrostomy in the WA cohort and were generally lower in the combined cohort. Fundoplication seemed to decrease the relative incidence of acute LRTI admissions in the combined cohort.

Conclusions Gastrostomy was associated with health benefits including reduced all-cause and epilepsy hospitalizations, but was not protective against acute LRTI. These decreases in hospitalizations may reflect improved delivery of nutrition and medications. *(J Pediatr 2020;217:131-8)*.

Intellectual disability is the largest contributor to years lived with disability over the last 25 years.[1] Children with intellectual disability have greater risks of hospitalization than children without, particularly those with a severe disability.[2] Hospitalization is often related to infections, epilepsy, and gastrointestinal conditions.[3] Feeding difficulties are common and consequences may include poor nutrition and aspiration, which contribute to morbidity profiles and the complexity of care.[4]

Gastrostomy insertion is one management option to assist with daily feeding regimens.[5] The incidence of gastrostomy insertion has increased substantially among very low birth weight infants[6] and children with severe disability.[7-9] Complications such as external leakage may occur in the short term, but these reduce so that gastrostomy may be used continuously for many years.[10-13] Besides improved feeding, gastrostomy has been associated with weight gain in children,[9] observed specifically in Rett syndrome,[14] and more generally in children with severe developmental disability.[15]

Despite its benefits, gastrostomy has been associated with increased hospitalizations for respiratory conditions, observed over a 1-year period in 65 children after gastrostomy insertion compared with 49 children at risk of aspiration but who were fed orally.[16] However, the orally fed population in this study had a lower baseline frequency of neurologic comorbidity. The use of gastrostomy may exacerbate gastroesophageal reflux disease,[17] potentially increasing

ICD	*International Classification of Diseases*
ICU	Intensive care unit
IRR	Incidence rate ratio
LRTI	lower respiratory tract infection
NSW	New South Wales
WA	Western Australia

From the [1]Telethon Kids Institute, Center for Child Health Research, The University of Western Australia, Perth; [2]Department of Developmental Disability Neuropsychiatry, School of Psychiatry, UNSW Sydney, Sydney; [3]Medical School, The University of Western Australia, Perth; [4]Department of Gastroenterology, Perth Children's Hospital, Perth; [5]Department of Respiratory Medicine, Perth Children's Hospital, Perth; [6]School of Pediatrics, The University of Western Australia, Perth; [7]School of Physiotherapy and Exercise Science, Curtin University, Perth; and [8]Children's Neuroscience Service, Department of Neurology, Perth Children's Hospital, Perth, Australia

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respiratory comorbidity, although hospitalizations for reflux-related problems were stable in the 2 years after gastrostomy in children with neurologic impairments[18] and were reduced in the 12 months after fundoplication in another study.[19] The potential for fundoplication to mitigate this is therefore mixed.[20,21] Epilepsy also contributes to high rate of hospitalizations, potentially exacerbated by feeding problems and associated difficulties administering anti-epileptic medications.[3] Easier delivery via gastrostomy is valued by parents, yet no studies have investigated whether this influences the need for subsequent epilepsy-related hospitalizations.[14]

Using a population-linked dataset, we assessed the impact of pediatric gastrostomy on the incidence of all-cause hospital admissions, and specifically for subsets of admissions owing to respiratory and neurological causes over a 5-year observation period in 2 states in Australia.

Methods

We conducted a retrospective cohort study using linked health administrative, disability, and population databases from Western Australia (WA) and New South Wales (NSW). Ethical approval in WA was obtained from the Department of Health WA (#2016/32). Ethical approval in NSW was obtained from the NSW Population and Health Services Research Ethics Committee (2013/02/446; Sub study reference: 2017/UMB0401).

Study Sample and Data Sources

As part of a broader investigation into pediatric gastrostomy, all WA live births between January 1, 1983 and December 31, 2009, diagnosed with intellectual disability with a minimum follow-up of 5 years to December 31, 2014, and had their first gastrostomy insertion at <18 of age within the period January 1, 1983, and December 31, 2014, were included.[8] The following population-based datasets were linked by the WA Data Linkage Branch and used in this study as reported previously: (1) the Midwives Notification System for birth data, (2) the Intellectual Disability Exploring Answers database, (3) the WA Register of Developmental Anomalies – Birth Defects and Cerebral Palsy for case ascertainment and disability data, (4) the Hospital Morbidity Data Collection for hospital admission data, and (5) death registrations.[8]

Individuals with intellectual disability who were born in NSW between January 1, 2002 (when data linkage became available), and December 31, 2010, were also included. They were identified from either the Disability Services Minimum Data Set or the Targeted Specialised Program in public schools from NSW Department of Education databases. Individuals aged <18 years when they were first admitted to hospital for gastrostomy insertion between January 1, 2002, and December 31, 2015, were identified from the Admitted Patient Data Collection using the same codes as that for WA.[8] Mortality data from the Registry of Births, Deaths and Marriages were used to calculate the follow-up period.

Access to these 2 cohorts provided opportunity to combine datasets from WA and NSW for analyses of the most recent decade of observations, to maximize study power and the generalizability of findings.

Outcome Variables

Linked hospitalization data were extracted from the Hospital Morbidity Data Collection in WA and the Admitted Patient Data Collection in NSW. Based on diagnostic codes of the *International Classification of Diseases, 9th Revision* (ICD-9) (January 1, 1979, to December 31, 1987), the clinical modification version of ICD-9 (ICD-9-CM) (January 1, 1988, to June 30, 1999), and the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification* (July 1, 1999, to December 31, 2015), the principal diagnosis recorded for each episode of hospitalization was classified into ICD disease chapters (**Appendices 1, 2,** and **3**; available at www.jpeds.com). This diagnosis was also used to classify events as related to acute lower respiratory tract infections (LRTI; including influenza and pneumonia, acute bronchitis, acute bronchiolitis, pneumonitis owing to solids and liquids, and other acute LRTI) or epilepsy (**Appendix 4**; available at www.jpeds.com). An intensive care unit (ICU) admission variable was coded as 1 if an individual was admitted to ICU during hospitalization; otherwise it was coded as 0.

Study Design and Data Management

The self-controlled case series method was used to estimate the relative incidence (incidence rate ratio [IRR]) of events in defined periods after gastrostomy insertion compared with the period a year before the procedure was performed.[22] This method was chosen because time-invariant confounders, either known or unknown, are automatically adjusted.[22]

We defined our observation periods by intervals between date of birth and last date of observation, which was either December 31, 2014 (WA), December 31, 2015 (NSW), or date of death, whichever came first. The risk periods extended from the admission date of hospitalization during which the first gastrostomy insertion was performed to the end of the observation period (**Figure 1**; available at www.jpeds.com). An event was defined as an acute single hospitalization and for the first hospitalization of a hospital transfer set. Hospitalizations were restricted to those with overnight stay and admission dates ranging from January 1, 1983, to December 31, 2014 (WA) or December 31, 2015 (NSW) inclusive.

Owing to the skewed age distribution in all hospitalizations (**Figure 2**; available at www.jpeds.com), age groups were defined based on quantiles of the age at event and resulted in a finer partitioning in younger ages where hospitalization was more frequent. The risk period for individuals after first gastrostomy insertion was stratified into years for the first 5 years after first gastrostomy insertion: 0-1, 1-2, 2-3, 3-4, 4-5, and ≥6 years, and the control period spanned the interval 1 year before the

admission date of first gastrostomy insertion (Figure 1). The time period before the control interval was also included in the analysis if available depending on the age of the child at gastrostomy. We excluded time spent in hospital from the time at risk variable in the models. We removed the hospitalizations in which gastrostomy insertion was first performed.

Statistical Analyses

Conditional Poisson regression models were used to evaluate the associations of acute hospital admissions with risk intervals after gastrostomy insertion for all-cause and specific cause (acute LRTI, epilepsy) hospitalizations. The relative incidence of ICU admissions was also investigated. The influence of age at first gastrostomy insertion was examined by splitting the cohort into 2 groups using the cut point of 3 years (the median age of insertion) and repeating the above analyses for each group. To investigate the effects of fundoplication, we included a fundoplication specific time-varying exposure variable in the models. The variable was defined as exposed (coded as 1) after the admission date of hospitalization for first fundoplication, and unexposed (coded as 0) if otherwise.

All statistical models were adjusted for categorical quantile-partitioned age groups and offset by the log of time at risk. Relative incidence estimates and their 95% confidence intervals are presented. Meta-analysis using DerSimonian-Laird random-effects model in the "metan" package was used to combine the estimates obtained from each site, limited to the birth cohort 2002-2009 (WA) and 2002-2010 (NSW) (cohort 2), into a single pooled estimate. Statistical analyses of data were performed using Stata 15.1 software.[23]

Results

Among the 24 252 individuals with intellectual disability born in WA (n = 11 729) and NSW (n = 12 523), 673 (WA, n = 325; NSW, n = 348) had a gastrostomy inserted before age 18. The characteristics of the 2 cohorts with gastrostomy (cohort 1: WA only 1983-2009; cohort 2: WA 2002-2009 and NSW 2002-2010) by hospitalization type are shown in Tables I and II, respectively. Males were more prevalent than females in both cohorts (cohort 1: n = 174 [53.5%]; cohort 2: n = 261 [57.4%]). Fewer children received a gastrostomy in the first 2 years of life in cohort 1 (n = 149 [45.9%]) than in cohort 2 (n = 319 [70.1%]), illustrating earlier gastrostomy in more recent years.[24] Fundoplication was carried out in less than one-third of individuals with gastrostomy insertion (cohort 1: n = 91 [28.0%]; cohort 2: n = 138 [30.3%]).

There were 8322 and 8973 hospital admissions in cohort 1 and 2, respectively (Tables I and II). Around one-fifth of the hospitalizations were due to acute LRTI (cohort 1: n = 1745 [21.0%]; cohort 2: n = 1568 [17.4%]). The median length of overnight stay of all-cause hospitalizations was 3-4 days

Table I. Characteristics of cohort 1* by hospitalization type

Characteristics	All-cause	Acute LRTI	Epilepsy
Individual level			
No. of individuals	325	257	164
Year of birth			
1983-1989	52 (16.0)	41 (16.0)	29 (17.7)
1990-1999	142 (43.7)	115 (44.7)	71 (43.3)
2000-2009	131 (40.3)	101 (39.3)	64 (39.0)
Sex			
Male	174 (53.5)	137 (53.3)	86 (52.4)
Female	151 (46.5)	120 (46.7)	78 (47.6)
Death	113 (34.8)	103 (40.1)	69 (42.1)
Age at first gastrostomy insertion (y)	3.4 (1.6-7.9)	3.0 (1.6-6.9)	4.1 (2.0-8.6)
0-2	149 (45.9)	127 (49.4)	62 (37.8)
≥3	176 (54.1)	130 (50.6)	102 (62.2)
Age at first fundoplication (y)	2.2 (1.1-5.7)	2.1 (1.0-5.1)	3.3 (2.0-8.3)
0-2	54 (16.6)	48 (18.7)	22 (13.4)
≥3	37 (11.4)	31 (12.1)	24 (14.6)
Never	234 (72.0)	178 (69.3)	118 (72.0)
Overall length of observation period (y)	13.6 (8.6-19.4)	13.1 (8.4-18.7)	14.4 (9.0-19.8)
Length of observation period after first gastrostomy insertion (y)	7.5 (3.8-13.8)	7.5 (3.8-13.7)	7.5 (3.4-13.6)
Admission level			
No. of acute hospital admissions†	8322 (100)	1745 (21.0)	1096 (13.2)
No. of admissions per annum	1.5 (0.9-2.9)	0.4 (0.2-0.9)	0.3 (0.1-0.6)
Age at acute hospital admissions (y)	4.6 (1.8-9.2)	5.5 (2.3-10.0)	4.6 (1.8-8.1)
Length of overnight stay (d)	3 (2-7)	5 (3-9)	3 (2-6)
No. of ICU admissions†	446 (100)	87 (19.5)	87 (19.5)
No. of individuals admitted to ICU	146	44	26

Values are number (%) or median (IQR).
*Children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted at <18 years of age.
†Percent of all-cause admissions.

(Tables I and II) and did not vary after gastrostomy insertion (Tables III and IV; available at www.jpeds.com). More than one-half of the group was ever admitted to ICU (n = 261 [57.4%]) in cohort 2 and fewer in cohort 1 (n = 146 [44.9%]), but the number of ICU admissions as a proportion of all admissions was relatively uncommon (cohort 1: n = 446 [5.4%]; cohort 2: n = 814 [9.1%]).

Cohort 1

Acute Hospitalizations and ICU Admissions after First Gastrostomy Insertion. Compared with the control period (the year before gastrostomy) and adjusted for age, the incidence of acute hospitalizations was reduced for all-cause, acute LRTI, and epilepsy admissions before the control

Table II. Characteristics of cohort 2* by hospitalization type and state

Characteristics	All-cause		Acute LRTI		Epilepsy	
	WA	NSW	WA	NSW	WA	NSW
Individual level						
No. of individuals	107	348	82	256	54	117
Year of birth						
2002-2004	46 (43.0)	109 (31.3)	36 (43.9)	88 (34.4)	22 (40.7)	35 (29.9)
2005-2007	41 (38.3)	131 (37.6)	31 (37.8)	88 (34.4)	22 (40.7)	44 (37.6)
2008-2010 (WA: 2008-2009)	20 (18.7)	108 (31.0)	15 (18.3)	80 (31.3)	10 (18.5)	38 (32.5)
Sex						
Male	57 (53.3)	204 (58.6)	43 (52.4)	149 (58.2)	28 (51.9)	67 (57.3)
Female	50 (46.7)	144 (41.4)	39 (47.6)	107 (41.8)	26 (48.1)	50 (42.7)
Death	21 (19.6)	37 (10.6)	20 (24.4)	31 (12.1)	12 (22.2)	15 (12.8)
Age at first gastrostomy insertion (y)	2.7 (1.3-4.6)	1.5 (0.6-3.0)	2.1 (1.3-3.7)	1.5 (0.7-2.9)	3.3 (2.0-6.0)	2.4 (1.2-4.1)
0-2	59 (55.1)	260 (74.7)	51 (62.2)	197 (77.0)	23 (42.6)	78 (66.7)
≥3	48 (44.9)	88 (25.3)	31 (37.8)	59 (23.0)	31 (57.4)	39 (33.3)
Age at first fundoplication (y)	2.0 (1.0-4.9)	1.4 (0.6-2.5)	2.0 (1.0-4.9)	1.6 (0.9-2.6)	2.5 (1.8-6.3)	2.3 (1.4-2.8)
0-2	22 (20.6)	87 (25.0)	20 (24.4)	70 (27.3)	9 (16.7)	25 (21.4)
≥3	12 (11.2)	17 (4.9)	11 (13.4)	15 (5.9)	8 (14.8)	7 (6.0)
Never	73 (68.2)	244 (70.1)	51 (62.2)	171 (66.8)	37 (68.5)	85 (72.6)
Overall length of observation period (y)	8.8 (6.5-10.5)	9.1 (7.0-11.3)	8.5 (6.4-10.3)	9.0 (7.1-11.4)	8.9 (6.4-10.3)	9.2 (7.1-11.2)
Length of observation period after first gastrostomy insertion (y)	4.8 (2.6-7.4)	6.7 (4.6-9.1)	5.4 (2.8-7.9)	6.8 (4.6-9.1)	3.9 (2.2-7.0)	5.9 (3.6-8.3)
Admission level						
No. of acute hospital admissions†	2294 (100)	6679 (100)	495 (21.6)	1073 (16.1)	390 (17.0)	493 (7.4)
Age at acute hospital admissions (y)	3.3 (1.5-5.6)	3.5 (1.5-6.0)	3.6 (1.7-6.1)	3 (1.5-5.5)	3.1 (1.5-5.3)	4 (2.0-6.5)
Length of overnight stay (d)	3 (2-7)	3 (1-5)	5 (3-9)	4 (2-8)	3 (2-7)	3 (1-6)
No. of ICU admissions†	230 (100)	584 (100)	49 (21.3)	141 (24.1)	66 (28.7)	51 (8.7)
No. of individuals admitted to ICU	66	195	21	77	17	22

Values are number (%) or median (IQR).
*Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age.
†Percent of all-cause admissions.

period (Table V). After gastrostomy, the relative incidence of all-cause hospitalizations was similar for years one and 2 and then declined (year 3: IRR, 0.88 [95% CI, 0.79-0.99]; year 5: IRR, 0.70 [95% CI, 0.60-0.80]) (Table V and Figure 3 [available at www.jpeds.com]). There was increased risk of hospitalization for acute LRTI in year 1 (IRR, 1.26 [95%

Table V. Age-adjusted relative incidence of hospitalizations before and after first gastrostomy insertion in cohorts 1* and 2†

Hospitalizations (no. of patients)	Years before gastrostomy		Years after gastrostomy					
	>1	IRR, n	1	2	3	4	5	≥6
Cohort 1								
All-cause (325)	0.53 (0.48-0.57), 2252	1.00, 1040	1.07 (0.98-1.17), 1038	1.01 (0.91-1.11), 781	0.88 (0.79-0.99), 582	0.82 (0.72-0.93), 483	0.70 (0.60-0.80), 366	0.59 (0.52-0.67), 1763
Acute LRTI (257)	0.42 (0.34-0.52), 287	1.00, 200	1.26 (1.03-1.54), 221	1.21 (0.96-1.53), 159	1.30 (1.00-1.69), 130	1.61 (1.22-2.12), 140	1.34 (0.98-1.83), 101	1.42 (91.03-1.95), 507
Epilepsy (164)	0.68 (0.54-0.86), 379	1.00, 139	0.89 (0.69-1.16), 111	0.99 (0.75-1.30), 104	0.87 (0.64-1.18), 86	0.61 (0.43-0.88), 53	0.48 (0.32-0.72), 38	0.52 (0.37-0.74), 186
Cohort 2‡								
All-cause (455)	0.50 (0.38-0.64), 1422	1.00, 1351	0.86 (0.79-0.93), 1359	0.78 (0.71-0.85), 1090	0.68 (0.58-0.80), 800	0.66 (0.58-0.75), 701	0.63 (0.45-0.86), 611	0.60 (0.51-0.71), 1584
Acute LRTI (338)	0.42 (0.29-0.62), 205	1.00, 238	0.88 (0.73-1.07), 232	0.88 (0.64-1.20), 194	1.07 (0.81-1.41), 166	1.14 (0.83-1.57), 148	1.05 (0.72-1.53), 112	1.04 (0.68-1.59), 270
Epilepsy (171)	0.60 (0.46-0.78), 247	1.00, 132	0.84 (0.51-1.39), 108	0.95 (0.71-1.27), 108	0.86 (0.43-1.72), 78	0.75 (0.50-1.11), 54	0.83 (0.53-1.30), 48	0.64 (0.40-1.04), 105

The control period is defined as within 1 year before the admission date of first gastrostomy insertion; the risk period is from the admission date of first gastrostomy insertion to the end of the observation period, which was either December 31, 2014 (WA)/December 31, 2015 (NSW) or date of death, whichever came first.
Values are IRR (95% CI), number of acute hospitalizations.
*Children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted at <18 years of age.
†Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age.
‡Pooled estimates.

CI, 1.03-1.54]) compared with the control period, which persisted (Table V and Figure 3). The incidence of admission for epilepsy was similar to the control period for years 1, 2, and 3, but decreased in years 4 and 5 (year 4: IRR, 0.61 [95% CI, 0.43-0.88]; year 5: IRR, 0.48 [95% CI, 0.32-0.72]) (Table V and Figure 3). There was no notable change in the relative incidence of all-cause ICU admissions, but the estimates were imprecise owing to small sample size (Table VI and Figure 4; available at www.jpeds.com).

Subgroup Analyses. Age at first gastrostomy insertion did not seem to modify the relative incidence of all-cause hospitalization (Table VII and Figure 5; available at www.jpeds.com). However, children who underwent gastrostomy when <3 years of age experienced approximately twice the incidence of acute LRTI admission after 4 and 5 years, but fewer epilepsy admissions in years 3, 4, and 5 (Table VII and Figure 5). Compared with gastrostomy only, patients with gastrostomy and fundoplication experienced a similar number of acute LRTI hospitalizations (Figure 6).

Cohort 2

Acute Hospitalizations and ICU Admissions after First Gastrostomy Insertion. Compared with the control period and adjusted for age, the incidence of all-cause acute hospitalizations decreased over time after first gastrostomy insertion (year 1: IRR, 0.86 [95% CI, 0.79-0.93]; year 5: IRR, 0.63 [95% CI, 0.45-0.86]) (Table V and Figure 3). Similarly, ICU admissions were reduced, particularly in years 4 and 5 (Table VI and Figure 4). The relative incidence of acute LRTI hospitalizations appeared to be lower initially then trended higher after gastrostomy insertion (Table V and Figure 3). We could not demonstrate conclusively that the relative incidence of acute LRTI associated ICU admissions had changed after gastrostomy insertion (Table VI and Figure 4). Relative incidences of epilepsy hospitalizations were generally lower after gastrostomy insertion (Table V and Figure 3). Hospitalizations and ICU admissions of each state are shown in Table VIII (available at www.jpeds.com).

Subgroup Analyses. In the most recent decade, age at first gastrostomy insertion seemed to modify the association between all-cause hospitalizations and gastrostomy insertion where individuals with earlier age at gastrostomy insertion (0-2 years) experienced fewer hospitalizations (Table VII and Figure 5). The difference was most apparent in the fourth year (0-2 years IRR, 0.54 [95% CI, 0.46-0.62]; ≥3 years IRR, 0.86 [95% CI, 0.65-1.14]) and fifth year (0-2 years IRR, 0.51 [95% CI, 0.43-0.61]; ≥3 years IRR, 1.07 [95% CI, 0.68-1.68]) after the procedure. The relative incidence of hospitalizations for acute LRTI or epilepsy did not vary by age of gastrostomy insertion. Compared with gastrostomy-only individuals, fundoplication with gastrostomy reduced the number of acute LRTI hospitalizations from 3 years after first gastrostomy insertion (year 3: fundoplication IRR, 0.78 [95% CI, 0.55-1.11]; no fundoplication IRR, 1.35 [95% CI, 0.99-1.85]; year 4: fundoplication IRR, 0.82 [95% CI, 0.56-1.21]; no fundoplication IRR, 1.50 [95% CI, 1.05-2.15]; year 5: fundoplication IRR, 0.67 [95% CI, 0.43-1.05]; no fundoplication IRR, 1.54 [95% CI, 1.01-2.35]) (Figure 6).

Discussion

Interrogating 2 large linked datasets for children with intellectual disability that represented a little less than one-half of the Australian child population,[25] we observed an elevated number of hospitalizations during the year before gastrostomy insertion. This morbidity was likely associated with feeding difficulties, aspiration pneumonia, and/or poor growth because gastrostomy insertion was then instigated. All-cause morbidity then decreased, observed in both the WA population dataset tracked since 1983 and in the combined WA/NSW dataset tracked since 2002. The initial sustained rate of hospitalizations may reflect those relating to children with very severe complex disabilities who were in receipt of palliative care and for whom gastrostomy was performed to assist short-term needs. Otherwise, improvements in hospitalization rates were observed after longer time periods, particularly in more recent years when gastrostomy has been more commonly accepted into home-based care practices.[26] This reduction in hospitalizations for any health issue could have reflected generally improved nutrition and better health. Children with intellectual disability are vulnerable to admissions for ambulatory care sensitive conditions and gastrostomy could mitigate this risk by supporting general health.[27]

We note that the WA cohort more likely included more severely affected children, supported by the WA mortality rates that were nearly double the NSW mortality rates, and were therefore likely to reflect children who did not survive long enough to be registered with the disability services dataset had they lived in NSW. However, the consistency of findings and our long observation period suggest that gastrostomy confers broad benefits to child health. We also note some differences in outcomes by age at gastrostomy insertion. Children who were <3 years of age when undergoing gastrostomy in our more recent cohort seemed to experience fewer hospitalizations overall, consistent with models of care characterized by more accessibility to proactive management during the early years.[24,28]

There is a causal relationship between gastrostomy insertion and aggravation of gastroesophageal reflux and aspiration pneumonia, but studies have had small sample sizes.[29] An exception was a large Canadian data linkage study of feeding tube placements in 948 children with neurologic impairment, which found no difference in hospitalization for reflux-related issues 2 years after the procedure.[18] Hospitalizations in patients with poor swallow and aspiration have been compared between those treated with gastrostomy and those fed oral thickened liquids (n = 114) and more

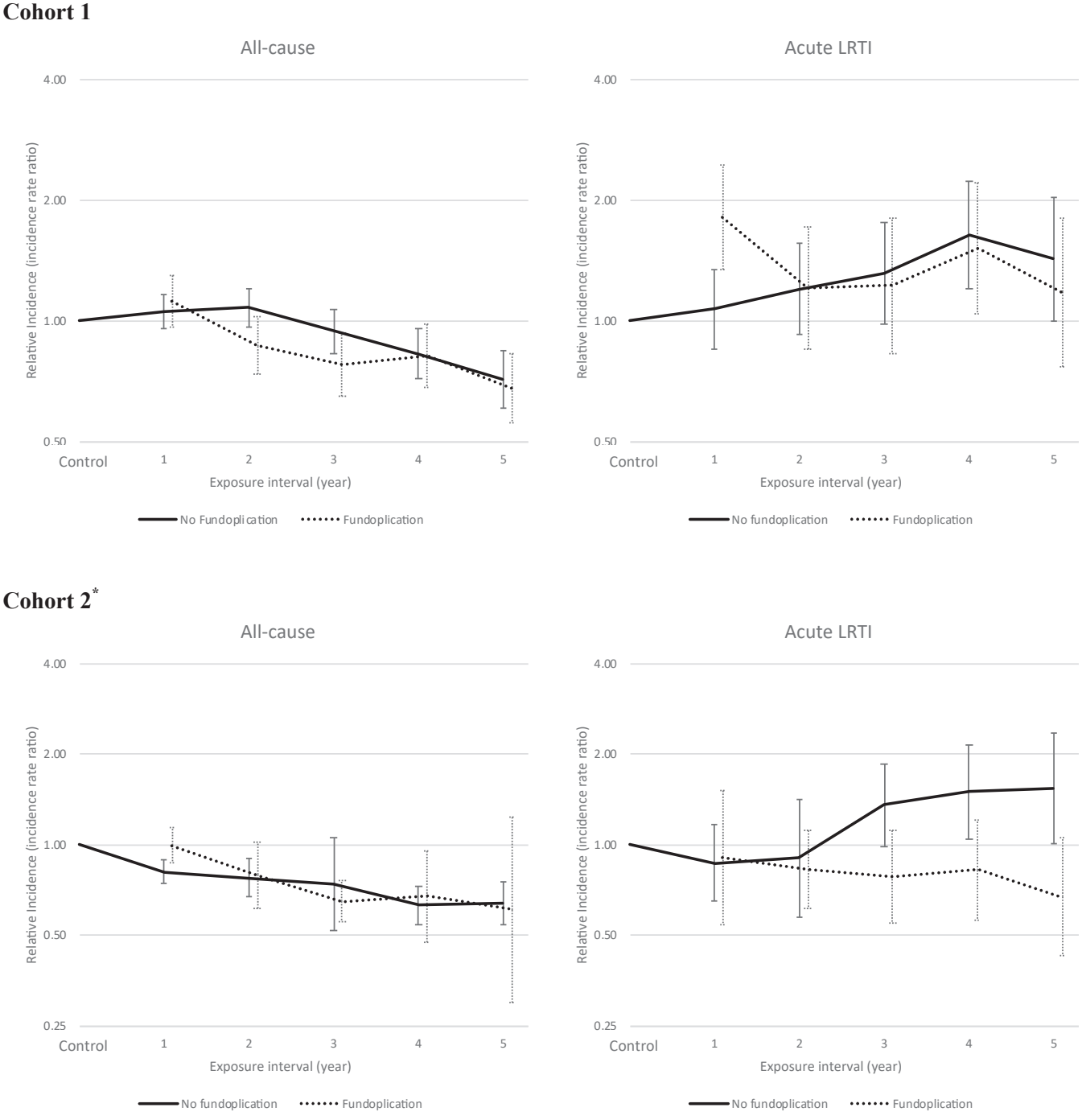

Figure 6. Age-adjusted relative incidence of hospitalizations after first gastrostomy insertion by fundoplication status in cohort 1 (children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted before 18 years of age) and cohort 2 (children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age) by age at first gastrostomy insertion. *Pooled estimates.

hospitalizations were observed in the gastrostomy group, who had higher rates of neurologic impairment, despite the risks of oral feeding.[16] In our sample, hospitalizations and admissions to ICU for acute LRTI increased over 5 years in the WA dataset and remained similar to the reference period for the combined WA/NSW dataset. Together, these findings suggest that gastrostomy does not entirely protect the lower respiratory tract from respiratory disease. We note that guidelines for the volume and timing of feed delivery are scant[30-32] and for some children feeding regimens may deliver too much feed in 1 bolus, aggravating reflux and respiratory health.

Persistent risk of acute LRTI was observed despite fundoplication in cohort 1, but, fundoplication appeared

protective in the combined WA/NSW cohort 2. A larger study using data from 42 hospitals in the US found decreasing reflux-related hospital admissions in the short term for children in whom fundoplication was performed, but not for pneumonia-related conditions.[19] Large multisite studies of neonates[20] and children[21] with neurologic impairment and gastrostomy experienced similar gastrointestinal or respiratory related admissions, with or without fundoplication. Fundoplication variably accompanies gastrostomy[7] and use could be increasing[6] despite no clear evidence of respiratory health advantages. Ongoing surveillance with detailed physiologic studies to identify those with severe pharyngeal dysfunction is necessary to establish the indications for fundoplication in children who also require gastrostomy feeding, as well as further studies assessing the usefulness of thickened feeds in for severely impaired children still capable of swallowing.[30]

Our analyses indicated that gastrostomy insertion is associated with reduced epilepsy admissions. This finding could relate to greater efficacy in the delivery of medications, although therapeutic drug monitoring would be necessary to confirm this notion. Epilepsy admissions decreased from 3 years after gastrostomy in the WA cohort. This finding could have reflected the time taken to achieve an effective combination of antiepileptic medications after a period of unreliable delivery, persistent hospitalizations for children with very complex disability for whom the gastrostomy was palliative, or parental thresholds for presentation to the hospital may have increased over time as families become more confident with home management of seizures. This same effect was observed in the combined WA/NSW dataset. We note that the prevalence of epilepsy admissions in the WA children in cohort 2 was more than twice that observed in the NSW children, consistent with the WA group being more severely affected and again suggesting that gastrostomy has advantages for very severely affected children.

The capacity for data linkage in 2 Australian states enabled a substantial population-based analysis.[25] The WA dataset includes births since 1983 and children with intellectual disability were identified from multiple sources to capture the population, which is a unique capability worldwide.[33] Data linkage in NSW, which is the more populous state, commenced in 2002 and children with intellectual disability were identified from service provision and education datasets when slightly older, follow-up was shorter, and the dataset included fewer children with very severe intellectual disability as indicated by different mortality fractions. We conducted a self-controlled case series design[22] study because linked datasets contain limited information on potential confounding variables and between subject confounding such as severity of disease is automatically controlled for by within-subject analyses. Each analysis was adjusted for age and we used consistent statistical syntax to analyze each dataset and thereafter used meta-analysis to provide greater statistical power for more recent data. Analysis of complications, survival and costs after gastrostomy would be important future investigations to more fully characterize outcomes after gastrostomy.

We acknowledge that our data linkage analyses were limited by lack of access to primary care data. Analysis of less frequent causes of admission and effects associated with gastrojejunal tube feeding was not possible for our population. The dataset did not contain detailed clinical data, such as nutritional status and the efficiency and safety of swallow nor patterns of care, data that would provide an important supplement to hospitalization data. Further evaluation of feeding regimens after gastrostomy are needed to inform whether adjustments to the volumes and timing of gastrostomy feeds can provide protection to the respiratory tract as well as fundoplication. Our study cannot address whether hospitalizations after gastrostomy decreased because caregivers become more confident with or acquired more resources for home management. We also do not have a comparison cohort of children who were candidates for gastrostomy, but did not undergo that procedure. We cannot address changing practice patterns in inpatient vs outpatient care. Despite these limitations, our data show that gastrostomy in children with intellectual disability was associated with health benefits including reduced all-cause and epilepsy hospitalizations, but not protective against acute LRTI. ■

*Acknowledgments available at www.jpeds.com (**Appendix**).*

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Reprint requests: Jenny Downs, PhD, PO Box 855, West Perth, Western Australia, Perth, Australia, + 863191000. E-mail: Jenny.Downs@telethonkids.org.au

Data statement

Data sharing statement available at www.jpeds.com.

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Appendix

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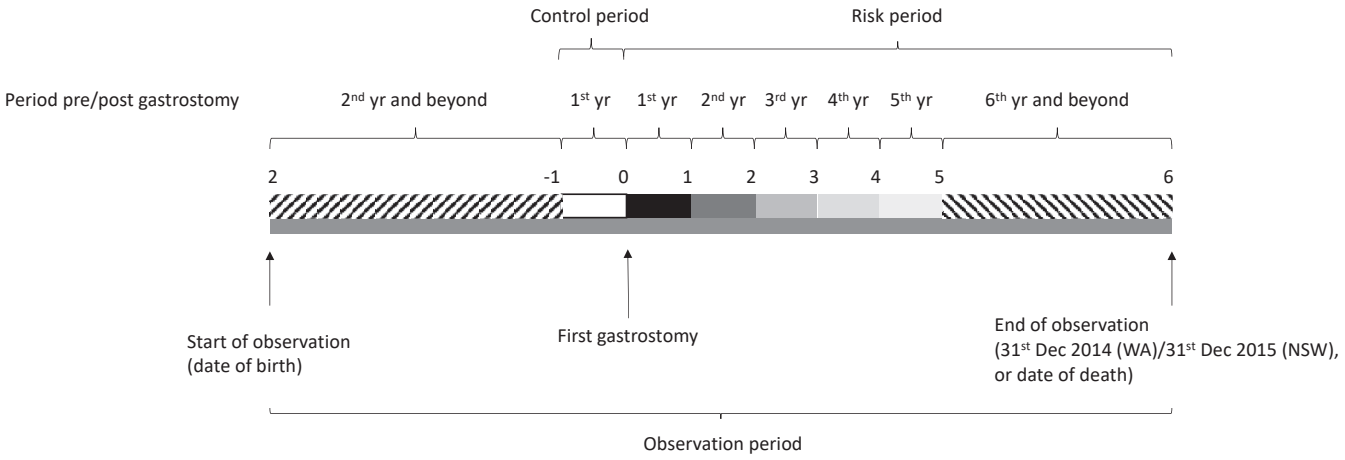


Figure 1. Study design: observation and risk periods. Study design for analyses of the association between first gastrostomy insertion and all-cause and specific hospitalizations using the self-controlled case series method in individuals who were born alive in WA (between January 1, 1983, and December 31, 2009, and January 1, 2002, and December 31, 2009) and NSW (between January 1, 2002 and December 31, 2010), and were diagnosed with intellectual disability. The control period spanned the interval within 1 year before the admission date of first gastrostomy insertion. The risk period included the duration after the first gastrostomy insertion and was stratified into years for the first 5 years after the first gastrostomy insertion: 0-1, 1-2, 2-3, 3-4, 4-5, and ≥6 years.

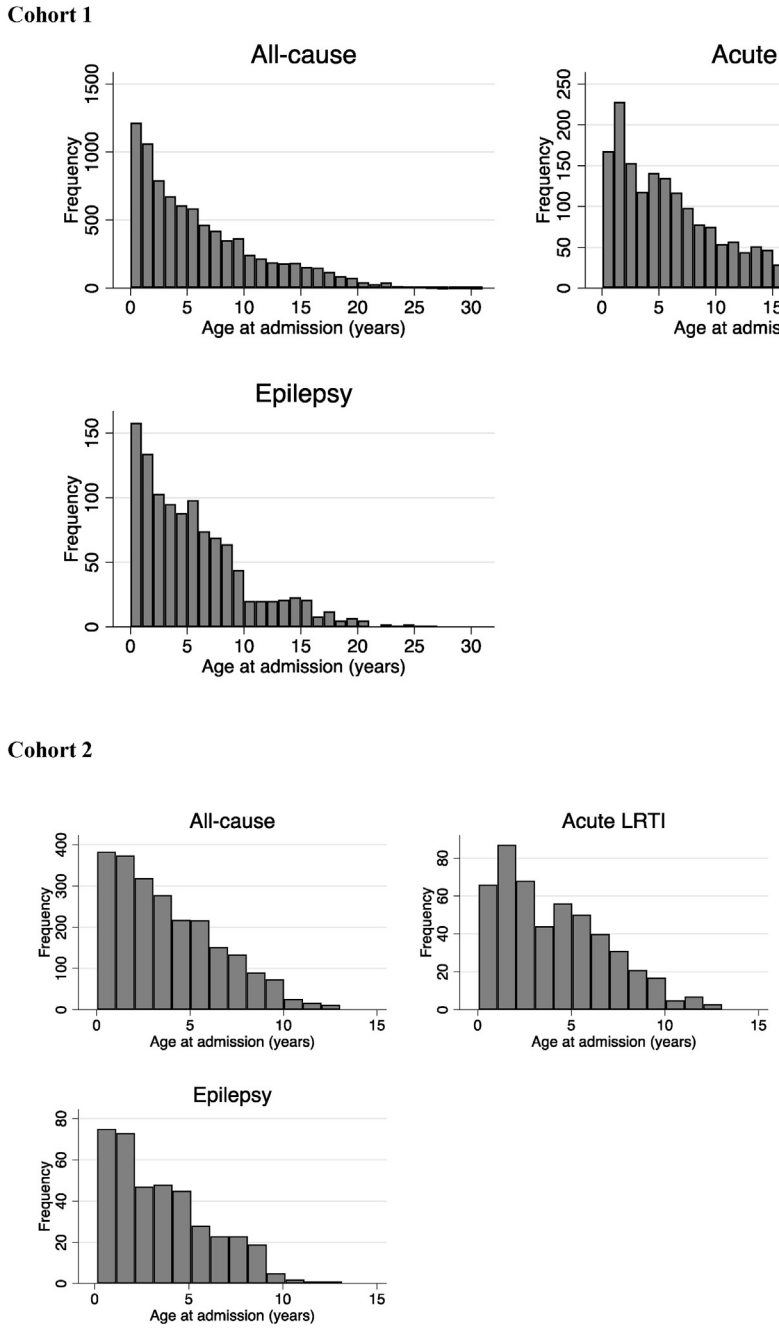


Figure 2. Frequency of hospitalizations by age in cohort 1 (children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted before 18 years of age) and cohort 2 (children with intellectual disability born in WA between 2002 and 2009 who had a gastrostomy inserted at <18 years of age).

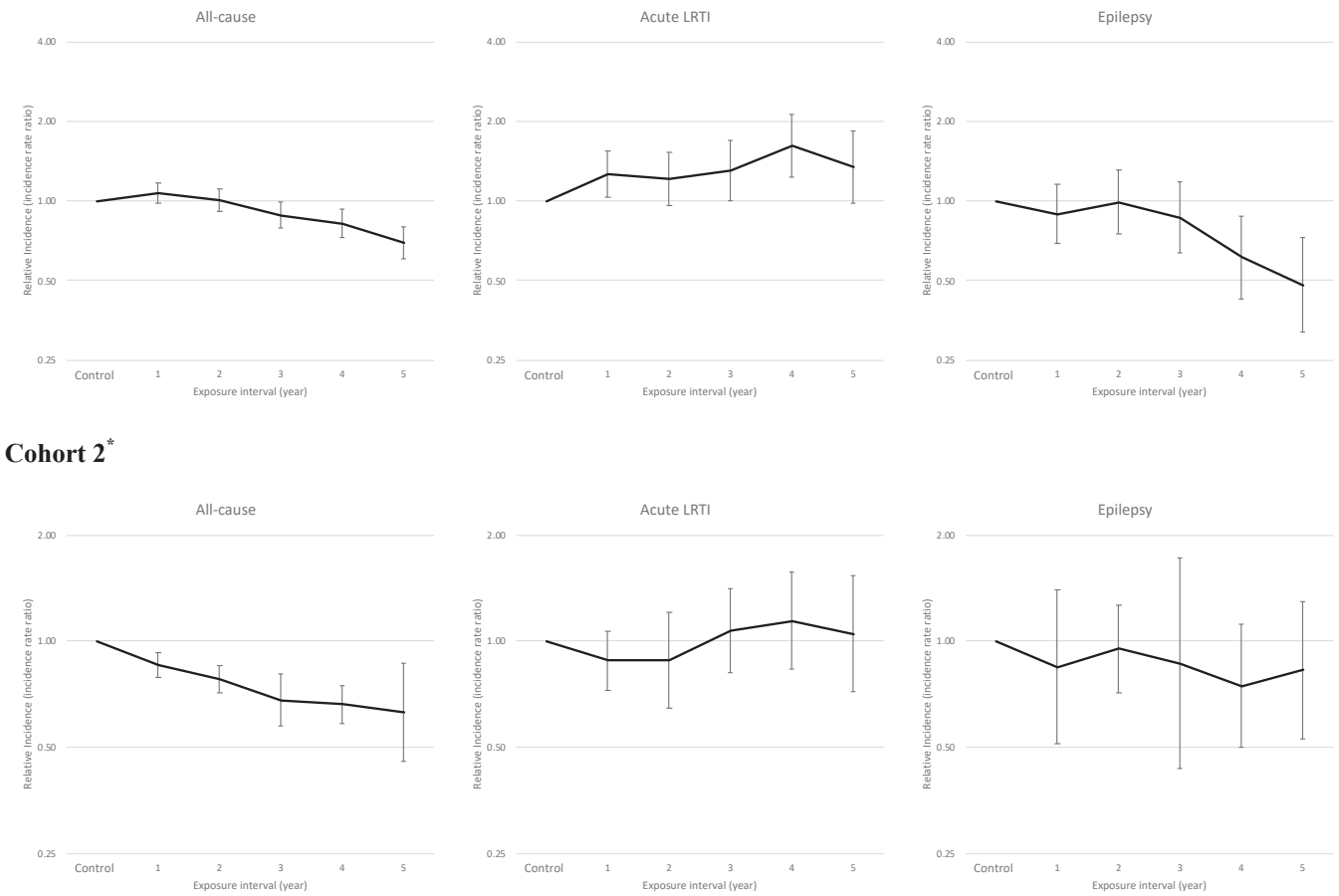
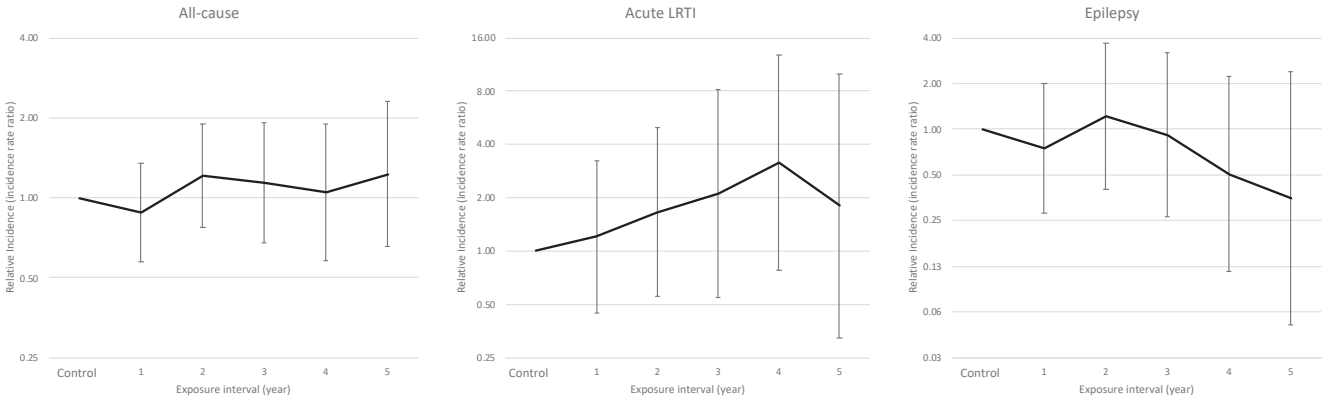


Figure 3. Age-adjusted relative incidence of hospitalizations after first gastrostomy insertion in cohort 1 (children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted before 18 years of age) and cohort 2 (children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age). *Pooled estimates.

Cohort 1



Cohort 2*

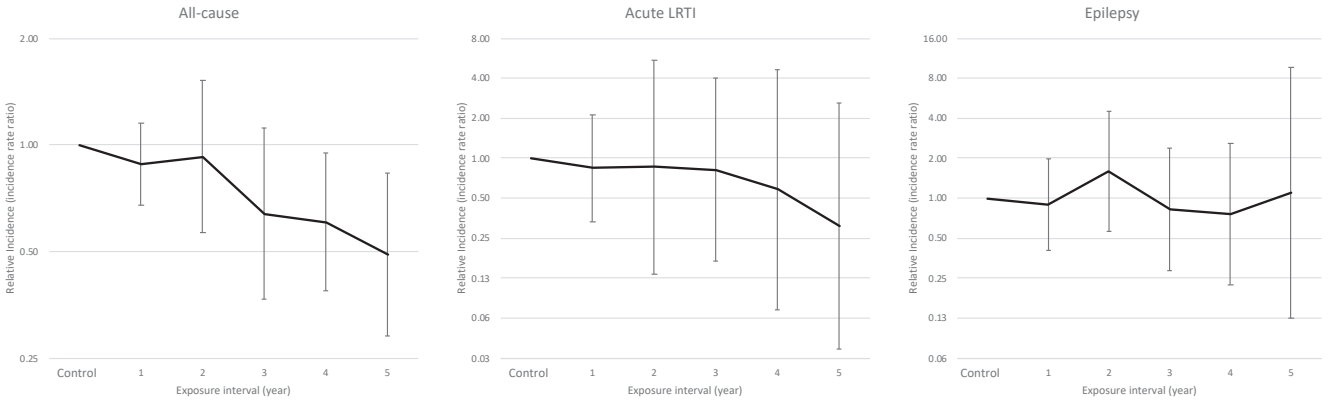


Figure 4. Age-adjusted relative incidence of ICU admissions after first gastrostomy insertion in cohort 1 (children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted before 18 years of age) and cohort 2 (children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age). *Pooled estimates.

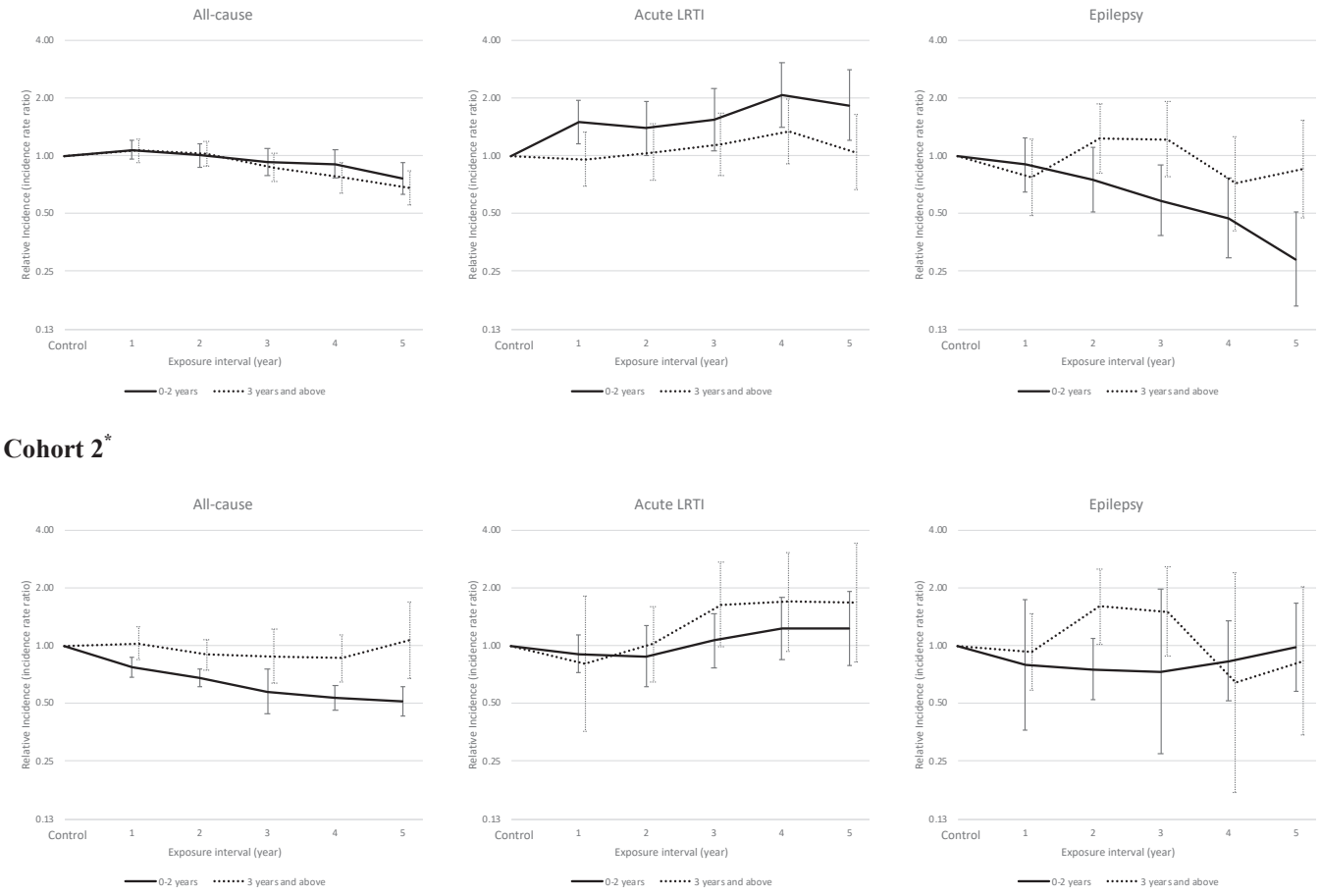


Figure 5. Age-adjusted relative incidence of hospitalizations after first gastrostomy insertion in cohort 1 (children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted before 18 years of age) and cohort 2 (children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age) by age at first gastrostomy insertion. *Pooled estimates.

Table III. Length of stay by hospitalizations before and after first gastrostomy insertion in cohort 1*

	Years before gastrostomy		Years after gastrostomy					
Hospitalizations	**>1**	**Control period**	**1**	**2**	**3**	**4**	**5**	**≥6**
All-cause								
Median LOS (IQR)	3 (2-7)	4 (2-9)	4 (2-8)	3 (2-7)	3 (2-7)	3 (2-7)	3 (2-7)	3 (2-7)
Total hospitalization	2263	1043	1040	782	582	483	366	1763
Total LOS	16 706	8232	6846	5000	3976	2957	2299	10 820
Acute LRTI								
Median LOS (IQR)	5 (2-8)	6 (3-10)	6 (3-11)	5 (2-9)	4 (3-8)	5 (3-8)	5 (3-10)	5 (3-10)
Total hospitalization	287	200	221	159	130	140	101	507
Total LOS	2114	1775	1898	1052	1299	982	932	4313
Epilepsy								
Median LOS (IQR)	3 (2-6)	4 (2-10)	3 (2-7)	3 (2-5)	3 (1-6)	2 (1-7)	2 (1-3)	2.5 (2-6)
Total hospitalization	379	139	111	104	86	53	38	186
Total LOS	2049	1177	565	475	503	306	106	896

LOS, length of stay.
Values are number unless otherwise noted.
*Children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted at <18 years of age.

Table IV. Length of stay by hospitalizations before and after first gastrostomy insertion in cohort 2*

	Years before gastrostomy		Years after gastrostomy					
Hospitalizations	**>1**	**Control period**	**1**	**2**	**3**	**4**	**5**	**≥6**
All-cause								
Median LOS (IQR)	4 (2-7)	3 (2-8)	4 (2-8)	3 (2-6)	3 (2-7)	3 (1.0-6.5)	3 (1.5-6.0)	2 (1-5)
Total hospitalization	513	389	356	271	216	144	104	301
Total LOS	3902	2737	2470	1952	1234	890	666	1497
Acute LRTI								
Median LOS (IQR)	5 (3-8)	5 (2.5-9.5)	7 (4-11)	5 (2-7)	3 (2-7)	3 (2-10)	5 (2.5-9.0)	4 (2-9)
Total hospitalization	73	82	78	53	47	39	28	85
Total LOS	686	761	737	382	253	346	329	669
Epilepsy								
Median LOS (IQR)	3 (2-7)	4 (2-9)	3 (1.5-5.5)	3 (1-5)	4 (1-9)	2 (1-8)	2 (1-2)	2 (1-4)
Total hospitalization	131	61	56	43	39	19	14	27
Total LOS	860	429	268	234	268	122	26	168

Values are number unless otherwise noted.
*Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 of age.

Table VI. Age-adjusted relative incidence of ICU admissions before and after first gastrostomy insertion in cohorts 1* and 2†

	Years before gastrostomy		Years after gastrostomy					
ICU admissions (no. of patients)	>1	IRR, n	1	2	3	4	5	≥6
Cohort 1								
All-cause (146)	0.63 (0.42-0.96), 76	1.00, 49	0.88 (0.58-1.34), 43	1.21 (0.77-1.90), 47	1.14 (0.68-1.91), 37	1.05 (0.58-1.89), 28	1.23 (0.66-2.30), 29	0.89 (0.47-1.71), 137
Acute LRTI (44)	0.30 (0.10-0.95), 11	1.00, 8	1.21 (0.45-3.25), 9	1.66 (0.55-4.99), 8	2.11 (0.55-8.17), 5	3.18 (0.79-12.83), 6	1.80 (0.32-10.03), 3	4.00 (0.83-19.39), 37
Epilepsy (26)	0.43 (0.17-1.09), 19	1.00, 16	0.75 (0.28-2.00), 10	1.23 (0.40-3.71), 11	0.92 (0.26-3.19), 11	0.50 (0.12-2.21), 5	0.35 (0.05-2.38), <5	1.75 (0.33-9.24), 13
Cohort 2‡								
All-cause (261)	0.64 (0.46-0.87), 128	1.00, 115	0.88 (0.68-1.15), 134	0.93 (0.56-1.52), 115	0.64 (0.37-1.12), 68	0.61 (0.39-0.95), 63	0.49 (0.29-0.83), 48	0.44 (0.14-1.36), 130
Acute LRTI (98)	0.62 (0.32-1.24), 23	1.00, 28	0.84 (0.34-2.10), 32	0.86 (0.13-5.50), 22	0.82 (0.17-3.98), 22	0.58 (0.07-4.61), 15	0.31 (0.04-2.61), 10	0.29 (0.01-7.15), 37
Epilepsy (39)	0.20 (0.03-1.53), 20	1.00, 20	0.90 (0.41-1.98), 14	1.60 (0.57-4.54), 22	0.82 (0.28-2.38), 12	0.76 (0.22-2.59), 8	1.10 (0.12-9.67), 8	1.06 (0.23-4.91), 12

The control period is defined as within 1 year before the admission date of first gastrostomy insertion; the risk period is from the admission date of first gastrostomy insertion to the end of the observation period, which was either December 31, 2014 or date of death, whichever came first.

Values are IRR (95% CI), number of ICU admissions.

*Children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted at <18 of age.

†Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 years of age.

‡Pooled estimates.

Table VII. Age-adjusted relative incidence of hospitalizations before and after first gastrostomy insertion in cohorts 1* and 2† by age at first gastrostomy insertion

Hospitalizations (no. of patients)	Age at first gastrostomy (y) (no. of patients)	Years before gastrostomy		Years after gastrostomy					
		>1	IRR, n	1	2	3	4	5	≥6
Cohort 1									
All-cause (325)	0-2 (149)	0.66 (0.57-0.75), 394	1.00, 628	1.07 (0.95-1.20), 640	1.00 (0.87-1.15), 443	0.92 (0.79-1.08), 345	0.91 (0.76-1.07), 298	0.76 (0.63-0.92), 232	0.66 (0.56-0.78), 1143
	≥3 (176)	0.46 (0.41-0.53), 1858	1.00, 412	1.06 (0.92-1.22), 398	1.02 (0.88-1.19), 338	0.87 (0.73-1.03), 237	0.77 (0.64-0.93), 185	0.68 (0.55-0.84), 134	0.59 (0.50-0.69), 620
Acute LRTI (257)	0-2 (127)	0.71 (0.51-1.00), 59	1.00, 115	1.49 (1.15-1.94), 149	1.39 (1.00-1.92), 89	1.54 (1.05-2.24), 73	2.07 (1.40-3.06), 85	1.83 (1.19-2.79), 67	1.89 (1.24-2.88), 306
	≥3 (130)	0.29 (0.21-0.39), 228	1.00, 85	0.95 (0.69-1.32), 72	1.04 (0.74-1.47), 70	1.15 (0.79-1.67), 57	1.33 (0.90-1.97), 55	1.04 (0.66-1.64), 34	1.24 (0.85-1.79), 201
Epilepsy (164)	0-2 (62)	0.62 (0.44-0.87), 73	1.00, 91	0.90 (0.65-1.24), 79	0.75 (0.51-1.10), 57	0.59 (0.38-0.90), 47	0.47 (0.29-0.76), 34	0.29 (0.16-0.51), 20	0.41 (0.27-0.64), 118
	≥3 (102)	0.82 (0.58-1.16), 306	1.00, 48	0.77 (0.49-1.22), 32	1.23 (0.81-1.87), 47	1.22 (0.78-1.90), 39	0.72 (0.41-1.26), 19	0.85 (0.48-1.52), 18	0.69 (0.43-1.11), 68
Cohort 2‡									
All-cause (455)	0-2 (319)	0.62 (0.48-0.79), 455	1.00, 1009	0.77 (0.68-0.87), 1043	0.68 (0.61,0.76), 861	0.58 (0.44-0.75), 640	0.54 (0.46-0.62), 575	0.51 (0.43-0.61), 492	0.54 (0.35-0.83), 1368
	≥3 (136)	0.51 (0.44-0.59), 967	1.00, 342	1.03 (0.84-1.26), 316	0.90 (0.75-1.07), 229	0.88 (0.63-1.21), 160	0.86 (0.65-1.14), 126	1.07 (0.68-1.68), 119	1.14 (0.83-1.57), 216
Acute LRTI (338)	0-2 (248)	0.69 (0.49-0.97), 75	1.00, 174	0.91 (0.72-1.14), 193	0.88 (0.61-1.27), 153	1.06 (0.76-1.47), 132	1.23 (0.85-1.79), 125	1.22 (0.79-1.91), 98	1.61 (0.63-4.09), 243
	≥3 (90)	0.28 (0.14-0.60), 130	1.00, 64	0.81 (0.36-1.82), 39	1.02 (0.65-1.60), 41	1.63 (0.98-2.70), 34	1.69 (0.94-3.03), 23	1.68 (0.83-3.43), 14	1.62 (0.85-3.11), 27
Epilepsy (171)	0-2 (101)	0.79 (0.56-1.11), 76	1.00, 86	0.79 (0.36-1.73), 76	0.75 (0.52-1.08), 67	0.73 (0.27-1.95), 53	0.83 (0.51-1.35), 45	0.98 (0.58-1.67), 41	0.75 (0.43-1.32), 91
	≥3 (70)	0.52 (0.35-0.78), 171	1.00, 46	0.92 (0.58-1.47), 32	1.59 (1.02-2.50), 41	1.50 (0.99-2.56), 25	0.64 (0.17-2.38), 9	0.83 (0.34-2.02), 7	1.00 (0.48-2.10), 14

Values are IRR (95% CI), number of acute hospitalizations.

The control period is defined as within 1 year before the admission date of first gastrostomy insertion; the risk period is from the admission date of first gastrostomy insertion to the end of the observation period, which was either December 31, 2014 (WA)/December 31, 2015 (NSW) or date of death, whichever came first.

*Children with intellectual disability born in WA between 1983 and 2009 who had a gastrostomy inserted at <18 of age.

†Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 of age.

‡Pooled estimates.

Table VIII. Age-adjusted relative incidence of hospitalizations and ICU admissions before and after first gastrostomy insertion in cohort 2* by state

Events (no. of patients)	State (no. of patients)	Years before gastrostomy		Years after gastrostomy					
		>1	IRR, n	1	2	3	4	5	≥6
All-cause (455)									
Acute hospitalizations (455)	WA (107)	0.57 (0.48-0.68), 513	1.00, 389	0.88 (0.75-1.02), 354	0.79 (0.66-0.95), 271	0.76 (0.61-0.95), 216	0.61 (0.46-0.80), 144	0.51 (0.37-0.71), 104	0.63 (0.44-0.90), 301
	NSW (348)	0.44 (0.39-0.49), 909	1.00, 962	0.85 (0.77-0.93), 1005	0.78 (0.70-0.86), 819	0.64 (0.56-0.73), 584	0.68 (0.59-0.78), 557	0.72 (0.61-0.84), 507	0.59 (0.49-0.71), 1283
ICU admissions (261)	WA (66)	0.77 (0.44-1.34), 57	1.00, 32	1.09 (0.65-1.82), 35	1.27 (0.70-2.28), 35	0.92 (0.44-1.92), 21	0.81 (0.33-1.97), 14	0.75 (0.27-2.11), 11	0.86 (0.27-2.71), 25
	NSW (195)	0.58 (0.40-0.86), 71	1.00, 83	0.82 (0.60-1.11), 99	0.76 (0.53-1.08), 80	0.51 (0.32-0.82), 47	0.55 (0.33-0.92), 49	0.42 (0.23-0.78), 37	0.27 (0.13-0.55), 105
Acute LRTI (338)									
Acute hospitalizations (338)	WA (82)	0.33 (0.22-0.51), 73	1.00, 92	0.88 (0.63-1.22), 78	0.71 (0.47-1.09), 53	0.96 (0.58-1.61), 47	1.00 (0.54-1.86), 39	0.90 (0.43-1.88), 28	1.40 (0.60-3.27), 85
	NSW (256)	0.50 (0.37-0.67), 132	1.00, 146	0.88 (0.69-1.11), 154	1.00 (0.76-1.30), 141	1.12 (0.81-1.55), 119	1.20 (0.83-1.73), 109	1.11 (0.71-1.72), 84	0.94 (0.57-1.54), 185
	WA (21)	0.92 (0.22-3.84), 9	1.00, <5	1.63 (0.45-5.90), 7	2.44 (0.60-9.89), 7	2.20 (0.40-11.98), <5	1.98 (0.29-13.83), <5	1.13 (0.12-10.58), <5	1.64 (0.17-15.60), 13
	NSW (77)	0.56 (0.26-1.21), 14	1.00, 24	0.60 (0.33-1.10), 25	0.36 (0.17-0.78), 15	0.43 (0.17-1.05), 18	0.23 (0.08-0.70), 12	0.12 (0.03-0.48), 8	0.06 (0.01-0.29), 24
Epilepsy (171)									
Acute hospitalizations (171)	WA (54)	0.64 (0.42-0.95), 131	1.00, 61	1.10 (0.74-1.62), 56	1.03 (0.66-1.63), 43	1.24 (0.74-2.09), 39	0.90 (0.46-1.73), 19	0.80 (0.38-1.72), 14	0.61 (0.27-1.34), 27
	NSW (117)	0.57 (0.40-0.82), 116	1.00, 71	0.66 (0.46-0.95), 52	0.90 (0.62-1.30), 65	0.62 (0.39-0.97), 39	0.67 (0.41-1.11), 35	0.84 (0.48-1.47), 34	0.66 (0.36-1.21), 78
ICU admissions (39)	WA (17)	0.48 (0.17-1.36), 18	1.00, 14	0.99 (0.36-2.75), 9	0.92 (0.26-3.24), 8	0.98 (0.25-3.85), 9	0.41 (0.07-2.38), <5	0.32 (0.03-3.77), <5	0.61 (0.08-4.48), <5
	NSW (22)	0.06 (0.01-0.45), <5	1.00, 6	0.78 (0.22-2.72), 5	2.68 (0.81-8.80), 14	0.62 (0.11-3.41), <5	1.37 (0.24-7.72), 5	2.96 (0.40-21.82), 7	2.35 (0.22-25.59), 8

Values are IRR (95% CI), number of events (acute hospital admissions/ICU admissions).

The control period is defined as within 1 year before the admission date of first gastrostomy insertion; the risk period is from the admission date of first gastrostomy insertion to the end of the observation period, which was either December 31, 2014 (WA)/December 31, 2015 (NSW) or date of death, whichever came first.

*Children with intellectual disability born in WA between 2002 and 2009 or NSW between 2002 and 2010 who had a gastrostomy inserted at <18 of age.